Process Specification for Electrodeposited Chromium Plating

Engineering Directorate

Structural Engineering Division

June 2020

Lyndon B. Johnson Space Center
Houston, Texas
<table>
<thead>
<tr>
<th>VERSION</th>
<th>CHANGES</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>--</td>
<td>Original version</td>
<td>5/96</td>
</tr>
<tr>
<td>A</td>
<td>Formatting; mandates 23 hour hydrogen bakeout for steel alloys.</td>
<td>7/26/99</td>
</tr>
<tr>
<td>B</td>
<td>Changed EM references to ES</td>
<td>9/2002</td>
</tr>
<tr>
<td>C</td>
<td>Updated specification reference to AMS-QQ-C-320</td>
<td>10/2004</td>
</tr>
<tr>
<td>D</td>
<td>Updated specification from AMS-QQ-C-320 to SAE AMS 2460, eliminated zinc and zinc alloys from scope and applicability, put a maximum final thickness class 2 dimension of 0.0050 inches, Does not cover thin dense chromium in the applicability section, Added information on anomalies and surface finishes, Added information and drawing callouts on hydrogen embrittlement and shot peening, Added references and definitions, added process requirements, process verification and process qualification, added appendix on shot peen media sizes and nominal diameters for shot selection.</td>
<td>6/2020</td>
</tr>
</tbody>
</table>
1.0 **SCOPE**

This process specification establishes technical requirements for the application of electrodeposited chromium plating on steels.

2.0 **APPLICABILITY**

This process specification applies to the electrodeposition of chromium plating on substrates of steel. This PRC does not cover alloys of copper and zinc. This PRC also does not cover thin dense chrome plating.

3.0 **USAGE**

This process specification shall be called out on the engineering drawing by using a drawing note that identifies the process specification, the class, the type and the thickness. Two examples are:

<table>
<thead>
<tr>
<th>CHROMIUM PLATE TO A THICKNESS OF 0.0005-0.0015 INCHES PER NASA/JSC PRC 5003, CLASS 1, TYPE II.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHROMIUM PLATE TO A FINAL THICKNESS AFTER GRINDING OF 0.0020-0.0050 INCHES PER NASA/JSC PRC 5003, CLASS 2.</td>
</tr>
</tbody>
</table>

The two classes of electrodeposited chromium plating are:

Class 1 Corrosion protective chromium plating (>0.00001 in. thick)

Class 2 Engineering chromium plating (>0.002 in. thick)

Class 1 chromium plating shall be one of the following types, as specified on the engineering drawing:

Type I – Bright Finish

Type II – Satin Finish

Class 1 plating is used to protect steels against corrosive attack in rural, industrial, or marine environments, which varies depending on the thickness of the chromium deposit. It may also be used as an undercoat for a chromium plating or for aesthetic purposes.

Class 2 plating is used primarily for wear resistance, abrasion resistance, and incidental corrosion protection. Heavy deposits of Class 2 plating may be used for build-up of worn or undersized parts. Class 2 plating is typically used for final dimensional thicknesses.
(after grinding) of 0.0020 to 0.0050 inches.

Drawing tolerances for as-plated thicknesses less than 0.0020 inches are commonly 0.0010 inches. Drawing tolerances for ground plating thicknesses of 0.0020 to 0.0050 inches thick are commonly 0.0005 inches. Closer tolerances can be achieved when required.

For chromium plating up to 0.002 inch thick, the surface finish will be similar to the original machined part. For chromium plating greater than 0.002 inch thick, the surface finish will become rougher with increasing plating thickness. Shot peening also typically increases surface finish roughness, and most class 2 applications utilize grinding after the post-hydrogen bakeout. Therefore, most class 2 applications utilize grinding after the hydrogen bakeout in order to achieve a finer surface finish.

If plating thickness measurement is required at critical locations of the part, it shall be specified on the drawing.

Most anomalies like pits and scratches prior to plating are amplified after plating. Removal of these anomalies prior to plating is recommended.

3.1 SHOT PEENING

A common requirement for chromium plated items is shot peening prior to plating. Chromium plate often has cracks that run from the surface through the thickness to the substrate. The frequency of these cracks increases with increasing pre-grinding plate thickness. The use of shot peening prior to plating adds compressive residual stresses which prevents cracks from propagating into the substrate.

If shot peening is desired prior to plating, it shall be specified on the drawing. These four items shall be specified in the drawing note for shot peening:

- Shot Material
- Shot Size
- Intensity
- Coverage

3.1.1 Shot Material

There are 4 common types of shot material: 1) cast shot, 2) cut wire shot, 3) glass bead shot, and 4) ceramic shot.

1) Cast shot is most common shot
2) Cut wire is made by cutting wire and rounding off the corners
3) Glass beads are typically used on aluminum or other softer non-ferrous alloys and are rarely use on steel
4) Ceramic shot is typically atomized powder with a hardness between 57-63 HRC

For steel parts over 200 ksi tensile strength, use hard steel shot (55-65 HRC) or
ceramic shot (57-63 HRC).

3.1.2 Shot Size and Selection

The nominal size of shot (see appendix A) used on fillet surfaces shall not be greater than one-half the smallest fillet radius. It is preferred that a fillet radius of 0.031 inches or greater be used when possible. Sharp corners should also be avoided and rounded when possible.

Selection of shot size based on intensity is listed in Table 1.

Table 1: Desired Minimum Shot Size for a Given Intensity

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Desired Minimum Size Peening Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.012 A</td>
<td>S-280 or CW-28 or Ceramic Bead Size 0.033</td>
</tr>
<tr>
<td>0.016 A</td>
<td>S-390 or CW-41 or Ceramic Bead Size 0.046</td>
</tr>
<tr>
<td>0.020 A</td>
<td>S-550 or CW-54</td>
</tr>
</tbody>
</table>

3.1.3 Intensity

Intensity can only be established during development by plotting a saturation curve, as shown in figure 1, and assuring that the required intensity (determined by the arc height of the test strip) falls on the right side of the knee of the curve. By doubling the time of exposure, the arc height of a test strip should not increase by more than 10%.

![Saturation Curve](image)

Figure 1: Saturation Curve to Verify Peening Intensity
For initial process development, a saturation curve shall be generated for each location where intensity is to be verified. A curve is produced by exposing individual test strips for increasing time periods and plotting the results (exposure time vs. arc height). A minimum of four points other than zero shall be used to define the curve; one of the four points used to indicate saturation shall be at least double the time of the saturation point. Saturation is achieved when, as the exposure time for the test strips is doubled, the arc height does not increase by more than 10%. The reuse of test strips is not permitted.

Except for sections less than 0.090 inches, a test strip “A” conforming to SAE J442 utilizing procedure conforming to SAE J443 is typically used to determine arc height. The test strip “A” is used for arc heights between 0.004 and 0.024 inches. For sections less than 0.090 inches, consult the cognizant material and process (M & P) engineer.

<table>
<thead>
<tr>
<th>Steel</th>
<th>Under 200 ksi UTS</th>
<th>Over 200 ksi UTS*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 0.090 Inches Thick</td>
<td>Discuss with M &amp; P</td>
<td>Discuss with M &amp; P</td>
</tr>
<tr>
<td>0.090 – 0.375 Inches Thick</td>
<td>0.008 – 0.012 A</td>
<td>0.006 – 0.010 A</td>
</tr>
<tr>
<td>Over 0.090 Inches Thick</td>
<td>0.012 – 0.016 A</td>
<td>0.006 – 0.010 A</td>
</tr>
</tbody>
</table>

*For steel parts over 200 ksi tensile strength, use hard steel shot (55-65 HRC) or ceramic shot (57-63 HRC).

### 3.1.4 Coverage

Complete visual coverage is a uniform and complete denting or obliterating of the original surface of the part or work piece as determined by either of the following methods.

Some vendors use a visual examination process using a 10X magnifying glass and other vendors use a liquid tracer system (typically fluorescent) using a 10X inspection. The liquid tracer system uses a pre-shot peen coating and typically fluorescent lighting to inspect post-shot peening.

Typically 100% coverage (T Exposure Time in Figure 1) is specified; however, 200% coverage (2T Exposure Time in Figure 1) is desired on low margin, fracture critical parts.

### 3.1.5 Drawing Note Examples for Shot Peening
For a steel under 200 ksi:

<table>
<thead>
<tr>
<th>Alloys</th>
<th>Type</th>
<th>Hardness / Temper</th>
<th>Ultimate Tensile Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Steel, Low Alloy Steel, &amp;</td>
<td>Fasteners</td>
<td>≥ 36 HRC</td>
<td>≥ 160 ksi</td>
</tr>
<tr>
<td>Martensitic Stainless Steels**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Steel, Low Alloy Steel, &amp;</td>
<td>All Parts Other Than</td>
<td>≥ 40 HRC</td>
<td>≥ 180 ksi</td>
</tr>
<tr>
<td>Martensitic Stainless Steels**</td>
<td>Fasteners</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Strength Precipitation Hardening</td>
<td>All Parts</td>
<td>See Tempers Listed in Table 1 Located in AMS 2759/9</td>
<td>≥ 150 ksi</td>
</tr>
<tr>
<td>Stainless Steels***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case-hardened Steel Parts***</td>
<td>All Parts</td>
<td>See Table 2 Located in AMS 2759/9</td>
<td>≥ 255 ksi in the Case</td>
</tr>
<tr>
<td>Music Wire, 52100, 440C, or Any Other</td>
<td>All Parts</td>
<td>See Table 2 Located in AMS 2759/9</td>
<td>≥ 255 ksi</td>
</tr>
<tr>
<td>Alloy Tempered Below 375 °F***</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Require a post-plating hydrogen baking procedure of 375 F for 23 hours.

For a steel over 200 ksi:

SHOT PEEN PER SAE AMS 2430 WITH CERAMIC BEAD 0.024 BEAD SIZE PRIOR TO CHROMIUM PLATING. AN INTENSITY OF 0.006-0.010 A IS REQUIRED WITH 100% COVERAGE.

3.2 POST-PLATING HYDROGEN BAKEOUT

If the base material is a high strength ferrous alloy or case hardened, and has a hardness/temper or strength as defined in Table 1, a hydrogen bakeout shall be required within four hours after the completion of the plating operation.

Table 1: Steels That Require a Hydrogen Bakeout after Chromium Plate

**Require a post-plating hydrogen baking procedure of 375 F for 23 hours.**
*** Require a post-plating hydrogen baking procedure listed in AMS 2759/9. An example for an alloy steel with a hardness greater than 40 HRC:

3.3 WORK INSTRUCTIONS

Work instructions shall be generated for implementing this process specification. The work instructions shall contain sufficient detail to ensure that the manufacturing process produces consistent, repeatable products that comply with this specification. For work performed at JSC facilities, these work procedures consist of Detailed Process Instructions (DPIs). For contracted work, the contractor shall be responsible for preparing and maintaining, and certifying written work procedures that meet the requirements of this specification.

A HYDROGEN BAKEOUT SHALL BE PERFORMED AT 375 F FOR 23 HOURS WITHIN 4 HOURS AFTER THE COMPLETION OF THE PLATING OPERATION.

4.0 REFERENCES

The following references were used in developing this process specification:

- ASTM B571 Qualitative Adhesion Testing of Metallic Coatings
- JPR 8500.4 Engineering Drawing System Requirements
- SAE AMS 2460 Plating, Chromium
- SAE AMS 2759/9 Hydrogen Embrittlement Relief (Baking) of Steel Parts
- SAE AMS-S-13165A Shot Peening of Metal Parts
- SAE AMS 2430 Shot Peening, Automatic
- SAE J442 Test Strip, Holder, and Gage for Shot Peening
- SAE J443 Procedures for Using Standard Shot Peening Almen Test Strip
- SAE J444 Cast Shot and Grit Size Specifications for Peening and Cleaning
- SOP-007.1 Preparation and Revision of Process Specifications
5.0 MATERIALS REQUIREMENTS

The materials used shall meet the requirements of SAE AMS 2460.

Prior to shot peening, parts shall be within dimensional and surface finish requirements. All heat treatment shall be completed before shot peening. All fillets shall be formed, all burrs shall be removed, and all sharp edges and corners to be peened shall be provided with sufficient radii to result in complete coverage.

Thin sections shall not distort after shot peening prior to plating.

6.0 PROCESS REQUIREMENTS

All electrodeposited chromium plating shall be applied according to the technical requirements of SAE AMS 2460. In addition to the control factors in SAE AMS 2460, these additional control factors are required:

- Organic contamination, metallic contamination and pH levels shall be checked at the same time periods and the plating bath composition
- Proper bath temperature and temperature uniformity shall be checked and maintained
- Composition, organic contamination, metallic contamination and pH levels shall be checked monthly (or more frequently)

Tanks used for cleaning, pickling (or other activation methods) and rinsing are critical for proper surface preparation for plating. These tanks shall be controlled and maintained for proper chemistry, pH and low contamination levels using documented procedures.

Fluoride levels often deplete in nitric/hydrofluoric pickling tanks over time and the typical titration test for “total acids” analysis is not adequate to check the nitric-to-hydrofluoric ratio. Periodic removal of the old pickling solution, cleaning out the drained tank, and creating a new pickling tank solution is often the easiest method to insure the proper nitric-to-hydrofluoric ratio.

In addition to the control factors in SAE AMS 2460, these additional control factors are required:

- Abrasive blasting media shall be removed prior to plating.
- The cleaning procedure shall not produce pitting or intergranular attack of the basis metal and shall preserve dimensional requirements.
- The plating shall be applied over a surface free from water breaks per AMS 2460.
7.0 PROCESS QUALIFICATION

Adhesion tests, if required, shall meet the requirements of ASTM B571 bend test 180 degrees with 4T mandrel to insure good plating deposit adhesion. Class 2 plating that will be ground to final dimensions typically does not require an adhesion test.

Tribology and microhardness tests (ASTM E384) on test specimens may be required to insure proper wear resistance.

Periodic corrosion test panel shall be periodically tested 48 hours to continuous salt spray corrosion test conducted in accordance with ASTM B117.

8.0 PROCESS VERIFICATION

The process verification shall include visual examination, adhesion tests, and thickness measurements, as specified by AMS 2460.

The chromium deposits shall be visually examined (after grinding for class 2) for the following general problems:

- Pits, pores and/or cracking
- Regions with missing or insufficient plating thickness
- Poor coverage
- Edge pullback
- Roughness in the deposits
- Discoloration in the deposits
- Step plating

If the drawing requires plating thickness measurements at specific locations of the part, then these measurements shall be performed and recorded by the vendor.

If a hydrogen bakeout is performed, a quality record documenting the time and temperature shall be supplied. A simple strip chart on the oven is adequate to document the process. A digital file of the bakeout run is also adequate. In addition, a recent record certifying the accuracy of the oven temperature and uniformity is needed.

A laboratory verification test (compared to known standards) of the ppm hydrogen on a simulation coupon (same material and mill lot as the parts being processed) can also be used to verify that hydrogen bakeout procedure was performed.

For shot peening, documentation for the measurements on the Almen Test Strip is required.

9.0 TRAINING AND CERTIFICATION OF PERSONNEL
This chromium plating process shall be performed by personnel qualified to conduct the process through training or experience. If this process is performed by an outside vendor, the development of an appropriate training program shall be the responsibility of the vendor.

10.0  DEFINITIONS

**Abrasive Blasting**: A process for cleaning or finishing by means of an abrasive directed at high velocity against a work piece.

**Activation**: Elimination of a passive condition on a surface, usually by chemical removal of oxides.

**Almen Test Strip**: A thin strip of SAE 1070 steel used to quantify the intensity of a shot peening process. Developed and patented by John O. Almen, the strip was originally supported by 2 knife edges; later improvements see it being supported on 4 small balls.

**Arc Height**: A measurement of the amount of deflection or bow in an Almen strip, after it has been shot peened. The measurement is taken at the center of the concave side of the peened Almen strip using an Almen gauge.

**Blister**: A dome-shaped imperfection or defect, resulting from loss of adhesion between a metallic deposit and the substrate.

**Electroless Plating**: Deposition of a metallic coating by a controlled chemical reduction that is catalyzed by the metal or alloy being deposited.

**Electrodeposit**: An electrolytic plating deposit.

**Electrolytic Plating**: Deposition of a metallic coating by putting a conductive material from a plating solution onto a substrate by the application of an electric current.

**Liquid tracer system**: A tracer system that employs liquid coating material which removes at a rate proportioned to peening coverage. A fluorescent tracer system has, in addition, a pigment which fluoresces under ultraviolet light.

**Pickling**: The removal of oxides or other compounds from a metal surface by means of a chemical solution.

**Pit**: A small depression or cavity produced in a metal surface during deposition or by corrosion.

**Substrate**: The material, component, or work piece to which the chromium plating is
deposited. The substrate may also be called “base metal.”

**Water Break**: The appearance of a discontinuous film of water on a surface, signifying non-uniform wetting and usually associated with a surface contamination.
Appendix A: Nominal Diameters for Common Shot Peen Media (See SAE J444) Sizes

<table>
<thead>
<tr>
<th>Cast Shot Sizes</th>
<th>Cut Wire Sizes</th>
<th>Glass Bead Sizes (Max)</th>
<th>Ceramic Bead Sizes (Max)</th>
<th>Nominal Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-780</td>
<td></td>
<td></td>
<td></td>
<td>0.095 Inches</td>
</tr>
<tr>
<td>S-660</td>
<td></td>
<td></td>
<td></td>
<td>0.080 Inches</td>
</tr>
<tr>
<td>S-550</td>
<td>CW-62</td>
<td>0.079 Inches</td>
<td></td>
<td>0.062 Inches</td>
</tr>
<tr>
<td>S-460</td>
<td>CW-54</td>
<td>0.066 Inches</td>
<td></td>
<td>0.054 Inches</td>
</tr>
<tr>
<td>S-390</td>
<td>CW-47</td>
<td>0.056 Inches</td>
<td></td>
<td>0.047 Inches</td>
</tr>
<tr>
<td>S-330</td>
<td>CW-41</td>
<td>0.047 Inches</td>
<td>0.046 Inches</td>
<td>0.041 Inches</td>
</tr>
<tr>
<td></td>
<td>CW-35</td>
<td></td>
<td></td>
<td>0.035 Inches</td>
</tr>
<tr>
<td>S-280</td>
<td>CW-32</td>
<td>0.039 Inches</td>
<td></td>
<td>0.032 Inches</td>
</tr>
<tr>
<td>S-230</td>
<td>CW-28</td>
<td>0.0331 Inches</td>
<td>0.033 Inches</td>
<td>0.028 Inches</td>
</tr>
<tr>
<td>S-190</td>
<td>CW-23</td>
<td>0.0278 Inches</td>
<td></td>
<td>0.023 Inches</td>
</tr>
<tr>
<td>S-170</td>
<td>CW-20</td>
<td>0.0234 Inches</td>
<td>0.024 Inches</td>
<td>0.020 Inches</td>
</tr>
<tr>
<td>S-110</td>
<td></td>
<td>0.0165 Inches</td>
<td>0.017 Inches</td>
<td>0.016 Inches</td>
</tr>
<tr>
<td>S-70</td>
<td></td>
<td>0.0139 Inches</td>
<td></td>
<td>0.011 Inches</td>
</tr>
</tbody>
</table>