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|  | Industrial Sector Hydraulics Group Fluid Conveyance Products Maumee, Ohio U.S.A. Code Ident. No. 01276 | Engineering Standard | ES 2751 |
| | | Category | Process |
| | | Revision | L |
| | | Page | 1 of 11 |
| Zinc Plate, Electrodeposited Industrial Quality, Trivalent Chromate Type, General Performance Requirements for | | | |

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ALTERNATE LANGUAGE ES

**ALL VERSIONS SHALL BE IDENTICAL
WITH SAME REVISION LEVEL**

1.0 SCOPE

This standard establishes the product, process and performance requirements for zinc plating of steel parts for Eaton Hydraulics Group, Fluid Conveyance Products (HGFCP) globally.

All product families and regions for HGFCP steel parts are to be plated per ES 2751 with exceptions to those in Table 1. For these exceptions, adhere to the listed engineering standard appendix for ES 2751.

NOTE: This standard explicitly prohibits the use of hexavalent chromate as a supplemental treatment.

2.0 APPLICABLE DOCUMENTS

The following documents form a part of this standard to the extent specified herein.

2.1 ENGINEERING STANDARDS

| | |
|------------|---|
| ES 2751 D4 | Zinc Plate, Electrodeposited Industrial Quality, Trivalent Chromate Type, General Performance Requirements for, Eaton in E.M.E.A. and Walterscheid Globally |
| ES 2751 D7 | Zinc Plate, Electrodeposited Industrial Quality, Chromium (VI)-Free Type "Guardian Seal", General Performance Requirements for Eaton Globally |
| ES 2751 D8 | Zinc Plate, Electrodeposited Industrial Quality, Trivalent Chromate Type, General Performance Requirements for FC Global locations (Dura-Kote) |

2.2 OTHER DOCUMENTS

| | |
|------------------|---|
| ASTM B117 | Standard Practice for Operating Salt Spray (Fog) Apparatus |
| ASTM B633 | Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel |
| ASTM B571 | Standard Practice for Qualitative Adhesion Testing of Metallic Coatings |
| DIN 946 | Determination of Coefficient of Friction of Bolt/Nut Assemblies under Specified Conditions |
| DIN EN 1403 | Corrosion Protection of Metals - Electrodeposited Coatings - Method of Specifying General Requirements |
| DIN EN 12329 | Electrodeposited Coatings of Zinc with Supplementary Treatment on Iron and Steel |
| DIN EN ISO 4042 | Fasteners - Electroplated Coatings |
| DIN EN ISO 10289 | Methods for Corrosion Testing of Metallic and Other Inorganic Coatings on Metallic Substrates - Rating of Test Specimens and Manufactured Articles Subjected to Corrosion Tests |
| DIN EN ISO 2819 | Metallic Coatings on Metallic Substrates - Electrodeposited and Chemically Deposited Coatings - Review of Methods Available for Testing Adhesion |
| ISO 2081 | Metallic and Other Inorganic Coatings - Electroplated Coatings of Zinc with Supplementary Treatments on Iron or Steel |
| ISO 4520 | Chromate Conversion Coatings on Electroplated Zinc and Cadmium Coatings |
| ISO 9227 | Corrosion Tests in Artificial Atmospheres - Salt Spray Tests |
| ISO 16047 | Fasteners - Torque/Clamp Force Testing |
| ISO 9588 | Metallic and Other Inorganic Coatings - Post-Coating Treatments of Iron or Steel to Reduce the Risk of Hydrogen Embrittlement |
| SAE/USCAR-5 | Avoidance of Hydrogen Embrittlement of Steel |
| SAE/USCAR-7 | Deembrittlement Verification Test |
| SAE/USCAR-11 | Torque-Tension Testing and Evaluation of Fastener Finishes |
| SAE J514 | Hydraulic Tube Fittings |
| SAE J516 | Hydraulic Hose Fittings |
| GMW 3044 | Zinc Plating, General Motors Corporation Worldwide Engineering Standards, Material Specification Finish (Coating) |

| | |
|------------|--|
| 2000/53/EG | European End of Life Vehicle Directive |
| 1E0397 | Plating- Zinc or Zinc Alloy, Caterpillar Inc. Corporate Product & Process Specification |
| 1E4377 | Connectors- General Requirements, Caterpillar Inc. Corporate Product & Process Specification |

3.0 GENERAL PLATING REQUIREMENTS

TABLE 1 ZINC PLATING STANDARDS BY PRODUCT FAMILY AND REGION

| Engineering Standard | Document Title | Product Family | Region ¹ |
|----------------------|--|---------------------------|-------------------------|
| ES 2751 | Zinc Plate, Electrodeposited Industrial Quality, Trivalent Chromate Type, General Performance Requirements for | Eaton | Americas & Asia/Pacific |
| | | Eaton Winner ² | Global |
| ES 2751 Appendix D4 | Zinc Plate, Electrodeposited Industrial Quality, Trivalent Chromate Type, General Performance Requirements for, Eaton in E.M.E.A. | Eaton E.M.E.A | |
| ES 2751 Appendix D7 | Zinc Plate, Electrodeposited Industrial Quality, Chromium (VI)-Free Type "Guardian Seal", General Performance Requirements for Eaton Globally | Eaton | Global |
| | | Eaton Walterscheid | Global |
| ES 2751 Appendix D8 | Zinc Plate, Electrodeposited Industrial Quality, Trivalent Chromate Type, General Performance Requirements for FC Global locations (Dura-Kote) | Eaton Winner ³ | Global |

1 Region is specific to "manufactured and sold in" locations.

2 This ES controls zinc-plating requirements for Winner part numbers that utilize the "ZF" or "Z" suffix only.

3 Suitable for Winner part numbers that utilize the "ZD" suffix only.

3.1 PLATING

The base metal finish shall be electrodeposited zinc. The layer shall be homogeneous and completely coat the base metal.

References: DIN EN ISO 4042, ASTM B 633

3.2 CHROMATE

The zinc plate shall be treated with a clear trivalent chromate conversion coating (optional with nanoparticles). Certificate of conformance for hexavalent-free chromate is required.

References: DIN EN 12329 Code C, ASTM B633 Type III

3.3 SEALER

The clear, chromated zinc coating may be treated with a chromate sealer as required by Eaton and/or to meet performance requirements. The sealing process can also be done after chromating by dipping the parts in a suitable solvent. Droplet formation or any deposit resulting in interference at threads or affects part/assembly function is not allowed. Additionally, the sealer shall be compatible with standard PAG and ester oils used in air conditioning applications.

3.4 CORROSION INHIBITOR & LUBRICANT

Parts shall be coated with a dry to touch rust inhibiting coating to protect unplated surfaces - such as through holes - and may enhance lubrication for assembly. This layer may become optional if the sealer incorporates corrosion inhibiting and/or lubricating characteristics into its design.

3.5 PLATING THICKNESS**3.5.1 General Requirements**

Plating thickness shall be between 5 & 15 μm (0.0002 & 0.0006 inch) and shall be based on an average of three readings taken on significant surfaces. No individual reading shall be below 4 μm (0.00016 inch). Significant surfaces include any area of the part that can be touched with a 12.7 mm (0.5 inch) ball excluding sharp edges, threads, holes, and recesses.

3.5.2 Sampling

Plating thickness shall be verified through sampling. Sampling frequency shall be once every hour, unless otherwise approved through the PPAP process.

3.5.3 Dimensional Corrections and Tolerances

When qualifying a new plating source, for existing parts, plating thickness of each supplier shall be compared. If differences exist, the parts shall be evaluated to determine if dimensional corrections are required. This evaluation shall be part of the PPAP process. Thread correction recommendations are covered in Section 7.

Plating thickness may be sufficient to require corrections to pre-plate dimensions. To ensure that all parts meet after-plate dimensions, Eaton may require plating thickness tolerances tighter than 5 - 15 μm (0.0002 - 0.0006 inch). Plating suppliers are required to maintain plating thickness within the limits approved through the PPAP process. Failure to plate, within the approved tolerance, is cause for rejection.

3.6 HYDROGEN EMBRITTLEMENT RELIEF

Plating suppliers may be required to perform additional processing to eliminate hydrogen embrittlement. It is the responsibility of Eaton to specify if parts require bake out.

3.6.1 General Processing Requirements

Parts with a core hardness greater than R_c 32, surface hardness greater than R_c 35, or parts subject to flexure, repeated impact or sustained tensile loads shall be baked out. Parts shall be baked out a 175°C to 205°C (350°F to 400°F) according to the following:

- a) For 3 hours within 1 hour after plating.
- b) For 4 hours from 1 to 3 hours after plating.
- c) For 23 hours for over 3 hours after plating.

Bake-out shall precede chromate and sealer application unless otherwise supported by performance testing.

Bake-out requirements shall be noted on the drawing.

Reference: ASTM B633, ISO 9588

3.7 REPLATING

Parts that fail to meet the requirements of this specification may be stripped and replated a maximum of 2 times (i.e. plated 3 times maximum).

TABLE 2 GENERAL AND PERFORMANCE PLATING REQUIREMENTS

| Engineering Standard | General Plating Requirements | Performance Requirements |
|-----------------------------|--|--|
| ES 2751 | Plating Thickness: Average between 5 - 15 µm (0.0002 - 0.0006 inch) with no reading less than 4µm (0.00016 inch). Approving location may require a tighter tolerance | Corrosion: a) Formed parts 24/96 for white/red corrosion b) Unformed parts 96/360 for white/red corrosion Plating Adhesion Threaded Connection Verification/Coefficient of Friction Thread Locking/Sealing Compatibility |
| ES 2751 Appendix D4 | Plating Thickness: Average between 10 - 15 µm (0.0004 - 0.0006 inch) with no reading less than 10µm (0.0004 inch) | Corrosion: a) Formed parts 96/240 for white/red corrosion b) Unformed parts 96/360 for white/red corrosion Plating Adhesion Threaded Connection Verification/Coefficient of Friction |
| ES 2751 Appendix D7 | Plating Thickness: Per design record, 8-12 µm (0.0003 – 0.0005 inch.) default. To be specified in purchase detail. No reading less than 5µm (0.0002 inch). | Corrosion : Unformed parts 360/720 for white/red Plating Adhesion |
| | Per L&P 9.51.0429 | Per L&P 9.51.0429 |
| ES 2751 Appendix D8 | Plating Thickness: Average between 5 - 10 µm (0.0002 - 0.0004 inch) with no reading less than 4µm (0.00016 inch). | Corrosion: a) Formed-Bent parts 48/144 for white/red corrosion. b) Formed-Crimped parts 360/408 for white/red corrosion. c) Unformed parts 456/768 for white/red corrosion. Plating Adhesion Threaded Connection Verification/Coefficient of Friction |

4.0 APPEARANCE

4.1 PLATING DEPOSIT

The plating deposit shall be smooth, fine grained, adherent and free from blisters, burning or other defects. Superficial staining, which may be caused from rinsing, shall not be cause for rejection.

4.2 CHROMATE COLOR

The resultant color shall be a uniform and tightly adherent clear bright appearance (also referred to as colorless, blue-bright and silver-white) on all plated surfaces. Iridescence, opaqueness, or sheen is not critical unless specified on the drawing. Chromate coverage shall be complete.

5.0 GENERAL PERFORMANCE REQUIREMENTS

Zinc plating supplied in accordance with this standard shall be capable of meeting the performance requirements specified herein. Prior to testing, all test specimens shall have the plating thickness measured and recorded. Unless otherwise specified, all periodic control testing records shall be retained internally. All test parts shall be aged at ambient laboratory temperature for a minimum of 24 hours prior to any performance tests.

5.1 CORROSION TESTING

5.1.1 Salt Spray (Fog) Exposure

Parts shall be capable of withstanding exposure to a 5% neutral salt spray (fog) per ISO 9227 (equivalent to ASTM B117) as shown below. The appearance of corrosion products visible to the unaided eye at normal reading distance shall be cause for rejection with the exceptions noted. Corrosion resistance periodic control testing shall be performed once per month unless otherwise approved through the PPAP process.

References: ISO 9227, ASTM B117

5.1.1.1 Exceptions to Corrosion Requirements

- All internal fluid passages.
- Edges such as hex points, serrations, and crests of threads where there may be mechanical deformation of the plating or coating typical of mass-produced parts or shipping effects.
- Areas where there is mechanical deformation caused by crimping, flaring, bending (unless as part of formed part testing), and other post-plate metal forming operations.
- Areas where the parts are suspended or affixed in the test chamber where condensate can accumulate.

Reference: SAE J516, ASTM B633

5.1.1.2 Performance Requirements

| Test Part | White Corrosion | Red Rust |
|-----------|-----------------|----------|
| Formed | 24 hrs | 96 hrs |
| Unformed | 96 hrs | 360 hrs |

Formed Part Definition:

Formed parts defined as parts, which are subjected to crimping, flaring, bending, and other post-plate metal forming operations. Unless otherwise agreed upon between the approving Eaton location and the supplier, for testing purposes, a formed part is defined as a bent tube with the following characteristics.

- Tube outside diameter of 12 mm to 14 mm (0.472 inch to 0.551 inch)
- Surface finish of the tube before plating is not greater than 5 μ m (200 μ in) prior to plating

- c) The tube shall be bent to a centreline radius between 17.5 mm (0.689 inch) and 20 mm (0.787 inch)
- d) Plating shall occur before the bending operation
- e) An example of an acceptable bent part is FC3032-SALT

Note: The only area, that shall meet formed part performance requirements, is the bent portion of the tube. Tool marks and other features are exempt as described in the “Exceptions to Corrosion Requirements”.

It is permissible, for the approving Eaton location, to accept testing that has been completed with standard parts that have been formed after plating. The degree of deformation and significant surfaces shall be agreed on, by both Eaton and the supplier, prior to testing.

5.2 PLATING ADHESION

The adhesion of the zinc plating shall be checked by exposing the parts to 220°C ±5°C (428°F ±9°F) for 30 ±5 minutes and quenching in water at room temperature. After quenching in water, blistering and/or chipping are not allowed. Plating adhesion periodic control testing shall be performed once per month unless otherwise approved through the PPAP process.

Reference: GMW 3044, ASTM B571, DIN EN ISO 2819

5.2.1 Customer Specific Requirements

When qualifying a new plating source, if the plating is to be supplied to one of the customers listed below, then the additional testing listed is required.

- 1) John Deere- Plating Adhesion per ISO 2819 sec 2.1 (Burnishing Test)

5.3 MECHANICAL REQUIREMENTS

5.3.1 Threaded Connection Verification/Coefficient of Friction

To ensure proper loading, of threaded connections at recommended torque values, the plating shall be evaluated for reference coefficient of friction (μ_{ges}).

As an option, functional and performance testing can be substituted for coefficient of friction testing. Please contact the approving Eaton location for functional/performance testing requirements, if that option shall be used.

Testing is required for initial qualification only. Re-testing is required only if process changes are made.

Coefficient of Friction Test Requirements

Test Samples:

A minimum of 15 bolts shall be used for testing.

- a) Bolts: Bolts shall be new M10 x 1.50-6g x 40 mm grade 9.8 certified test bolts (GMW 3044 part number 11516105). The finish shall be plain as supplied by the bolt manufacturer. It then shall be zinc plated with the finish being evaluated by the supplier. Bolts shall be cleaned thoroughly prior to plating.
- b) Nuts: Nuts shall be new M10 x 1.50-4H grade 9 certified test nuts (GMW 3044 part number 11516090). The finish shall be zinc plated as applied by the nut supplier.
- c) Washers: Washers shall be new square M10 test washers made from SAE 1050 annealed carbon steel (GMW 3044 part number 11502644). The surface hardness shall be between 85 and 88 R15N with core hardness between 73 and 78 Rockwell A. The dimensions shall be 22.86 x 22.86 x 1.88 mm (0.90 x 0.90 x 0.07 inch) The finish shall be zinc plated as applied by the nut supplier.

Test Procedure:

Samples are to be tested per SAE/USCAR-11 with the following exceptions.

- a) The required test load is 28.3 kN (6362.1 lbs)
- b) Continuous run down rate is 30 ±3 rpm
- c) Reference coefficient of friction is to be calculated per ISO 16047 (equivalent to DIN 946)

Acceptance Criteria:

The reference coefficient of friction tolerance is 0.13 ± 0.06 . The minimum Cpk value shall be 1.0 for the sample.

References: GMW 3044, SAE/USCAR-11, DIN 946, ISO 16047

5.3.1.1 Customer Specific Requirements

When qualifying a new plating source, if the plating is to be supplied to one of the customers listed below, then the additional testing listed is required.

- 1) CATERPILLAR- Torque Coefficient per 1E0397

5.3.2 Thread Locking/Sealing Compatibility

This testing is required for any facility that plates male pipe thread parts. Testing required for initial qualification only. Re-testing is required only if process changes are made.

The finish shall be compatible with thread locking/sealers such as Loctite Vibraseal 516 (ref. ES 2088) or equivalent when tested per the following procedure.

Initial Installation

- a) Assemble 5 samples per normal production practice at room temperature to a pressure test fixture. Pipe threads shall be installed $1 \frac{1}{2}$ turns past hand tight and opposite end shall be suitably capped or plugged.
- b) Pressurize samples with air to 10 bar (145 psi) and immerse in water for 60 seconds. There shall be no leaks.

Reuse Requirements

- a) After releasing the pressure from the test fixture, remove the parts and clean the internal fixture threads to remove all evidence of sealant residue.
- b) Re-insert the test parts and assemble to the test fixture. Pipe threads shall be installed $1 \frac{1}{2}$ turns past hand tight.
- c) Pressurize samples, with air, to 10 bar (145 psi) and immerse in water for 60 seconds. There shall be no leaks.

Repeat the reuse requirements for a total test count of 3 times

References: GMW 3044

5.3.3 Customer Specific Requirements

When qualifying a new plating source, if the plating is to be supplied to one of the customers listed below, then the additional testing listed is required.

- 1) CATERPILLAR- Over-Torque Test per 1E4377
- 2) CATERPILLAR- Break Loose Torque Retention Test per 1E4377

6.0 RELEASE REQUIREMENTS

PPAP's submitted for approval shall include sample parts as well as data and test reports that show that the plating meets all requirements. Part deliveries, without documentation required for approval, shall be sent back to the supplier immediately and not released.

6.1 TYPE OF PART

Due to the differing properties, a separate corrosion test report is necessary for the following parts:

- a) Standard/Threaded parts (turned parts, etc.)
- b) Forged parts (SAE flanges, etc.)
- c) Bent / formed parts ($45^\circ/90^\circ$ fittings, sockets, etc.)

Note: Barrel and rack plated processes shall be considered separately.

6.2 CORROSION TEST REPORT

- Required
 - a) Barrel and/or rack plated parts (formed or unformed)
 - b) Plating thickness of samples
 - c) Corrosion test results (first hours to white corrosion and first hours to red rust)
- Optional
 - a) Pre treatment process steps
(degreasing, pickling including medium type, temperature and time parameters)
 - b) Zinc plating process
(method including plating thickness, bath and time parameters)
 - c) Chromate process steps
(method including temperature and time parameters)
 - d) Sealing process steps (if necessary)
(method including medium type, temperature and time parameters)

7.0 DIMENSIONAL ADJUSTMENTS

Due to the effects of plating on fine threads, recommendations for pre-plate pitch diameters of internal and external threads have been established. After plating, the thread shall meet the final part tolerances. The recommendations are shown in Table 3.

TABLE 3 RECOMMENDED THREAD CORRECTION VALUES

| Plating Thickness (µm) | Thread Location | Thread Type | After-Plating Requirement | Before Plating Maximum Pitch Diameter | Before Plating Minimum Pitch Diameter | Before Plating Maximum Major/Minor Diameters | Before Plating Minimum Major/Minor Diameters |
|------------------------|-----------------|-----------------------|---|---|---|---|---|
| 5 - 10 | External | 3/8-24 UNF-2A | Class 2A (major diameter may be to class 3A) | Subtract 0.04 mm (0.0016 in) from "after plating" maximum pitch diameters | Subtract 0.02 mm (0.0008 in) from "after plating" minimum pitch diameters | Subtract 0.02 mm (0.0008 in) from "after plating" maximum major diameters | Subtract 0.01 mm (0.0004 in) from "after plating" minimum major diameters |
| 5 - 10 | External | 5/16-24 UNF-2A | Class 2A (major diameter may be to class 3A) | Subtract 0.04 mm (0.0016 in) from "after plating" maximum pitch diameters | Subtract 0.02 mm (0.0008 inch) from "after plating" minimum pitch diameters | Subtract 0.02 mm (0.0008 inch) from "after plating" maximum major diameters | Subtract 0.01 mm (0.0004 inch) from "after plating" minimum major diameters |
| 10 - 15 | External | Unified Screw Threads | Class 2A | Subtract 0.06 mm (0.0024 inch) from "after plating" maximum pitch diameters | Subtract 0.04 mm (0.0016 inch) from "after plating" minimum pitch diameters | N/A | N/A |
| 10 - 15 | External | BSP Parallel Threads | Class B | Subtract 0.06 mm (0.0024 inch) from "after plating" maximum pitch diameters | Subtract 0.04 mm (0.0016 inch) from "after plating" minimum pitch diameters | N/A | N/A |

| | | | | | | | |
|---------|----------|---------------------------------|--------------------|--|---|-----|-----|
| 10 - 15 | External | Metric Thread s | Class 6g | Machine to Class 6e tolerance | Machine to Class 6e tolerance | N/A | N/A |
| 10 - 15 | Internal | Unified Screw Thread s | Class 2B | Add 0.04 mm (0.0016 inch) to "after plating" maximum pitch diameters | Add 0.04 mm (0.0016 inch) to "after plating" minimum pitch diameters | N/A | N/A |
| 10 - 15 | Internal | BSP Parallel Thread s | Standard Limits | Add 0.04 mm (0.0016 inch) to "after plating" maximum pitch diameters | Add 0.04 mm (0.0016 inch) to "after plating" minimum pitch diameters | N/A | N/A |
| 10 - 15 | Internal | Metric Thread s | Class 6H | Machine to Class 6G tolerance | Machine to Class 6G tolerance | N/A | N/A |

8.0 ABOUT ES 2751

| REV | DESCRIPTION | BY | CHK | DATE | ECR/ECO |
|-----|--|-----|---------|------------|-------------|
| - | Issued | N/A | N/A | 10/17/1989 | Unknown |
| A | Unknown | N/A | N/A | 12/17/1990 | Unknown |
| B | Unknown | N/A | N/A | 02/20/2001 | SN-7150 |
| C | Unknown | N/A | N/A | 12/12/2006 | SN-7863 |
| D | Unknown | N/A | N/A | 06/27/2007 | SN-7948 |
| E | Unknown | N/A | N/A | 09/12/2008 | SN-8080 |
| F | 1. Changed temperature tolerance for Plating Adhesion test. 2. Updated to new format. | GRL | JML/PRD | 09/15/2011 | 0059637-ECO |
| G | Updated section 1.0 and Table 1. | AAP | YRB/PRD | 06/18/2012 | 0072230-ECO |
| H | Added ES 2751D6 reference in section 1.0 | AAP | YRB/PRD | 11/08/2012 | 0077629-ECO |
| J | Added ES 2751D7 reference in section 1.0. Changed Walterscheid specifications from D4 to D7 and revised to L&P 9.51.0429 | KRC | TJT/PRD | 06/06/2013 | 0085692-ECO |
| K | 1) Updated section 1.0. 2) Added reference to ES 2751D4 thru ES 2751D8 in section 2.1. 3) Added ES 2751D8 reference in Tables 1 & 2. 4) Added Customer Specific Testing in section 5.2.1, 5.3.1.1. & 5.3.3. | KRC | CMS/PRD | 12/01/2014 | 0103984-ECO |
| K | 1) Updated section 2.1 and 3.1. 2) Removed ES 2751D6 reference in Tables 1 and 2. | HLV | PRD | 07/29/2019 | CO-0189675 |