AEROSPACE RECOMMENDED PRACTICE

ARP1631™ REV. A

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Superseding ARP1631

Manufacturing Sequence for Fabrication of High-Strength Steel Parts 300M or 4340 Modified Low-Alloy Steels 270,000 psi (1860 MPa) Tensile Strength and Higher

RATIONALE

ARP1631A has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

This document establishes the requirements for the sequencing of processes relating to parts fabricated from 300M or 4340 modified steel heat treated to, or to be heat treated to, 270,000 psi (1860 MPa) minimum ultimate tensile strength (UTS) and higher.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase orders. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AMS 2300	Steel Cleanliness, Premium Aircraft-Quality, Magnetic Particle Inspection Procedure
AMS 2401	Plating, Cadmium, Low Hydrogen Content Deposit
AMS 2403	Plating, Nickel, General Purpose
AMS 2406	Plating, Chromium, Hard Deposit
AMS 2419	Plating, Cadmium-Titanium
AMS 2423	Plating, Nickel Hard Deposit
AMS 2424	Plating, Nickel Low-Stressed Deposit
AMS 2426	Coating, Cadmium Vacuum Deposition

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
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SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/ARP1631A/

AMS 2427	Aluminum Coating Ion Vapor Deposition
AMS 2430	Shot Peening, Automatic
AMS 2630	Inspection, Ultrasonic Product Over 0.5 inch (12.5 mm) Thick
AMS 2649	Etch Inspection of High Strength Steel Parts
AMS 2759/2	Heat Treatment of Low-Alloy Steel Parts Minimum Tensile Strength 220 ksi (1517 MPa) and Higher
AMS 2759/9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
AMS 2800	Identification, Finished Parts
AMS 6257	Steel Bars, Forgings, and Tubing 1.6Si 0.82Cr 1.8Ni 0.40Mo 0.08V (0.40-0.44C) Consumable Electrode Vacuum Remelted Normalized and Tempered
AMS 6417	Steel Bars, Forgings, and Tubing, 1.6Si 0.82Cr 1.8Ni 0.40Mo 0.08V Consumable Electrode Vacuum Remelted
AMS 6419	Steel Bars, Forgings, and Tubing, 1.6Si 0.82Cr 1.8Ni 0.40Mo 0.08V (0.40 - 0.45C), Consumable Electrode Vacuum Remelted
AMS-C-8837	Coating, Cadmium (Vacuum Deposited)
AMS-QQ-C-320	Chromium Plating (Electrodeposited)
AMS-S-13165	Shot Peening of Metal Parts
AMS-STD-2154	Inspection, Ultrasonic, Wrought Metals, Process for
AS1182	Standard Machining Allowance, Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing
ARP4462	Barkhausen Noise Inspection for Detecting Grinding Burns in High Strength Steel Parts

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19482-2959, Tel: 610-832-9585, www.astm.org.

ASTM E 18	Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 1444	Magnetic Particle Testing
ASTM E 1742	Radiographic Examination

2.3 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch.

2.3.1 Federal Specifications

A-A-113 Tape, Pressure Sensitive Adhesive

2.3.2 Military Specifications

MIL-W-6873 Welding, Flash, Carbon and Alloy Steel

2.3.3 Military Standards

MIL-STD-866 Grinding of Chrome Plated Steel and Steel Parts Heat Treated to 180,000 psi or over

MIL-STD-1500 Cadium-Titanium Plating, Low Embrittlement, Electrodeposition

MIL-STD-1501 Chromium Plating, Low Embrittlement, Electro-Deposition

MIL-STD-2219 Fusion Welding for Aerospace Applications

2.4 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ANSI B74.13 Marking for Identifying Grinding Wheels and Other Bonded Abrasives

2.5 American Welding Society Publications

Available from American Welding Society, 2671 W. 81st Street, Hialeah, FL 33016, Tel: 305-826-6193, www.aws.org.

AWS D17.1 Specification for Fusion Welding for Aerospace Applications

3. TECHNICAL REQUIREMENTS

3.1 Material

Shall be normalized or normalized and tempered 300M or 4340 modified low-alloy steel conforming to AMS 6257, AMS 6417 or AMS 6419, produced by the vacuum arc remelting process and meeting the nonmetallic inclusion requirements of AMS 2300 except that the cleanliness rating shall have maximum frequency/severity rating of 0.10/0.20.

3.2 Processing Prior to Heat Treatment (Hardening and Tempering)

3.2.1 Metal Removal

Surface magnetic particle indications and mill decarburization shall be removed from all surfaces. All products, other than those certified to be decarburization free, shall have minimum stock removed from all surfaces in accordance with AS1182, unless the part drawing specifically permits as-forged surfaces or "stock size" to be used.

3.2.1.1 Tapped Holes

Holes that are tapped prior to final heat treatment shall be protected during heating above 1200 °F (649 °C) by copper plated steel plugs.

3.2.1.2 Deep Holes

Holes, both closed and open ended, of a depth-to-diameter ratio 4:1 or greater shall be protected during heating above 1200 °F (649 °C). This protection shall be provided just prior to putting the parts into the furnace by filling the hole with an inert atmosphere and closing the hole with tape conforming to A-A-113, Type I, Class A..

3.2.2 Cleaning

All organic contamination, such as grease and oil, shall be removed prior to welding and any thermal processing.

3.2.3 Welding

Welding, when permitted by the part drawing, shall be performed prior to heat treatment, unless otherwise specified. Welded parts shall be stress relieved within the range 1000 to 1200 °F (593 to 649 °C). Unless otherwise specified, welding shall be in accordance with AWS D17.1 and/or MIL-STD-2219.

3.2.3.1 Weld Bead or Flash Removal

Unless otherwise specified, the weld bead, external flash, or upset shall be removed to within 0.030 in (0.75 mm) of the part surface. The weld bead, external flash, or upset shall not be machined or ground below the surface of the parent metal. This metal removal shall be performed before hardening heat treatment and machining marks shall be made transverse to the weld line.

3.2.3.2 Post Weld Heat Treatment

Prior to hardening and tempering, all welded parts shall be normalized or normalized and tempered. All heat treatments, including normalizing, hardening, and tempering, shall be performed in accordance with AMS 2759/2 and the requirements of the part drawing.

3.2.4 Copper Plating

To protect from furnace atmosphere, parts may be copper plated. Copper plating shall be used only in reducing atmospheres or neutral salt baths.

3.3 Heat Treatment

Heat treatment, including hardening (austenitizing and oil quenching) and double tempering, shall be in accordance witih AMS 2759/2 or other heat treat procedure approved by the Coginzant Engineering Organization. The temperature of subsequent tempers shall be not lower than the temperature of previous tempers.

3.3.1 Copper Plate Stripping

When used, copper plating may either be stripped after the first temper or snap temper and before the final temper or, optionally, the stripping may occur after the final temper in that case the part shall be baked in accordance with AMS 2759/9 for not less than 3 h at 375 °F ± 10 °F (191 °C ± 6 °C). Stripping shall be accomplished by immersion in hot alkaline cyanide solution or by processes approved by the cognizant engineering organization.

3.3.2 Hardness Testing

All heat treated parts shall be hardness tested in accordance with AMS 2759/2 and ASTM E 18 after final tempering. The approximate relationship between ultimate tensile strength and hardness is as follows:

TABLE 1

Ultimate Tensile Strength		Hardness
psi	MPa	HRC
270,000	1860	52
275,000	1895	52.5
280,000	1930	53
290,000	2000	54
300,000	2070	55
310,000	2140	56

3.4 Post Heat Treatment (Hardening and Tempering) Processing

3.4.1 Cleaning

Grease and oil shall be removed by vapor degreasing or non-electrolytic alkaline cleaning.

3.4.1.1 Surface Blasting

Dry sand blasting is required after final heat treatment. Parts which are thermally stress relieved after final heat treatment do not require recleaning by sand blasting.

3.4.2 Straightening

Shall only be performed when specifically authorized by the cognizant engineering organization. Straightening shall be performed on hot parts. This straightening shall be performed during tempering, after a 400 °F (204 °C) snap temper, or, alternately, on heated parts in the tempered condition. The straightening temperature shall be within a range of temperatures from the tempering temperature to 50 °F (28 °C) below the tempering temperature. Straightened parts shall be immediately retempered. Parts straightened and retempered shall be hardness tested as required by 3.3.2 after the final temper.

3.4.3 Weldment Proof Testing and Inspection

3.4.3.1 Weldment Proof Testing

Proof testing of weldments, when required, shall be performed on 100% of the weldments after removal of weld bead or flash and after heat treatment.

3.4.3.2 Weldment Inspection

Shall be in accordance with the part drawing and the applicable welding specification after any proof testing. Magnetic particle inspection shall be in accordance with ASTM E 1444, radiographic inspection shall be in accordance with ASTM E 1742, and ultrasonic inspection shall be in accordance with AMS 2630 or AMS-STD-2154.

3.4.4 Metal Removal

3.4.4.1 Grinding

Grinding after heat treatment shall be in accordance with MIL-STD-866 and Table 1 herein and is permitted only where specifically authorized by the cognizant engineering organization. A grinding procedure is required for each part number. This grinding procedure shall be established and documented prior to or concurrent with grinding the first production part.

3.4.4.2 Hole Drilling

Before producing holes in heat treated parts, three samples of the finished hole shall be made to demonstrate a technique for producing the hole that will, without overheating the part, meet hole surface finish requirements. This technique may include honing the hole after drilling. The samples shall be sectioned, nital etch inspected in accordance with AMS 2649, and examined at 500X magnification to ensure freedom from overheating as evidenced by lack of untempered martensite or overtempered martensite on the hole surfaces. The tool material, configuration, feeds, speeds, coolant, and equipment used to prepare the acceptable samples shall be recorded and that procedure shall be used for fabrication of holes in production parts.

3.4.4.3 Machining or Grinding

Areas machined or ground in the heat treated condition shall be processed in the following sequence:

3.4.4.3.1 Remove metal (grind or machine).

3.4.4.3.2 Nital etch inspect in accordance with AMS 2649.

3.4.4.3.3 Stress relieve in accordance with AMS 2759/2 at 50 °F ± 10 °F (28 °C ± 6 °C) below the part tempering temperature. This stress relief shall be accomplished before any peening, flexing, stressing, or plating of the parts. Baking for hydrogen embrittlement relief is accomplished during the stress relieving operation.

3.4.4.4 Honed Surfaces

Surfaces to be honed shall be magnetic particle inspected in accordance with ASTM E 1444 after machining, drilling, or grinding and prior to honing.

3.4.5 Magnetic Particle Inspection

All parts shall be magnetic particle inspected in accordance with ASTM E 1444 after heat treatment, final machining, grinding, nital etch, and stress relieve before honing, shot peening, or plating, whichever is performed first.

3.4.5.1 Removal of magnetic particle indications in accordance with ASTM E 1444 is permissible, providing part drawing tolerances are met and the area is reinspected in accordance with 3.4.4.3.2 and 3.4.5 and stress relieved.

3.4.6 Shot Peening

All surfaces, except threads, holes less than 0.75 in (19.0 mm) in diameter, and areas exempted by the part drawing, shall be shot peened in accordance with AMS 2430 or AMS-S-13165. Shot peening shall be performed after straightening, final machining, grinding, nital etch inspection, stress relieving, and magnetic particle inspection and before plating. Shot peened surfaces may be lapped, honed, or polished provided that the material removed, measured in inches (millimeters), does not exceed 10% of the applicable maximum Almen "A" peening intensity.

Example: For 0.010 to 0.014 "A" intensity, a maximum of 0.0014 in (0.035 mm) may be removed.

3.4.6.1 Parts that have been shot peened and are subsequently straightened shall be reshot peened in accordance with 3.4.6 after stress relieving.

3.4.6.2 Cleaning After Shot Peening

All shot peened parts shall be cleaned immediately after peening by sand or grit blasting followed by alkaline soak.

3.4.7 Preparation for Vacuum Coating

Parts to be vacuum coated shall be baked for not less than 3 h at 375 °F ± 10 °F (191 °C ± 6 °C) before vacuum coating if baking was not performed previously after precleaning operations. Following baking, the parts shall be degreased and the surfaces to be coated shall be lightly sandblasted.

3.4.8 Plating and Coating

All plating and coating shall be as required by the part drawing and, unless otherwise specified, shall conform to the following:

3.4.8.1 Chromium plate in accordance with AMS 2406 or MIL-STD-1501.

3.4.8.2 Vacuum cadmium coat in accordance with AMS 2426 or AMS-C-8837.

3.4.8.3 Cadmium-titanium plate in accordance with AMS 2419 or MIL-STD-1500.

3.4.8.4 Ion vapor deposited aluminum coat in accordance with AMS 2427.

3.4.8.5 Low hydrogen cadmium plate in accordance with AMS 2401.

3.4.8.6 Nickel plate in accordance with AMS 2424, AMS 2403, or AMS 2423.

3.4.9 Post Plate Requirements

3.4.9.1 Baking

Unless otherwise specified, all electrolytically plated parts shall be hydrogen embrittlement relief baked in accordance with AMS 2759/9. For vacuum cadmium coating, a 3 h bake cycle shall be performed to promote maximum adhesion between the coating and the subsequent primer. Baking shall be performed immediately after plating and coating and before plate grinding for the following minimum times:

3.4.9.1.1 Chromium plate - 23 h.

3.4.9.1.2 Vacuum cadmium coat - 3 h cure to promote maximum adhesion between coating and subsequent primer.

3.4.9.1.3 Cadmium-titanium, low hydrogen cadmium, nickel, and sulfamate nickel plate - 23 h.

3.4.9.2 Grinding Chromium and Nickel Plate

3.4.9.2.1 Grinding of chromium and nickel plating shall be in accordance with MIL-STD-866. A grinding procedure is required for each part number. The grinding procedure shall be established and documented prior to, or concurrent with, grinding of the first production parts. Grinding parameters shall be adhered to on all subsequent grinding of the production part.

3.4.9.2.2 Grinding parameters selected shall be within limits specified by Table 1. In addition, procedures shall document wheel type, wheel diameter and width, coolant type and flow rate (gal (L) per min), and other parameters necessary to ensure grinding of subsequent parts or lots in the same manner and sequence applied at the time of establishment of the grinding procedure. Finish grinding shall be at not more than 0.0002 in (0.005 mm) per pass to the final plate thickness required.

3.4.9.3 Magnetic Particle Inspection

All plated surfaces, except vacuum cadmium and ion vapor deposited aluminum coated surfaces, shall be post plate magnetic particle inspected in accordance with ASTM E 1444 after final baking and plate machining or grinding.

3.4.9.3.1 Ground Chromium and Nickel Magnetic Particle Inspection

Ground chromium and nickel plated surfaces shall be magnetic particle inspected using the wet, continuous method in both longitudinal and circumferential directions. Small areas of the part shall be inspected just after the current is off, using the multiple hit technique, until the entire ground surface has been inspected. Plating thickness must be less than 0.004 in (0.010 mm) to detect indications by magnetic particle inspection.

3.4.9.4 Parts that have ground chromium plating shall be inspected for grinding burns on the base metal in accordance with ARP4462.

3.4.10 Coatings

Solid film lubricant, application, priming, and painting shall be performed in accordance with the part drawing.

3.4.11 Identification

All parts shall be identified in accordance with AMS 2800. Identification symbols used shall be traceable to the following:

Manufacturer
Heat treat batch and equipment
Stress relieve batch number, if performed after heat treatment
Baking batch numbers
Finish operations, such as shot peening, plating, and solid film lubrication, by batch number

4. HANDLING AND TRANSPORTATION

4.1 Parts fabricated to the requirements of this recommended practice shall be handled and transported in such a manner as will ensure that the required physical characteristics and properties are preserved.

4.2 Protective Treatment

Parts processed to the requirements of this recommendation practice shall be protected in accordance with good commercial practice; plated parts shall be protected only with materials that are not detrimental to the plating.

5. NOTES

5.1 Processing Sequence Flow Chart

The Table 2 flow chart is a guideline to the sequence of operations for processing high strength 300M steel parts. the sequence shown includes those operations that could normally be applied to a part, depending on its designed configuration. For example, if the drawing does not Include a requirement for welding or chromium plating, those operations would automatically be excluded from the processing sequence without altering the remaining sequence of operations.

TABLE 2 - GRINDING PARAMETER LIMITS (1)

Grinding Method	Grinding Wheel Characteristics (2)			Max Wheel Speeds SFM (SMM) 2	Work Speed Range SFM (SMM) 3	Cross Feed Wheel Width per Revolution (4)	Rough Grind Maximum In-Feed per Pass in (mm)	Final Grind		
	Grit (1)	Grade	Structure					Min Thickness Removal, in per Surface (mm per surface)	Max In-Feed Per Pass, in (mm)	Min Passes Number
Surface (Flat) Bare Steel	46/80	G-I	6 - 12	4000 (1200)	30 - 100 (9.0 - 30.5)	1/10	0.001 (0.025)	0.003 (0.075)	0.0005 (0.012)	6
Cylindrical Bare Steel	46/80	G-I	6 - 12	4000 (1200)	30 - 100 (9.0 - 30.5)	1/10	0.001 (0.025)	0.003 (0.075)	0.0005 (0.012)	6
Internal Bare Steel	46/80	G-I	6 - 12	6500 (1980)	30 - 100 (9.0 - 30.5)	1/8-1/4	0.0005 (0.012)	0.001 (0.025)	0.0002 (0.005)	5
Surface (Flat) Chromium Plated	46/90	G-I	6 - 12	6500 (1980)	30 - 200 (9.0 - 60)	1/8-1/4	0.0005 (0.012)	0.001 (0.025)	0.0002 (0.005)	5
Cylindrical Chromium Plated	46/90	I-K	6 - 12	6500 (1980)	30 - 200 (9.0 - 60)	1/8-1/4	0.0005 (0.012)	0.001 (0.025)	0.0002 (0.005)	5
Internal Chromium	46/120	I-K	6 - 12	12,000 (3660)	30 - 300 (9.0 - 9.0)		0.0005 (0.012)	0.001 (0.025)	0.0002 (0.005)	5

NOTES:

(1) These parameters do not preclude the need for establishing specified grind procedure and proof checks.

(2) These characteristics refer to the industry standard designators for grinding wheels. See ANSI B74.13.

Examples:

32(3)	A	80	I	9(3)	V	BG(3)
Type Abrasive	Abrasive (Aluminum Oxide)	Grain Size (Grit)	Grade	Structure	Bond (Vitrified)	Bond Type

(3) May vary with manufacturer (code symbols not standardized).

(a) Abrasive - Alundum (Aluminum oxide).

(b) Wheel speed - Surface and outside diameter grinding should preferably be conducted at 3000 to 4000 surface feet/minute (SFM) (910 to 1220 surface meters/minute) (SMM) whenever possible. Internal grinding may be conducted at a higher surface speed with a maximum as noted.

(c) Work speed - Maximum available on the grinding machine should be used whenever possible. Normally this will be 60 SFM (18 SMM) on surface grinders. Rotational drivers that allow higher surface speeds [up to 200 SFM (60 SMM)] should be used whenever possible.

(d) 1/8 to 1/4 of wheel width per pass or per part revolution, as applicable. Cross feed not to exceed 1/4 in (6.2 mm) per revolution. Record as in per min (mm/min) on procedure.