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AEROSPACE MATERIAL SPECIFICATION

AMS 2759/5

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Revised

HEAT TREATMENT OF MARTENSITIC CORROSION RESISTANT STEEL PARTS

1. SCOPE: This specification, in conjunction with the general requirements for steel heat treatment covered in AMS 2759, establishes the requirements for heat treatment of martensitic corrosion-resistant steel parts. Parts are defined in AMS 2759.

1.1 Application: This specification is applicable to parts made from the following steels: Types 403, 410, 416, 420, 422, 431, 440C, and Greek Ascoloy (UNS S40300, S41000, S41600, S42000, S42200, S43100, S44004, and S41800).

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications and Aerospace Recommended Practices shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2759 - Heat Treatment of Steel Parts, General Requirements

2.1.2 Aerospace Recommended Practices:

ARP 1820 - Chord Method of Evaluating Surface Microstructural Characteristics

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2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E384 - Microhardness of Materials

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Federal Specifications:

QQ-P-35 - Passivation Treatments for Corrosion-Resisting Steel

3. TECHNICAL REQUIREMENTS:

3.1 Heat Treatment: Shall conform to AMS 2759 and the requirements specified herein.

3.2 Equipment: Shall conform to AMS 2759. Furnace temperature uniformity requirements for annealing, subcritical annealing, hardening, straightening, stress relieving, and baking shall be ±25°F (±15°C) and for tempering shall be ±15°F (±8°C).

3.3 Heating Environment: Parts shall be controlled by type, described in 3.3.1, and heat treated in the class of atmosphere, described in 3.3.2, permitted in Table I for that type when heating above 1300°F (700°C). When heating parts at 1300°F (700°C) or below, class A, B, or C may be used (See 8.2).

3.3.1 Types of Parts: The heat treating processor shall determine the part type.

Type 1: Parts with 0.020 in. (0.5 mm) or more to be machined off all surfaces after heat treatment and parts with as-forged, as-cast, or hot-finished mill surfaces at the time of heat treatment with all surfaces to be machined off. Unless informed that all surfaces will have at least 0.020 in. (0.5 mm) machined off, the heat treating processor shall assume they will not and shall control the part as Type 2, 3, or 4 as applicable.

Type 2: Forgings, castings, sheet, plate, bar, rod, tubing, and extrusions with hot-finished surfaces at time of heat treatment that will remain on the finished part.

Type 3: Parts with finished machined surfaces or surfaces with less than 0.020 in. (0.5 mm) to be machined off any surface after heat treatment and parts with protective coating on all surfaces.

Type 4: Parts that are partially machined with both unmachined, as-forged, as-cast, or hot-finished mill surfaces and finished machined surfaces or machined surfaces with less than 0.020 in. (0.5 mm) to be machined off after heat treatment.

3.3.1.1 If part type cannot be determined, the part shall be processed as Type 3.

3.3.2 Classes of Atmospheres:

Class A: Argon, hydrogen, helium, nitrogen, nitrogen-hydrogen blends, vacuum, or neutral salt.

Class B: Endothermic, exothermic, or carbon-containing nitrogen-base.

Class C: Air.

TABLE I

Atmospheres (1) (2) (3)

Part Classification (4)	Class A	Class B (5)	Class C
Type 1	Permitted	Permitted	Permitted
Type 2	Permitted	Prohibited (6)	Permitted (7)
Type 3	Permitted	Permitted	Prohibited
Type 4	Permitted	Permitted (7)	Prohibited

(1) Austenitizing in atmospheres containing hydrogen shall be limited to parts to be tempered above 1000°F (540°C).

(2) Use of nitrogen from dissociated ammonia is prohibited.

(3) Atmospheres containing nitrogen at 1800°F (980°C) and higher shall not be permitted when finished machined surfaces exist.

(4) See 3.5.1.2.

(5) Endothermic and carbon-containing nitrogen-base atmosphere prohibited for 431 and when heat treating any alloy to 180,000 psi (1240 MPa) or higher.

(6) Permitted provided the atmosphere is controlled to produce no carburization or nitriding as described in 3.5.1.

(7) Prohibited if a specific requirement to control the surface carbon on all surfaces is specified.

3.3.3 Atmosphere: Atmosphere in furnaces shall be controlled to ensure that the surfaces of parts are within the limits specified in 3.5.1. Salt baths shall be tested in accordance with AMS 2759.

3.3.4 Protective Coatings: A supplemental coating or plating is permitted when approved by the cognizant engineering organization.

3.4 Procedure:

3.4.1 Passivation: Parts, except for Type 1, shall be passivated in accordance with QQ-P-35 before all thermal treatments following forming with dies made from lead, kirksite, or other low-melting temperature materials. Parts, except for Type 1, shall be passivated in accordance with QQ-P-35 before thermal treatments above 1350°F (730°C).

3.4.2 Preheating: Preheating in the 1200° - 1500°F (650° - 815°C) range is recommended before heating parts above 1500°F (815°C) if the parts have previously been heat treated to 35 HRC or higher, have abrupt changes of section thickness, have finished machined surfaces, have been welded, have been cold formed or straightened, have holes, or have sharp or only slightly rounded corners.

3.4.3 Soaking: Heating shall be controlled, as described in AMS 2759, in such a manner that either the heating medium or the part temperature, as applicable, is maintained at the set temperature in Table II or Table III for the soak times specified herein. Soaking shall commence when all control, indicating, and recording thermocouples reach the specified set temperature or, if load thermocouples as defined in AMS 2759 are used, when the part temperature reaches the minimum of the furnace uniformity tolerance at the set temperature. In all cases, the parts shall be held for sufficient time to ensure that the center of the most massive area has reached temperature and the necessary transformation and diffusion have taken place.

3.4.3.1 Parts coated with copper plate or similar coatings which tend to reflect radiant heat shall have their soak time increased by at least 50%, unless load thermocouples are used.

3.4.4 Annealing: Shall be accomplished in accordance with Table II by heating to the temperature specified, soaking for the time specified in Table IV, and cooling to below the temperature specified at the rate shown, followed by air cooling to ambient temperature. Isothermal annealing treatments may be used providing equivalent hardness and microstructure are obtained. Isothermal annealing shall be accomplished by heating to the annealing temperature specified in Table II, soaking for the time specified in Table IV, salt cooling to a temperature below the critical, holding for enough time to complete transformation, and air cooling to ambient temperature.

3.4.5 Subcritical Annealing (Stress Relieving): Subcritical annealing or stress relieving prior to hardening shall be accomplished by heating in the range 1350° - 1450°F (730° - 790°C), except 431 shall be at 1150° - 1200°F and 440C shall be 1250° - 1350°F (675° - 730°C), soaking for the time specified in Table IV, and cooling to ambient temperature.

3.4.6 Hardening (Austenitizing and Quenching): Shall be accomplished by heating to the austenitizing temperature specified in Table II, soaking for the time shown in Table IV, and quenching as specified in Table II.

3.4.7 Tempering: Shall be accomplished by heating quenched parts to a temperature as required to produce the required properties. Suggested tempering temperatures for specific tensile strengths for each alloy are given in Table III. The parts shall be held at the set temperature for not less than 2 hr plus 1 hr additional for each inch (25 mm) of thickness or fraction thereof greater than 1 in. (25 mm). Thickness is defined in AMS 2759. When load thermocouples are used, the soaking time shall be not less than 2 hours.

3.4.7.1 If hardened parts cannot be tempered within 2 hr of quenching, they shall be snap tempered for 2 hr at a temperature that is lower than the tempering temperature.

3.4.8 Straightening: When straightening of heat treated parts is authorized by the cognizant engineering organization and the procedure is not specified, straightening shall be performed as follows:

3.4.8.1 Hardened Parts: Shall be straightened during the tempering operation.

3.4.8.2 Hardened and Tempered Parts: Shall be straightened at room temperature or at an elevated temperature not exceeding 50 F (30 C) deg below the tempering temperature. Room or elevated temperature straightening shall be followed by stress relieving at a temperature not exceeding 50 F (30 C) deg below the tempering temperature.

3.4.9 Stress Relieving: When required by the cognizant engineering organization, parts shall, after operations which follow hardening and tempering, be stress relieved by heating the parts to 50 F (30 C) deg below the tempering temperature and holding for not less than 1 hr plus 1 hr additional for each inch (25 mm) of thickness or fraction thereof greater than 1 in. (25 mm). When load thermocouples are used, the soaking time shall be not less than one hour. Stress relief is prohibited on parts which have been peened or thread or fillet rolled after hardening and tempering.

3.4.10 Embrittlement Relieving (Baking): Baking for hydrogen embrittlement relief shall be accomplished by heating to the temperature specified by the specification controlling the embrittling process (plating, pickling, etc) and holding for the specified time. If the tempering temperature of the parts was below the specified baking temperature, the baking temperature shall be reduced to a temperature 25 F (15 C) deg below the tempering temperature.

3.5 Properties: Parts shall conform to the hardness specified by the cognizant engineering organization, or for types 403 and 410 in the 180,000 - 200,000 psi (1240 - 1380 MPa) range the hardness limit shall be HRC 44 max and for type 431 in the 180,000 - 200,000 psi (1240 - 1380 MPa) range the hardness limit shall be HRC 47 maximum.

3.5.1 Surface Contamination: The atmospheric protection medium in furnaces for heating parts above 1300°F (700°C), when less than 0.020 in. (0.5 mm) of metal is to be removed from any surface, shall be controlled to preclude carburization or nitriding and permit no complete decarburization (See 3.5.1.1). Partial decarburization shall not exceed 0.005 in. (0.12 mm). Intergranular oxidation shall not exceed a depth of 0.0007 in. (0.018 mm). Rejection criteria for depth of decarburization shall be the microhardness reading at which there is not more than a 20-point Knoop, or equivalent, decrease in hardness from the core hardness. Rejection criteria for carburization and nitriding shall be that the microhardness shall not exceed the core hardness by 20 points Knoop or more, or equivalent, at a depth of 0.0003 in. (0.008 mm). Tests shall be in accordance with 3.6.1. The requirements of this paragraph also apply to the cumulative effects of operations such as austenitizing followed by reaustenitizing (See 3.5.1.3).

3.5.1.1 Unless specifically informed that at least 0.020 in. (0.5 mm) will be removed from all surfaces of parts, the heat treating processor shall heat treat the parts as though less than 0.020 in. (0.5 mm) will be removed from some surfaces and, therefore, shall heat treat using controlled atmosphere which will conform to the surface contamination requirements.

3.5.1.2 Parts that will be machined after heat treatment, but which will have less than 0.020 in. (0.5 mm) of metal removed from any machined surface may be reclassified as Type 1, as described in 3.3.1, and need not meet the requirements of 3.5.1 as heat treated, when it is demonstrated by tests on each load that all surface contamination exceeding the requirements of 3.5.1 will be removed from all machined surfaces, taking into account distortion after heat treatment.

3.5.1.3 It is the responsibility of the heat treating processor to determine whether cumulative heat treating operations at processor's facility, as described in 3.5.1, have caused excessive surface contamination.

3.6 Test Methods: Shall be in accordance with AMS 2759 and as follows:

3.6.1 Surface Contamination: Testing shall be by the microhardness method in accordance with ASTM E384, unless otherwise specified. Test specimens shall be in the as-quenched condition. The presence of total decarburization, carburization, and nitriding and the depth of any intergranular oxidation shall be determined by etching with the appropriate etchant and examining at approximately 250X magnification. The chord method and acceptance limits in ARP 1820 may be used as the alternate and to enhance the intergranular oxidation examination.

4. QUALITY ASSURANCE PROVISIONS: The responsibility for inspection, classification of tests, sampling, approval, entries, records, and reports shall be in accordance with AMS 2759 and as specified in 4.1.

4.1 Classification of Tests: The classification of acceptance, periodic, and preproduction tests shall be as specified in AMS 2759 and the following:

4.1.1 Acceptance Tests: In addition to the tests specified in AMS 2759, tests to determine conformance to requirements for surface contamination (3.5.1) for parts tempered below 700°F (370°C) are classified as acceptance tests and shall be performed on each lot.

4.1.2 Periodic Tests: In addition to the tests specified in AMS 2759, tests to determine conformance to the requirements for surface contamination (3.5.1) are classified as periodic tests. Surface contamination tests shall be performed monthly on each piece of equipment (furnace) in service for each kind of atmosphere to be used.

4.1.3 Preproduction Tests: In addition to the tests specified in AMS 2759, tests to determine conformance to requirements for surface contamination (3.5.1) are classified as preproduction tests and shall be performed prior to any production heat treating for each piece of equipment (furnace) for each kind of atmosphere to be used.

5. PREPARATION FOR DELIVERY: Shall be in accordance with AMS 2759.

6. ACKNOWLEDGMENT: The heat treating processor shall mention this specification number in all quotations and when acknowledging purchase orders.

7. REJECTIONS: Parts not heat treated in accordance with this specification or modifications authorized by the cognizant engineering organization will be subject to rejection and shall be submitted for disposition in accordance with purchaser's procedures for nonconformance.

8. NOTES: Shall be in accordance with AMS 2759 and 8.2 and 8.3.

8.1 Definitions: Shall be as stated in AMS 2759.

8.2 Caution: Heating below 1400°F (760°C) with Class B atmosphere containing 5% or more of hydrogen (H_2), carbon monoxide (CO), or methane (CH_4) risks explosion and fire.

8.3 When supplemental plating or coating, such as copper plate, is used, all atmosphere controls and surface contamination tests are still required.

8.4 Processes meeting the requirements of this specification have been classified under Federal Supply Classification (FSC) 95GP.

This specification is under the jurisdiction of AMS Committee "B".

TABLE II

ANNEALING AND AUSTENITIZING TEMPERATURES AND QUENCHANTS

Material Designation	Annealing Temperature °F	Annealing Temperature °C	Austenitizing Temperature °F	Austenitizing Temperature °C	Hardening Quenchant (1)(2)
403	1550 (8)	845 (8)	1800 (4)	980	Oil
410	1550 (8)	845 (8)	1800 (4)	980	Oil
416	1600 (8)	870 (8)	1825	995	Oil
420	1600 (8)	870 (8)	1875	1025	Oil
422	1600 (3)	870 (3)	1925	1055	Oil or Salt (5)
431	1600 (6)	870 (6)	1875	1025	Oil or Salt (5)(7)
440C	1650 (8)	900 (8)	1925	1055	Oil (7)
Greek Ascoloy	1550 (8)	845 (8)	1825	995	Oil

(1) Other media which have demonstrated that they will quench at equivalent speed as conventional oil (without additives) down to 150°F (65°C) or lower may be used. This demonstration would require approval by the cognizant engineering organization of the quenchant and concentration and of the test data verifying equivalent strength, stress-corrosion resistance, residual stress level, etc. Once this approval is granted for a specific quenchant, approval of individual heat treat shops is not required. Media which quench at slower or faster speeds or to lower or higher temperatures are permitted only when approved by the cognizant engineering organization.

(2) Cooling in air or other gases is permitted for parts with less than 0.250 in. (6.25 mm) maximum thickness provided they are not racked densely packed.

(3) Cool to 1300°F (705°C), hold at 1300°F (705°C) for 5 - 7 hr, cool to below 1000°F (540°C) at a rate not to exceed 50 F (30 C) deg per hr, and air cool to ambient.

(4) Austenitizing temperature of 1750°F (955°C) is permitted for thin sections to minimize warpage.

(5) Salt temperature shall be 375° - 525°F (190° - 275°C). Hold in salt for 10 to 15 minutes. Remove parts and cool in air to room temperature.

(6) Air cool to ambient temperature followed by heating to 1200°F (650°C) for 10 to 12 hr and air cooling.

(7) After hardening quench, cool 431 and 440C parts by immersing in cold water to ambient temperature water and then refrigerate at -90°F (-70°C) or lower for not less than 2 hours.

(8) Cool to below 1100°F (595°C) at a rate not to exceed 50 F (30 C) deg per hr followed by air cool to ambient.