AEROSPACE MATERIAL SPECIFICATION

AMS2759/5	REV. D

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Superseding AMS2759/5C

Heat Treatment
Martensitic Corrosion-Resistant Steel Parts

RATIONALE

AMS2759/5D has been reaffirmed to comply with the SAE five-year review policy.

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 respectively).

2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent supplied herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

AMS 2759 Heat Treatment of Steel Parts, General

ARP1820 Chord Method of Evaluating Surface Microstructural Characteristics

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 or www.astm.org.

ASTM A 380 Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems

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 (±14 °C), and for tempering shall be ±15 °F (±8 °C).

3.3 Heating Environment:

Parts shall be controlled by type (See 3.3.1), and heat treated in the class of atmosphere (See 3.3.2) permitted in Table 1 for that type when heating above 1250 °F (677 °C). When heating parts at 1250 °F (677 °C) or below, Class A, B, or C atmosphere may be used (See 8.2).

TABLE 1 - Atmospheres (1) (2)

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

NOTES:

(1) Austenitizing in atmospheres containing hydrogen shall be limited to parts to be tempered above 1000 °F (538 °C). Annealing in hydrogen-containing atmospheres is permitted.
(2) Atmospheres containing nitrogen at 1800 °F (982 °C) and higher shall not be permitted when finished machined surfaces exist.
(3) See 3.5.1.2.
(4) Endothermic and carbon-containing nitrogen-base atmosphere are prohibited for 431 and when heat treating any alloy to 180 ksi (1241 MPa) or higher.
(5) Permitted provided the atmosphere is controlled not to produce carburization or or nitriding as described in 3.5.1.
(6) Prohibited if a specific requirement to control the surface carbon on all surfaces is specified.

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

Type 1: Parts with 0.020-inch (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 time of heat treatment with all surfaces to be machined off. Unless informed that all surfaces will have at least 0.020-inch (0.51-mm) machined off, the heat treating processor shall assume parts will not be machined and shall control the part as Type 2, 3, or 4 as applicable.

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

Type 3: Parts with finished machined surfaces or surfaces with less than 0.020-inch (0.51-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-inch (0.51-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 molten salt. Nitrogen from dissociated ammonia is not permitted.

Class B: Endothermic, exothermic, or carbon-containing nitrogen-base (See 8.2).

Class C: Air or products of combustion.

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

3.3.3.1 Dew Point: Hydrogen and hydrogen-containing blends and atmospheres shall have a dew point of -40 °F (-40 °C) or lower in or at the exit of the furnace working zone.

3.3.4 Protective Coatings: A supplemental coating or plating is permitted when approved by the cognizant engineering organization (See 8.3).

3.4 Procedure:

3.4.1 Acid Cleaning: Parts, except for Type 1, shall be acid cleaned in accordance with ASTM A 380 before thermal treatment following forming with dies made from lead, kirksite, or other low-melting temperature materials.

3.4.2 Preheating: Preheating, until furnace stabilization in the 1200 to 1500 °F (649 to 816 °C) range, is recommended before heating parts above 1500 °F (816 °C) if the parts have previously been heat treated to a hardness greater than 35 HRC, have abrupt changes of section thickness, have sharp reentrant angles, have finished machined surfaces, have been welded, have been cold formed or straightened, have holes, or have sharp or only slightly rounded notches or corners.

3.4.3 Soaking: Heating shall be controlled, as described in AMS 2759, such that either the heating medium or the part temperature, as applicable, is maintained at the set temperature in Table 2 or 3 for the soak time 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 at the set temperature.

3.4.3.1 Parts with copper plated coated with reflective 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 by heating to the temperature shown in Table 2, soaking for the time shown in Table 4, and cooling to below the temperature shown in Table 2 at the rate shown in Table 2 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 shown in Table 2, soaking for the time shown in Table 4, cooling to a temperature below the critical, holding for sufficient 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 to 1450 °F (732 to 788 °C), except 431 shall be at 1150 to 1200 °F (621 to 649 °C) and 440C shall be at 1250 to 1350 °F (677 to 732 °C), soaking for the time shown in Table 4, and cooling to ambient temperature.

3.4.6 Hardening (Austenitizing and Quenching): Shall be accomplished by heating to the austenitizing temperature shown in Table 2, soaking for the time shown in Table 4, and quenching as shown in Table 2. The parts shall be cooled to or below the quenchant temperature before tempering.

3.4.7 Tempering: Shall be accomplished by heating quenched parts to the temperature required to produce the required properties. Suggested tempering temperatures for specific tensile strengths for each alloy are shown in Table 3. Soaking time shall be not less than two hours plus one hour additional for each inch (25-mm) of thickness or fraction thereof greater than one-inch (25-mm). Thickness is defined in AMS 2759. When load thermocouples are used, the soaking time shall be not less than one hour. Multiple tempering is permitted. When multiple tempering is used, parts shall be cooled to ambient temperature (or below, if specified) between tempering treatments.

3.4.7.1 Parts may be snap tempered for two hours at 300 °F (149 °C). If the tempering temperature is below 325 °F (163 °C) the snap temper shall be 25 °F (14 °C) degrees below 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 or after the tempering operation.

3.4.8.2 Hardened and Tempered Parts: Shall be straightened at ambient temperature or at an elevated temperature not exceeding 50 °F (28 °C) degrees below the tempering temperature. Ambient or elevated temperature straightening shall be followed by stress relieving at a temperature 50 °F (28 °C) degrees below the tempering temperature, unless otherwise specified. It is permissible to retemper at a temperature not higher than the last tempering temperature after straightening during tempering.

3.4.9 Post-Tempering 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 (28 °C) degrees below the tempering temperature and soaking for not less than one hour plus one hour additional for each inch (25-mm) of thickness or fraction thereof greater than one-inch (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.

3.5 Properties:

Parts shall conform to the hardness specified by the cognizant engineering organization. If maximum hardness is not specified for types 403 and 410 in the 180 to 200 ksi (1241 to 1379 MPa) tensile strength range, hardness shall be 44 HRC maximum. For type 431 in the 180 to 200 ksi (1241 to 1379 MPa) tensile strength range, hardness shall be 47 HRC maximum.

3.5.1 Surface Contamination: Salt baths and the protective atmosphere and backfill medium in furnaces for heating parts above 1250 °F (677 °C), when less than 0.020-inch (0.51-mm) of metal is to be removed from any surface, shall be controlled to prevent carburization or nitriding and prevent complete decarburization (See 3.5.1.1). Partial decarburization shall not exceed 0.005-inch (0.13-mm). Intergranular oxidation shall not exceed 0.0007-inch (0.018-mm). Rejection criteria for depth of decarburization shall be the microhardness reading at which there is 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 equivalent, at a depth of 0.003-inch (0.08-mm). Tests shall be in accordance with 3.6.1. These requirements also apply to the cumulative effects of operations such as austenitizing followed by reaustenitizing (See 3.5.1.4). For reheat treatments, the original specimen or a portion thereof shall accompany the parts and be tested after reheat treatment.

3.5.1.1 Unless specifically informed that at least 0.020-inch (0.51-mm) will be removed from all surfaces of parts, the heat treating processor shall heat treat the parts as if less than 0.020-inch (0.51-mm) will be removed from some surfaces and, therefore, shall heat treat using controlled atmosphere which will produce parts conforming 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-inch (0.51-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 (See 3.6.1.1) on each load that all surface contamination exceeding the requirements of 3.5.1 is removable from all machined surfaces, taking into account distortion after heat treatment.

3.5.1.3 Furnaces used exclusively to heat treat parts which will have all contamination removed shall not require testing.

3.5.1.4 The heat treating processor shall be responsible for determining whether cumulative heat treating operations at their 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 ARP1820 or an equivalent microhardness method that provides at least 3X increase in the apparent thickness of the surface layer. Other microhardness methods may be used when approved by the cognizant quality assurance organization and as approved in 3.6.1.1. Test specimens shall be of the same alloy as the parts. Unless otherwise specified, test specimens shall be in the as-quenched condition. In addition, the presence of total decarburization, carburization, and nitriding shall be determined by etching with the appropriate etchant and examining at approximately 250X magnification.

3.6.1.1 Testing for reclassification in 3.5.1.2 may be by any microhardness method if more than 0.002-inch (0.05-mm) is subsequently machined off all machined surfaces.

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 and 4.2.

4.1 Classification of Tests:

The classification of acceptance, periodic, and preproduction tests shall be as specified in AMS 2759 and as specified in 4.1.1 through 4.1.3.

4.1.1 Acceptance Tests: Surface contamination (3.5.1) for parts tempered below 700 °F (371 °C) is an acceptance test and shall be performed on each lot. An alternate sampling plan in accordance with 4.2 may be used.

4.1.2 Periodic Tests: Surface contamination (3.5.1) is a periodic test and shall be performed monthly for each furnace in service and for each kind of atmosphere to be used in each furnace.

4.1.3 Preproduction Tests: Surface contamination (3.5.1) is a preproduction test and shall be performed prior to any production heat treating for each furnace and for each kind of atmosphere to be used in each furnace.

4.2 Alternative Sampling Plan:

An alternative test plan to meet the requirements of 4.1.1 is permitted for heat treatment processes verified by statistical process control (SPC) to be stable and capable.

4.2.1 A process is considered stable when statistical evaluation of the product and process parameters show that all measured values fall within established control limits.

4.2.2 A process is considered capable when, after achieving and maintaining stability, all parts running to the process have a minimum C_{pk} of 1.33 with a confidence level of 90 percent.

NOTE: C_{pk} is defined as the smaller of either C_{pl} or C_{pu} as determined by Equation 1 or Equation 2:

$$C_{pl} = \frac{\bar{X} - LSL}{3\sigma} \quad \text{(Eq. 1)}$$

$$C_{pu} = \frac{USL - \bar{X}}{3\sigma} \quad \text{(Eq. 2)}$$

where:

$\bar{X}$ = process average

LSL= lower specification limit*

USL= upper specification limit*

*Specification limits are based on target values established by the supplier

σ= estimated standard deviation

4.2.3 The alternative sampling plan shall contain the following:

4.2.3.1 Statistical analysis of the heat treatment process parameters and the product test results of properties (3.5) for control and capability.

4.2.3.2 Documentation of the critical process parameters and of the product test results of properties (3.5) on a control plan. A change in these process parameters or product test results will require review to determine if the process capability requires reverification.

4.2.3.3 Periodic auditing of the heat treatment process parameters and the product test results of properties (3.5) to verify continued control and capability.

4.2.3.4 Monthly, or whenever needed by either the cognizant engineering authority or process constraints, decarburization shall be examined in accordance with 3.5.1.

5. PREPARATION FOR DELIVERY:

See AMS 2759.

6. ACKNOWLEDGMENT:

See AMS 2759.

7. REJECTIONS:

See AMS 2759.

8. NOTES:

Shall be in accordance with 8.1, 8.2, 8.3, and AMS 2759.

8.1 A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of a specification. An (R) symbol to the left of the document title indicates a complete revision of the specification, including technical revision. Change bars and (R) are not used in original publications, nor in specifications that contain editorial changes only.

8.2 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), may result in 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 Terms used in AMS are clarified in ARP1917.

8.5 Dimensions and properties in inch/pound units are primary; dimensions and properties in SI units are shown as the approximate equivalents of the primary units and are presented only for information.

8.6 Key Words:

Steels, parts, martensitic, annealed, tempered, preproduction tests