AEROSPACE MATERIAL SPECIFICATION

AMS2759™/5	REV. F

Issued 1984-10
Reaffirmed 2014-04
Revised 2020-09

Superseding AMS2759/5E

Heat Treatment
Martensitic Corrosion-Resistant Steel Parts

RATIONALE

AMS2759/5F makes changes to ordering information regarding qualification test specimens and properties, gas pressure quenching (3.4.6.1), and Note 1 of Table 2 deleting reference to vacuum to allow for non vacuum furnaces, 440 °C tempering temperature correction (Table 3), and improvements to Appendix A.

ORDERING INFORMATION: In addition to that listed in AMS2759, the purchaser shall supply the following information to the heat treating processor.

- AMS2759/5F
- Hardness or tensile strength if other than that listed in Table 3 (see 3.4.8 and 3.5.1)
- When required for qualification of gas quenching, tensile properties and number of specimens (see A.1 and A.2.4)

1. SCOPE

1.1 Purpose

This specification, in conjunction with the general requirements for steel heat treatment covered in AMS2759, establishes the requirements for heat treatment of martensitic corrosion-resistant steel parts. Parts are defined in AMS2759. General ordering instructions are specified in AMS2759.

1.2 Application

This specification is applicable to parts made from the following steels: Alloy types 403, 410, 416, 420, 422, 431, 440C, Greek Ascoloy, XD15NW, XD16N, and CX13VDW (UNS S40300, S41000, S41600, S42000, S42200, S43100, S44004, S41800, S42025, S42716, and S64152, respectively). Parts made from other martensitic stainless steels other than those specified may be heat treated in accordance with the applicable requirements using processing temperatures, times, and other parameters recommended by the material producer unless otherwise specified by purchaser.

1.3 The provisions of this specification revision shall become effective 90 days after publication.

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**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS2759/5F/

2. APPLICABLE DOCUMENTS

In addition to those listed in AMS2759, the issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The processor 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. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2418 Plating, Copper

AMS2750 Pyrometry

AMS2759 Heat Treatment of Steel Parts, General Requirements

AMS2769 Heat Treatment of Parts in a Vacuum

AS1260 Equivalent Sections of Certain Shapes to Round Bars

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM A370 Mechanical Testing of Steel Parts

3. TECHNICAL REQUIREMENTS

3.1 Pyrometry

Shall be in accordance with AMS2750 and as specified herein.

3.2 Furnace Equipment

Shall be in accordance with AMS2759. Furnaces used for annealing, subcritical annealing, hardening, straightening, and baking shall be a minimum of Class 5 and for tempering shall be a minimum of Class 3 in accordance with AMS2750.

3.3 Heating Environment

Parts shall be controlled by type and heat treated in the class of atmosphere 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). Types of parts and classes of atmosphere are defined in AMS2759. Atmosphere furnaces shall be controlled to ensure that the surfaces of heat treated parts are within the limits specified in 3.5.2. Salt baths shall be controlled and tested in accordance with AMS2759. Vacuum furnaces shall be controlled and tested in accordance with AMS2769.

Table 1 - Atmospheres [(1)(5)]

Part Classification [(3)]	Class A	Class B [(4)]	Class C
Type 1	Permitted	Permitted	Permitted
Type 2 [(2)]	Permitted	Prohibited	Prohibited

NOTES:

(1) Austenitizing in atmospheres containing hydrogen with a dewpoint greater than -40 °F (-40 °C) shall be limited to parts to be tempered above 1000 °F (538 °C). Annealing in hydrogen-containing atmospheres is permitted.

(2) Except for stainless steels, which have been purposely enriched with nitrogen during their manufacture, atmospheres containing nitrogen at 1800 °F (982 °C) and higher shall not be permitted when finished machined surfaces exist.

(3) Refer to AMS2759 regarding reclassification of part type for surface contamination testing.

(4) Endothermic and carbon-containing nitrogen-base atmosphere are prohibited for Alloy 431 and when heat treating any alloy to 180 ksi (1241 MPa) or higher.

(5) Types of parts and classes of atmospheres are defined in AMS2759.

3.4 Procedure

3.4.1 Cleaning

Shall be in accordance with AMS2759.

3.4.2 Preheating

Preheating, 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 re-entrant 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

Start of soak shall be in accordance with AMS2759. Soak times for annealing and hardening are shown in Table 4. Parts that are copper plated or coated with reflective coatings which tend to reflect radiant heat shall have the soak time increased by at least 50% when processing at setpoints above 1200 °F (649 °C), 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 or equivalent 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 or equivalent to ambient temperature.

3.4.5 Subcritical Annealing

When subcritical annealing is required, it shall be performed prior to hardening by heating in the range 1350 to 1450 °F (732 to 788 °C), except 431 alloy, which shall be at 1150 to 1200 °F (621 to 649 °C) and 440C alloy, which 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 liquid quenchant temperature or to a temperature low enough to achieve complete transformation before tempering. Quench liquids shall be controlled and tested as specified in AMS2759. Vacuum quench media shall be controlled and tested as specified in AMS2769.

3.4.6.1 Furnace Gas Pressure Quenching

For all materials listed in Table 2, forced gas quenching is permitted for parts where the minimum dimension of the maximum thickness of the part is 1 inch or less. For thickness greater than 1 inch (25.4 mm) qualification is required in accordance with Appendix A.

3.4.6.1.1 Quench gases shall be in accordance with AMS2769. Single gas types or mixtures may be used for gas pressure quenching provided the quenching process is qualified in accordance with the requirements contained in this document.

3.4.7 Subzero Cooling

After quenching and prior to tempering, subzero cooling may be required as shown in Table 2. It is recommended that subzero cooling begin within 2 hours from end of quench. For subzero treatments, interruptions of the soaking period are permitted. The total soak time shall not include any time when the temperature is warmer than -90 °F (-68 °C) due to interruptions.

3.4.8 Tempering

3.4.8.1 Shall be accomplished by heating quenched parts to the temperature required to produce the required properties. Suggested tempering temperatures for specific hardness or tensile strengths for each alloy are shown in Table 3. Initial tempering should begin within 2 hours from end of quench or within 2 hours from when subzero cooled parts have reached ambient temperature. Soaking time shall be not less than 2 hours plus 1 hour additional for each inch (25 mm) of thickness or fraction thereof greater than 1 inch (25 mm). Thickness is defined in AMS2759. When load thermocouples are used, the soaking time shall be not less than 1 hour. Multiple tempering is permitted for all alloys and required for some as shown in Table 3. When multiple tempering is used, parts shall be cooled to ambient temperature (or below, if specified) between tempering treatments.

3.4.8.2 If parts cannot be tempered within 2 hours from end of quench or within 2 hours from when subzero cooled parts have reached ambient temperature, parts may be snap tempered for a minimum of 2 hours at 300 °F (149 °C). If the tempering temperature is below 325 °F (163 °C), the snap temper shall be no greater than 25 °F (14 °C) below the final tempering temperature.

3.4.9 Straightening

When straightening of heat treated parts is required and the procedure is not specified, straightening shall be performed as follows:

3.4.9.1 Hardened parts shall be straightened during tempering, in between tempers, or after the tempering operation.

3.4.9.2 Hardened and tempered parts shall be straightened at ambient temperature or at an elevated temperature not exceeding 50 °F (28 °C) below the tempering temperature. Ambient or elevated temperature straightening shall be followed by stress relieving at a temperature 50 °F (28 °C) below the tempering temperature, unless otherwise specified.

3.4.10 Stress Relieving

When required, parts shall be stress relieved in accordance with AMS2759/11.

3.5 Properties

3.5.1 Hardness

Parts shall conform to the minimum hardness converted from the required tensile strength stated in Table 3. Frequency of hardness testing shall be in accordance with AMS2759.

3.5.2 Surface Contamination

Shall be in accordance with AMS2759, except partial decarburization shall not exceed 0.005 inch. These requirements also apply to the cumulative effects of operations such as austenitizing followed by reaustenitizing. For reheat treatments, the original specimen, sample part, or a portion thereof shall accompany the parts and be tested after reheat treatment.

3.5.2.1 Parts that are completely masked with a copper plate, not less than 0.0008 inch (20 microns) thick in accordance with AMS2418 shall not require testing. Parts exhibiting blistering, peeling or porosity of the plating are required to be tested.

3.6 Test Methods

Test method for surface contamination shall be in accordance with AMS2759.

4. QUALITY ASSURANCE PROVISIONS

4.1 The responsibility for inspection, classification of tests, sampling and testing, approval, records, record retention, and report/certification shall be in accordance with AMS2759 and as follows.

4.2 Acceptance Tests

Hardness (3.5.1) is an acceptance tests and shall be performed on each lot of parts. Surface contamination (3.5.2) for Type 2 parts with tensile strength 220 ksi (46 HRC) or above is an acceptance test and shall be performed on each lot except as allowed in 3.5.2.1 and 4.5.1.1.

4.3 Periodic Tests

Surface contamination (3.5.2) is a periodic test for Type 2 parts with tensile strength less than or equal to 220 ksi (46 HRC). The test shall be performed monthly for each furnace in service heating parts above a setpoint of 1250 °F (677 °C) and for each class of atmosphere to be used in each furnace.

4.4 Preproduction Tests

Surface contamination (3.5.2) is a preproduction test and shall be performed prior to any production heat treating for each furnace heating above 1250 °F (677 °C) and for each class of atmosphere to be used in each furnace.

4.5 Sampling and Testing

4.5.1 Surface Contamination Testing

One or more samples shall be processed.

4.5.1.1 For parts heat treated in a vacuum, lot acceptance testing (4.2) for surface contamination testing is not required if the weekly leak rate test is acceptable per AMS2769. For other heating environments, an alternate sampling plan in accordance with 4.5.1.2 may be used.

4.5.1.2 Alternative Sampling Plan

An alternative sampling plan is permitted for heat treatment processes verified by statistical process control (SPC) to be stable and capable.

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

4.5.1.2.2 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%.

4.5.1.2.3 The alternative sampling plan shall contain the following:

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

4.5.1.2.3.2 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 re-verification.

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

4.5.1.2.3.4 Monthly, or whenever needed by process constraints, surface contamination shall be examined in accordance with 3.5.2.

5. PREPARATION FOR DELIVERY

Shall be in accordance with AMS2759.

6. ACKNOWLEDGMENT

Shall be in accordance with AMS2759.

7. REJECTIONS

Shall be in accordance with AMS2759.

8. NOTES

8.1 Revision Indicator

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 this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents 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 is used that does not meet AMS2418, all atmosphere controls and surface contamination tests are still required on a plated or coated test specimen.

8.4 Terms used in AMS are clarified in ARP1917 and as follows:

8.4.1 Maximum Dimensional Stability

When specified on the purchase order and/or purchaser supplied documents (refer to AMS2759 ordering information), a subzero cool is recommended between tempers.

8.4.2 Equivalent Round (ER)

A part section thickness equated to a diameter based on the part shape and dimensions.

8.4.3 Family of Parts

Parts of the same alloy with similar shapes, thicknesses and configurations that have been demonstrated to exhibit similar cooling characteristics upon gas quenching.

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

Table 2 - Annealing and austenitizing temperatures and quenchants

Material Designation	Annealing Temperature		Austenitizing Temperature		Hardening Quenchant (1)
	°F	°C	°F	°C	
403	1550 (2)	843 (2)	1800 (3)	982 (3)	oil, polymer
410	1550 (2)	843 (2)	1800 (3)	982 (3)	oil, polymer
416	1600 (2)	871 (2)	1825	996	oil, polymer
420	1600 (2)	871 (2)	1875	1024	oil, polymer
422	1600 (4)	871 (4)	1925	1052	oil, polymer, salt (5)
431	1600 (6)	871 (6)	1875	1024	oil, polymer, salt (5)(7)
440C	1650 (2)	899 (2)	1925 (8)	1052	oil, polymer, salt (5)(7)
Greek Ascoloy	1550 (2)	843 (2)	1825	996	oil, polymer
XD15NW	1580 (2)	860 (2)	1922 (9)	1050 (9)	oil, polymer (7)
XD16N	1580 (2)	860 (2)	1922	1050	oil, polymer (10)
CX13VDW	1238 (2)(11)	670 (2)(11)	1925	1052	oil, polymer

NOTES:

(1) Except for parts made from 431, cooling in air or other protective gases is permitted for parts under 0.25 inch (6.4 mm) in maximum thickness provided they are not densely packed. Gas pressure quenching is allowed as specified in 3.4.6.1.

(2) Cool at a rate not to exceed 50 °F (28 °C) degrees per hour to below 1100 °F (593 °C) and air cool to ambient temperature.

(3) Austenitizing set temperature of 1750 °F (954 °C) is permitted for thin sections to minimize warpage.

(4) Cool at a rate not to exceed 50 °F (28 °C) degrees per hour to 1300 °F (704 °C), hold at 1300 °F (704 °C) for 5 to 7 hours, cool at a rate not to exceed 50 °F (28 °C) degrees per hour to below 1000 °F (538 °C), and air cool to ambient temperature.

(5) Salt temperature shall be 375 to 525 °F (191 to 274 °C). Hold in salt for 10 to 15 minutes. Remove parts and cool in air to ambient temperature.

(6) Air cool to ambient temperature followed by heating to 1200 °F (649 °C) for 10 to 12 hours and air cooling.

(7) After hardening quench, sub zero cool at -90 °F (-68 °C) or colder for not less than 2 hours.

(8) For section sizes 0.625 inch (15.9 mm) or less, austenitizing at 1950 to1975 °F (1066 to1079 °C) may be used to achieve 58 HRC minimum.

(9) When specified, parts designed for high temperature purpose, the temper temperature shall be 932 °F (500 °C) (see Table 3) and the recommended autenitizing temperature is 1967 °F (1075 °C) instead of 1922 °F (1040 °C).

(10) After hardening quench, sub zero cool at -90 °F (-68 °C) or colder for not less than 2 hours, only if the temper at 350 °F (177 °C) is to be performed. If the temper at 1202 °F (650 °C) is to be achieved, no sub-zero cooling is required after quenching.

(11) Temperature can be set between 1220 °F (660 °C) and 1292 °F (700 °C).

Table 3 - Suggested tempering temperature, °F (°C) by material and minimum tensile strength [1]

Material Designation	Minimum Tensile Strength 100 ksi (689 MPa) [2]	Minimum Tensile Strength 115 ksi (793 MPa) [2]	Minimum Tensile Strength 160 ksi (1103 MPa) [2]	Minimum Tensile Strength 180 ksi (1241 MPa) [2]	Minimum Tensile Strength 195 ksi (1344 MPa) [2]	
	Minimum Hardness Converted from Tensile 95 HRB	Minimum Hardness Converted from Tensile 23 HRC	Minimum Hardness Converted from Tensile 36 HRC	Minimum Hardness Converted from Tensile 40 HRC	Minimum Hardness Converted from Tensile 42 HRC	Minimum Hardness 58 HRC
403[10]	1300 (704) [3]	1075 (579) [3]	-	500 (260) [3][4]	-	
410[10]	1300 (704) [3]	1075 (579) [3]	-	500 (260) [3][4]	-	
416	1300 (704) [3]	1075 (579) [3]	-	500 (260) [3][4]	-	
420 [5]	1300 (704) [3]	1075 (579) [3]	-	-	600 (316) [3]	
422	-	-	1050 (566) [3]	-	-	
431 [11]	-	1200 (649) [3][6]	-	550 (288) [6][7]	550 (288) [6][7]	
440C [6][8]	-	-	-	-	-	325 (163)
Greek Ascoloy	-	1075 (579) [3][9]	-	-	600 (316) [3]	
XD15NW	-	-	[12]	-		360 (182) [13]
XD16N	-	-	1202 (650)	-		350 (177) [14]
CX13VDW	-	1202 (650)	-	-	482 (250)	

NOTES:

(1) It is recommended to avoid tempering these alloys in the range 700 to 1050 °F (371 to 566 °C) as it may result in low and erratic impact properties and poor resistance to corrosion and stress corrosion.

(2) Absence of values indicates the respective steel is not recommended for the specified tensile strength range.

(3) Recommended.

(4) This strength level may not be obtainable at this temperature with parts made from material bought to some material specifications.

(5) Recommended: Temper 420 at 300 °F (149 °C) for 52 HRC min, at 400 °F (204 °C) for 50 HRC min, and at 600 °F (316 °C) for 48 HRC min.

(6) At least two tempers required. For parts requiring maximum dimensional stability over time, a subzero cool to -90 °F (68 °C) or colder for not less than 2 hours is recommended between the first and second temper.

(7) Mandatory.

(8) Other suggested 440C tempers: 300 °F (149 °C) for 60 HRC min, 325 °F (163 °C) for 58 HRC min, at 375 °F (191 °C) for 57 HRC min, and at 450 °F (232 °C) for 55 HRC min.

(9) 32 to 38 HRC.

(10) 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.

(11) For type 431 in the 180 to 200 ksi (1241 to 1379 MPa) tensile strength range, hardness shall be 47 HRC maximum.

(12) Temper two times at 1202 °F (650 °C).

(13) For parts designed for high temperature applications, the temper at 360 °F (180 °C) can be replaced by a double temper at 932 °F (500 °C).

(14) For parts designed for high temperature applications, the temper at 350 °F (177 °C) can be replaced by a temper at 932 °F (500 °C).

Table 4 - Soak time for annealing and austenitizing

Thickness [1] Inches	Thickness [1] Millimeters	Minimum Soak Time [2][3][4][5] Air or Atmosphere	Minimum Soak Time [2][3][4][5] Salt
Up to 0.250	Up to 6.35	25 minutes	18 minutes
Over 0.250 to 0.500	Over 6.35 to 12.70	45 minutes	35 minutes
Over 0.500 to 1.000	Over 12.70 to 25.40	1 hour	40 minutes
Over 1.000 to 1.500	Over 25.40 to 38.10	1 hour, 15 minutes	45 minutes
Over 1.500 to 2.000	Over 38.10 to 50.80	1 hour, 30 minutes	50 minutes
Over 2.000 to 2.500	Over 50.80 to 63.50	1 hour, 45 minutes	55 minutes
Over 2.500 to 3.000	Over 63.50 to 76.20	2 hours	1 hour
Over 3.000 to 3.500	Over 76.20 to 88.90	2 hours, 15 minutes	1 hour, 5 minutes
Over 3.500 to 4.000	Over 88.90 to 101.60	2 hours, 30 minutes	1 hour, 10 minutes
Over 4.000 to 4.500	Over 101.60 to 114.30	2 hours, 45 minutes	1 hour, 15 minutes
Over 4.500 to 5.000	Over 114.30 to 127.00	3 hours	1 hour, 20 minutes
Over 5.000 to 8.000	Over 127.00 to 203.20	3 hours, 30 minutes	1 hour, 40 minutes
Over 8.000	Over 203.20	[6]	[7]

NOTES:

[1] Thickness is the minimum dimension of the heaviest section of the part.

[2] Soak time commences as specified in 3.4.3.

[3] 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.

[4] Maximum soak time should be no more than three times the minimum specified, except for subcritical annealing.

[5] Longer times may be necessary for parts with complex shapes or parts that do not heat uniformly.

[6] Four hours plus 30 minutes for every 3 inches (76 mm) or portion thereof greater than 8 inches (203 mm).

[7] Two hours plus 20 minutes for every 3 inches (76 mm) or portion thereof greater than 8 inches (203 mm).

PREPARED BY AMS COMMITTEE “F” AND AMEC