



AEROSPACE MATERIAL SPECIFICATION

AMS2759™/3**REV. K**

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Superseding AMS2759/3J

Heat Treatment,
Precipitation-Hardening Corrosion-Resistant, Maraging, and
Secondary Hardening Steel Parts

RATIONALE

AMS2759/3K results from a Five-Year Review and update of this specification with changes to Ordering Information, Heating Environment (see 3.2.2), Tensile (see 3.4.2.2), Surface Contamination (see 3.4.3 and 3.4.4), Tensile Testing (see 4.4.1), Heat-treating procedures (see Table 3), Soak time for normalizing, solution heat treating, and austenite conditioning (see Table 4), Minimum tensile strength for condition (see Table 7), and Normalizing and annealing temperature (see Table 8).

NOTICE

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

- AMS2759/3K
- If any parts have finished surfaces and/or surfaces with less than 0.020 inch (0.51 mm) to be removed after heat treatment (see 3.4.3)

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 precipitation-hardening corrosion-resistant, maraging, and secondary hardening steel parts. Parts are defined in AMS2759. Parts made from steels other than those specified in this specification may be heat treated in accordance with the applicable requirements herein using processing temperatures, times, and other parameters recommended by the material producer unless otherwise specified by the cognizant engineering organization. General ordering instructions are specified in AMS2759.

1.2 Application

This specification is applicable to parts made from the steels listed in Table 1.

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Table 1 - List of steels

Precipitation Hardenable: Martensitic	Precipitation Hardenable: Semi-Austenitic	Precipitation Hardenable: Austenitic	Maraging	Secondary Hardening
15-5 PH	17-7 PH	A-286	Maraging 250	AerMet 100
17-4 PH	PH 15-7 Mo		Maraging 300	AF1410
PH 13-8 Mo	AM 350		Maraging 350	Ferrium M54
Custom 450	AM 355			Ferrium S53
Custom 455				
Custom 465				
MARVAL X12				
MARVAL X12H				
MLX17				

The above designations are trademarks or commercial designations and are for alloy recognition only.

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 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 International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 1-877-606-7323 (U.S. and Canada only) or 1-724-776-4970 (outside U.S. and Canada), www.sae.org.

AMS2750	Pyrometry
AMS2759	Heat Treatment of Steel Parts, General Requirements
ARP1820	Chord Method of Evaluating Surface Microstructural Characteristics
AS7766	Terms Used in Aerospace Metals Specifications

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 E3	Preparation of Metallographic Specimens
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2.3 Definitions

Terms used in AMS are defined in AS7766 and as follows:

2.3.1 CARBIDE SOLUTIONING TREATMENT

Heating AM 355 to the solution heat-treating temperature followed by rapid cooling and then holding at subzero temperatures improves the structural uniformity for further heat treatments.

2.3.2 AUSTENITE CONDITIONING

Heating PH 15-7 Mo, 17-7 PH, AM 350, and AM 355 to a temperature below that used for solution heat treating. This conditioning treatment produces a metastable austenite for subsequent transformation upon air cooling or subzero cooling.

2.3.3 TRANSFORMATION

Cooling to a sufficiently low temperature after austenite conditioning to complete the austenite-to-martensite transformation.

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 and as follows:

- a. Furnaces used at temperatures of 1400 °F (760 °C) and higher and for stress relieving: AMS2750 Class 5.
- b. Furnaces used at temperatures from 1300 to 1375 °F (704 to 746 °C): AMS2750 Class 3.
- c. Furnaces used at temperatures below 1300 °F (704 °C): AMS2750 Class 2.
- d. Furnaces shall have a minimum of type D instrumentation in accordance with AMS2750.

3.2.1 Atmospheres

Atmospheres shall be controlled so as not to contaminate the parts being heat treated.

- 3.2.1.1 Furnaces used to heat treat other classes of steel using atmospheres that could contaminate precipitation-hardening, maraging, or secondary hardening steel parts, such as endothermic, exothermic, carbon-containing nitrogen-base, etc., shall have purge cycles (see 8.2) run. Parts shall then be tested to ensure that the surfaces have not been contaminated beyond the limits specified in 3.4.3.
- 3.2.1.2 Parts being heat treated shall be suitably isolated from products of combustion. Materials that could attack or contaminate metal shall not contact parts during heat treatment.
- 3.2.1.3 Composition and maintenance of salt baths shall be such as to prevent contamination of the parts. Salt baths shall be in accordance with AMS2759.

3.2.2 Heating Environment

Type 1 parts shall be heat treated in air or protective atmosphere.

Type 2 parts shall be heat treated in air or protective atmosphere when heating at or below 1450 °F (788 °C) and shall be heat treated in a protective atmosphere when heating above 1450 °F (788 °C).

- 3.2.2.1 Acceptable protective atmospheres shall be in accordance with AMS2759 and are limited to helium, argon, hydrogen, neutral salt, nitrogen, nitrogen-hydrogen blends, and vacuum in accordance with AMS2769. For scale-free or discoloration-free parts, air atmospheres and air cooling should be avoided.
- 3.2.2.1.1 Nitrogen and nitrogen-hydrogen blends are permitted below 1475 °F (802 °C). Nitrogen and nitrogen-hydrogen blends are permitted at or above 1475 °F (802 °C) for Type 1 parts only. Nitrogen and nitrogen-hydrogen blends are permitted up to 1975 °F (1079 °C) as a backfill quench for vacuum furnaces. The use of nitrogen from dissociated ammonia is prohibited.

3.2.3 Protective Coatings

A supplemental coating is permitted to minimize oxidation of parts heated in air.

3.3 Procedure

3.3.1 Cleaning

Shall be in accordance with AMS2759.

3.3.2 Start of Soaking

Start of soak shall be in accordance with AMS2759. When a load thermocouple is used, it shall be in contact with the thickest cross section within each furnace load.

3.3.3 Preheating and Normalizing of Secondary Hardening Grades

Parts should be preheated at 1200 to 1250 °F $\pm$ 25 °F (649 to 677 °C $\pm$ 14 °C) for a minimum of 30 minutes before normalizing or solution annealing. Normalizing shall be accomplished by heating to the temperature specified in Table 8, soaking for the time specified in Table 4, and cooling in air or a protective atmosphere to ambient temperature.

3.3.4 Annealing of Secondary Hardening Grades

Shall be accomplished by heating to the temperature and soaking for the time specified in Table 8 and cooling in air or a protective atmosphere to ambient temperature.

3.3.5 Re-Solution of Secondary Hardening Grades

Shall be accomplished by heating to the temperature in Table 3 and soaking for the time specified in Table 4.

3.3.5.1 When reworking material (e.g., material with low hardness and/or mechanical properties, equipment malfunctions, interrupted cycles except as allowed by 3.3.6.1), normalizing and annealing are not required before re-solution as long as the solution temperature has not been exceeded.

3.3.6 Solution Heat Treating (Solution Annealing), Austenite Conditioning, and Aging (Precipitation Heat Treating)

Shall be accomplished by heating to the temperature specified in Tables 3 and 6, soaking for the time specified in Tables 3, 4, and 6, and cooling as specified in Tables 3 and 6. Times for low-temperature processes (90 °F [32 °C] and below) are cumulative. When a strength or hardness range not listed in Tables 5, 6, or 7 is specified by customer purchasing documents, process the parts at the times and temperatures appropriate to achieve the specified properties. Gas quenching in a vacuum furnace is acceptable when an air cool is specified in Table 3.

3.3.6.1 Aging Cycle Interruption

If the aging cycle is interrupted due to power loss or furnace malfunction that causes the furnace temperature to drop below the required set point tolerance, the aging cycle can be continued to complete the required soak time. For example, if power is lost 1 hour and 20 minutes into a 4-hour age cycle, the parts can be reheated to the aging temperature and aged for 2 hours and 40 minutes in order to complete the 4-hour age.

In no cases shall the cumulative aging time exceed the maximum time tolerance (for example, 4-hour ages allow +30 minutes, so the cumulative aging time cannot exceed 4 hours and 30 minutes). Only one such interruption is allowed per aging cycle. Further interruptions or exceeding the aging time tolerance require reworking via re-solution treatment.

3.3.7 Re-solution heat treating is required in the following cases:

3.3.7.1 Material previously heat treated to the H1150M condition.

3.3.7.2 Material previously heat treated to a lower strength/hardness.

3.3.7.3 Material with low hardness or mechanical properties, equipment malfunctions, interrupted cycles, except as allowed by 3.3.6.1.

3.3.8 Stress relieving, if required, shall be performed in accordance with AMS2759/11.

3.3.9 Carbide Solutioning Treatment (for AM 355)

When required, carbide solutioning (see 2.3.1) shall be accomplished by heating to 1900 °F (1038 °C), soaking for the times shown in Table 2 for the respective section thickness, water quenching to room temperature, cooling to ≤ 90 °F (≤ 32 °C) or colder, holding for a minimum of 3 hours, and warming in air to room temperature.

Table 2 - Time for carbide solution treatment

Section Thickness Inches	Section Thickness Millimeters	Minimum Soaking Time Hours
Up to 1, excl	Up to 25, excl	1
1 to 3, incl	25 to 76, incl	2
Over 3	Over 76	3

3.3.10 Straightening

Straightening may be accomplished at ambient temperature, during aging, or after aging by heating to not higher than 50 °F (28 °C) below the final aging temperature. Straightening performed after aging shall be followed by stress relieving.

3.4 Properties

3.4.1 Hardness

Parts shall conform to the hardness ranges stated in Table 5 for the required condition.

3.4.2 Tensile

3.4.2.1 Tensile testing is required for the following alloys and conditions. Properties shall conform to those stated in Table 7.

- AM 350 and AM 355 parts
- 17-7 PH and PH 15-7 Mo parts heat treated to an RH condition
- 15-5 PH and 17-4 PH parts heat treated to the H1100 and H1150 conditions, excluding the H1150M condition

3.4.2.2 If the condition and/or the properties are not specified or are not listed in Table 7 for any of the alloys in 3.4.2.1, then the properties shall conform to those specified by the applicable material specification.

3.4.2.3 For all the other alloys and conditions listed in Table 7, tensile testing shall only be performed when specified and properties shall conform to those stated in Table 7 for the applicable alloy and condition. If tensile testing is specified and no properties are listed for the material and condition in Table 7, then the tensile properties shall conform to those specified by the applicable material specification.

3.4.3 Surface Contamination for Precipitation-Hardenable and Maraging Steels

When heat treating parts that have finished surfaces and/or surfaces with less than 0.020 inch (0.51 mm) to be removed after heat treat, the protective atmosphere or backfill medium in furnaces for heating parts above 1450 °F (788 °C) shall be controlled to not produce carburization or nitriding (see 3.5.1.1) and intergranular oxidation shall not exceed 0.0007 inch (0.018 mm). Parts heat treated in salt baths shall be free of residual salts.

3.4.3.1 Unless specifically informed that the parts will be machined all over, the heat-treating processor shall process the parts as though some surfaces will not have subsequent metal removal and therefore shall heat treat above 1450 °F (788 °C) with controlled atmosphere that will conform to the surface contamination requirements. Unless specified, controlled atmosphere is not required for parts with only raw material surfaces, except those made from sheet or strip.

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

3.4.4 Surface Contamination for Secondary Hardening Steels

When heating to a temperature above 1250 °F (677 °C), surface contamination shall be in accordance with AMS2759.

3.5 Test Methods

Shall be in accordance with AMS2759 and as follows:

3.5.1 Surface Contamination

3.5.1.1 Precipitation-Hardenable and Maraging Grades

Testing shall be by metallurgical examination between 400 and 600X magnification of etched specimens prepared in accordance with ASTM E3. The chord method in ARP1820 may be used to enhance this examination.

3.5.1.2 Secondary Hardening Grades

Testing shall be performed in accordance with the surface contamination requirements of AMS2759.

4. QUALITY ASSURANCE PROVISIONS

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:

4.1 Acceptance Tests

Hardness (see 3.4.1) and tensile (see 3.4.2) are acceptance tests and shall be performed on each lot of parts. In the event of conflict between hardness and tensile properties, parts shall not be rejected on the basis of hardness if the tensile properties are acceptable when determined on specimens taken from the same heat and load.

4.2 Periodic Tests

Surface contamination (see 3.4.3) is a periodic test and shall be performed on each piece of equipment after the purging of atmospheres whenever the heat-treat equipment has been used previously with atmospheres, such as endothermic, exothermic, carbon-containing nitrogen-base, etc., that could contaminate precipitation-hardening or maraging steels.

4.3 Preproduction Tests

Surface contamination (see 3.4.3) is a preproduction test and shall be performed prior to any production heat treating for each piece of equipment and for each type of atmosphere to be used in each furnace.

4.4 Sampling and Testing

Shall be in accordance with AMS2759 and as follows:

4.4.1 Tensile Testing

All tensile test specimens shall be supplied in accordance with AMS2759.

4.4.1.1 For AM 350 and AM 355 Parts

One or more tensile samples shall be processed with each austenite-conditioning load. It shall be of the same alloy designation as the parts and shall continue with the parts through final aging.

4.4.1.2 For 17-4 PH and 15-5 PH Parts Heat Treated to the H1100 and H1150 Conditions, Excluding the H1150M Condition (see 3.4.2)

One or more tensile samples shall be processed with each aging load. It shall be of the same alloy designation as the parts.