



AEROSPACE MATERIAL SPECIFICATION

AMS2761™

Issued

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Heat Treatment of Steel Raw Materials

RATIONALE

AMS2761 is a new document that covers heat treatment of steel raw materials.

NOTICE

ORDERING INFORMATION: The following information shall be provided to the heat treating processor.

Purchase order and/or purchaser supplied documents shall specify not less than the following:

- AMS2761
- Quantity
- Material alloy designation
- Heat treating operations required
- Final heat treatment condition required

1. SCOPE

- 1.1 This specification establishes general requirements for the heat treatment of steel raw material (see 8.2.1) by producers or for producers.
 - 1.1.1 This specification covers the requirements for furnace equipment, test procedures and information for heat-treating procedures, heat-treating temperatures, and material test procedures.
 - 1.1.2 This specification describes procedures that will produce the desired properties and material qualities of the alloys covered herein. Alloys other than those specifically covered herein may be heat treated using all applicable requirements of this specification.
 - 1.1.3 This document is intended to replace MIL-H-6875 (cancelled) and AMS-H-6875 (stabilized) for new design or when approved by the Cognizant Engineering Organization (CEO) on existing design. It is considered similar but not equivalent, as it does not cover parts (refer to AMS2759). Differences from AMS-H-6875 are a consequence of removing part application content.

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Full document details: SAE AMS2761

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Documents

Document Sharing Hub

1.2 Limitations

- 1.2.1 Unless otherwise specified, this specification is not applicable to heating or to intermediate (non-final) heat treatment, of raw material; e.g., hot working. This specification and the controls specified herein are applicable to capability heat treats required by material specifications to verify response to heat treatment. Processes not covered include deliberate surface heat-treating and specialized heat-treating, such as induction hardening, flame hardening, carburizing, and nitriding; however, this specification may be referenced for equipment and controls. Austempering, ausbay quenching, and martempering may be used when specified by the cognizant engineering organization.
- 1.2.2 Final heat treat condition as used in this specification is defined as the end item condition specified in the raw material specification or the purchase order.

1.3 Safety - Hazardous Materials

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards that may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

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 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.

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 and Canada), www.sae.org.

AMS2750	Pyrometry
AMS2759	Heat Treatment of Steel Parts, General Requirements
AMS2769	Heat Treatment of Parts in a Vacuum
ARP1917	Clarification of Terms Used in Aerospace Metals Specifications
ARP1962	Training and Approval of Heat-Treating Personnel
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: 610-832-9598, www.astm.org.

ASTM A262	Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
ASTM A370	Test Methods and Definitions for Mechanical Testing of Steel Products

3. TECHNICAL REQUIREMENTS

3.1 Pyrometry

3.1.1 Thermal processing equipment shall meet the requirements of AMS2750.

3.1.2 All furnaces shall be instrumented to a minimum of Type D Instrumentation in accordance with AMS2750. Unless the material specification temperature tolerance or range requires a different furnace class or otherwise indicated herein, furnace class requirements per AMS2750 shall be used. These are also shown in Table 1 for reference.

Table 1 - Furnace classification

Process	Furnace Class
Tempering (after hardening) of alloy steel greater than 220 ksi, except H-11, D6AC, and 9Ni-4Co	Class 2 or better
Aging of PH corrosion resistant and maraging steels at 1025 °F (704 °C) and below	Class 2 or better
Aging of PH corrosion resistant and maraging steels above 1025 °F (704 °C)	Class 3 or better
All other processes	Class 5 or better

3.2 Atmospheres

3.2.1 Furnaces shall be supplied with gases of a consistent analysis such that the material meets the requirements of the appropriate material specification. Furnaces, gases, and gas generators shall be controlled. Ducts and working zones shall be sealed to prevent contamination by outside gases. Vacuum system shall conform to AMS2769. All atmosphere furnaces and gas supply lines shall be purged with the designated and approved atmosphere gas for the specific steel to be heat treated.

3.2.2 The gaseous medium for heat treating steel above 1250 °F (677 °C) shall be air/products of combustion, argon, helium, hydrogen, nitrogen, or blends of these gases, vacuum, exothermic, endothermic, nitrogen based, or dissociated ammonia conforming to the requirements shown in Table 2.

3.2.3 Salt Baths

Salt baths may be used for heat treatment. Salt baths shall be tested initially and shall be adjusted to assure that surfaces shall be free from contamination (see 3.6.3). Additives used for adjustments shall be limited to salts in bath and rectifiers recommended by the salt manufacturer.

Table 2 - Furnace atmosphere requirements

Atmosphere	Low Alloy and Carbon Steel ⁽¹⁾	Martensitic Corrosion Resistant Steel ⁽¹⁾	Austenitic Corrosion Resistant Steel ⁽¹⁾	PH Corrosion Resistant and Maraging Steel ⁽¹⁾
Air/Products of Combustion	X ⁽²⁾	X ⁽²⁾	X	X
Argon ⁽³⁾	X	X	X	X
Helium ⁽³⁾	X	X	X	X
Hydrogen ⁽³⁾	X	X ⁽⁷⁾	X	X ⁽⁵⁾
Nitrogen ⁽³⁾⁽⁶⁾	X	X	X	X ⁽⁹⁾
Vacuum	X	X	X	X
Exothermic ⁽⁴⁾	X	X	X	No
Nitrogen Based or Endothermic ⁽⁴⁾	X	X	No	No
Dissociated Ammonia ⁽³⁾⁽⁸⁾	No	No	X	No

Notes:

- (1) X denotes atmosphere acceptable for use on the specified steel with or without limitations.
- (2) Unless otherwise specified, an air/product of combustion atmosphere shall be limited to precipitation hardening, tempering, stress relieving, and 1400 °F (760 °C) transformation treatments. An air/product of combustion atmosphere may be used for treatment above 1400 °F (760 °C) for low alloy, carbon, and martensitic steel material that will have a minimum of 0.020 inch (0.51 mm) metal removed from all surfaces after heat treatment.
- (3) Dew point shall be not higher than -40 °F (-40 °C) at the inlet of the furnace.
- (4) Atmosphere shall be refined or blended to avoid a change in carbon content at the surface of the material as specified in 3.2.2. A product of combustion at -40 °F (-40 °C) maximum dew point (e.g., endothermic) may be used for carbon and low alloy steel material that allows 0.003 inch (76 µm) maximum partial decarburization at the surface. Exothermic atmosphere permissible only for heat treatment of carbon and low alloy steels.
- (5) Acceptable up to 1950 °F (1066 °C).
- (6) Nitrogen atmosphere does not include nitrogen from dissociated ammonia.
- (7) Only acceptable when tempered at 1000 °F (538 °C) or above. Acceptable for annealing.
- (8) Permissible only for annealing or annealing/quenching of mill products providing residual ammonia at the outlet of the generator does not exceed 15 ppm.
- (9) The use of a nitrogen atmosphere shall be limited to heat treating temperatures of 1400 °F (760 °C) and below. A nitrogen atmosphere may be used for heat treatment above 1400 °F (760 °C), provided a minimum of 0.020 inches (0.50 mm) of metal is subsequently removed from all surfaces of heat treated material.

3.3 Equipment**3.3.1 Quenching Equipment**

The quench system equipment and quench media (see 3.4) shall be sufficient to achieve the properties required by the heat treat process and material specification.

3.3.2 Auxiliary Equipment

Fixtures and fixture materials shall not cause contamination of material. Fixtures and fixture materials shall be designed to allow maximum flow of heat around the material; otherwise, the mass and section size of heat treat fixtures shall be accounted for during establishment of heat up times, soak times, and quench rates.

3.3.3 Sub-Zero Cooling or Deep Freeze

When required to complete transformation and provide desired microstructure, material shall be cooled to a temperature within the range specified, held at the selected temperature for a time commensurate with section thickness, and warmed in air to room temperature.

3.4 Quenching Media

3.4.1 Quenching media shall be as follows:

3.4.1.1 Oil quenchants shall be in the range of 60 to 160 °F (16 to 71 °C) at the initiation of the quench operation. Oils shall not be used at temperatures exceeding the manufacturer's recommended maximum temperature.

3.4.1.2 Polymer quenchants shall be in the range of 60 to 110 °F (16 to 43 °C) at the initiation of the quench operation or at a temperature specified by the manufacturer. When salt bath furnaces are used (quenching from salt bath furnaces), polymers shall be monitored to ensure salt content does not exceed 6% by weight.

3.4.1.3 Water quenchant requirements and limitations (including purity) shall be defined by the material producer.

3.4.2 Alternative Quenching

Alternative quenching methods may be used when qualified by a methodology approved by the cognizant engineering organization.

3.5 Procedures

3.5.1 Cleaning

Cleaning shall be defined by the producer. At a minimum, the material shall be clean enough such that contaminants do not have a detrimental effect on the material as defined by the material specification.

3.5.2 Racking

Material shall be racked and supported, or otherwise oriented, to ensure free circulation of the heating, cooling, and quenching media and to minimize distortion.

3.5.3 Loading

3.5.3.1 Batch Furnaces

Material shall not be loaded into a furnace with the temperature higher than the set temperature.

3.5.3.2 Continuous Heat Treating

When continuous heat treating is used, process parameters (e.g., furnace temperature set points, heat input, travel rate, etc.) for continuous heat treating lines shall be established by the material producer and validated by testing of product to the requirements of the material specification, this specification, or the purchase order.

3.5.4 Temperature Control

Control instrument(s) shall be set in the temperature ranges specified by the material specification or as stated in Tables 3, 4, 5, 6, and 7.

3.5.5 Rate of Heating

Heating rates shall be controlled to prevent damage to the material. Pre-heating at 1000 to 1200 °F (538 to 649 °C) is recommended before heating material above 1300 °F (704 °C) if the material has any of the following conditions:

- Has been previously hardened above HRC 35.
- Is made of steel of 0.50 (nominal) percent carbon or higher.
- Has abrupt changes of section, or sharp re-entrant angles.

3.5.6 Start of Soaking

- 3.5.6.1 When only furnace control sensors are used, soaking time starts when the temperature indicated by the furnace control instrument recovers to within 5 °F (3 °C) of the set heat treating temperature, or as approved by their cognizant engineering organization.
- 3.5.6.2 When furnace control sensors and recording sensors are used, soaking time starts when the temperatures indicated by all recording sensors reach the minimum of the required temperature tolerance applicable to the set heat treating temperature.
- 3.5.6.3 For continuous furnaces, soaking time starts when material enters the zone of the furnace shown by the last temperature uniformity test to be within the range described by the set temperature and the applicable tolerance.

3.5.7 Soaking Time

Recommended soaking time should be in accordance with Tables 8, 9, or 10, as applicable. AS1260 indicates the approximate equivalence of various shapes to equivalent round sections and shall be used when estimating soak times for various shapes and especially complex shapes.

3.5.8 Thermal Treatment

3.5.8.1 Hardening

Low alloy steel, carbon steel, and martensitic corrosion resisting steel material shall be hardened by austenitizing and quenching.

3.5.8.1.1 Austenitizing

The austenitizing temperature should conform to Table 3 for carbon and low alloy steels and Table 4 for martensitic corrosion resistant steel. Material should be held within the specified temperature range for sufficient time for the necessary transformation and diffusion to take place. The recommended holding times at temperature are listed in Table 8 for all steels except austenitic corrosion resistant steels. Use Table 9 for recommended temperatures for austenitic corrosion resistant steels.

3.5.8.1.2 Quenching

Material should be quenched from the austenitizing temperature. The material should be transferred from the furnace into a quench medium (i.e., water, oil, air, polymer, etc.) in a timely manner such that a successful quench shall be achieved. The material shall be cooled to a temperature low enough to achieve complete transformation, before tempering. The start time of tempering after the completion of the quench is at the discretion of the producer based on material grade, geometry, section size, etc.

3.5.8.2 Tempering

Carbon steels, low alloy steels, and martensitic corrosion resisting steels should be tempered at the temperatures shown in Tables 3 and 4, as applicable. Time at temperature and the number of tempers should be as shown in Table 10. When multiple tempering is used, material shall be cooled to ambient temperature between tempering treatments.

3.5.8.3 Aging

Precipitation hardening stainless steel material is normally acquired in the solution treated or solution treated and cold worked (i.e., spring temper) condition. Thermal treatment for precipitation hardening stainless steel material should conform to the material specification or Tables 6 and 7. The aging temperature in Table 7 may be adjusted to meet the specified tensile strength range or minimum. If this is done, it shall be stated as such on the certification with the aging temperature used.

3.5.8.4 Other Thermal Treatment

3.5.8.4.1 Normalizing Carbon Steel and Low Alloy Steel

Normalizing of carbon and low alloy steels should be accomplished by cooling from Table 3 temperatures in air or in a circulated protective atmosphere. The recommended minimum holding times at temperature are listed in Table 8.

3.5.8.4.2 Annealing Carbon Steel, Low Alloy Steel, and Martensitic Corrosion Resistant Steel

Full annealing of carbon and low alloy steels should be accomplished in accordance with Table 3 using recommended holding times in Table 8. Sub-critical (partial) annealing of steel material should be accomplished by heating to 1200 to 1400 °F (649 to 760 °C) and at suggested holding times in Table 8. Sub-critical annealing of martensitic stainless steel material should be accomplished as specified in Tables 4 and 8, as applicable.

3.5.8.4.3 Annealing and Annealing/Quenching Austenitic Corrosion Resistant Steel

Annealing and annealing/quenching of austenitic stainless material should be accomplished as specified in Tables 5 and 9.

3.5.8.4.4 Stress Relieving

Stress relieving before hardening of low alloy steel material shall be accomplished at any temperature between 800 °F and 1400 °F (427 °C and 760 °C). Stress relieving after hardening of steel and martensitic stainless steel material shall be accomplished by heating to a maximum temperature of 50 °F (28 °C) below the tempering temperature. The recommended minimum holding times at temperature are listed in Table 8. Stress relieving of austenitic stainless steel material shall be accomplished by either heating to 875 °F $\pm$ 25 °F (468 °C $\pm$ 14 °C) maximum or to 1900 °F (1038 °C) and rapid cooling. Precipitation hardened material shall be stress relieved for a minimum of 1 hour at 100 °F (56 °C) below the aging temperature.

3.5.8.5 Additional Processes

Material shall not be subjected to thermal operations other than those specified in the ordering document.

3.6 Properties

3.6.1 Hardness

Shall be as specified by the material specification or purchase order.

3.6.2 Tensile Strength and Testing Method

Tensile strength and testing method shall be in accordance with the material specification or as otherwise specified. If no test method is specified in the material specification, then testing shall be in accordance with ASTM A370. Unless otherwise specified, the strain rate shall be set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ± 0.002 in/in/min (± 0.002 mm/mm/min) through 0.2% offset yield strain. After the yield strain, the speed of the testing machine shall be set between 0.05 in/in and 0.5 in/in (0.05 mm/mm and 0.5 mm/mm) of the length of the reduced section (or distance between the grips for specimens not having a reduced section) per minute. Alternatively, an extensometer and strain rate indicator may be used to set the strain rate between 0.05 in/in/min and 0.5 in/in/min (0.05 mm/mm/min and 0.5 mm/mm/min).

3.6.3 Surface Contamination

Shall be as specified. If not specified, and less than 0.020 inch (0.51 mm) stock is to be removed from finished raw material during final part fabrication, the surface contamination test shall be as required in AMS2759. The surface contamination test methods shall be in accordance with AMS2759.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The processor shall be responsible for the performance of all required tests and inspections. The processor may use its own facilities or a commercial laboratory. Purchaser and the cognizant quality assurance organization reserve the right to sample and to perform any confirmatory testing deemed necessary to ensure that processing conforms to specified requirements. The purchaser and the cognizant quality assurance organization may review heat treating records and the results of tests and inspections to verify that heat treatment conforms to specified requirements.

4.2 Classification of Tests

All testing shall be as specified by the material specification or purchase order.

4.3 Approval

4.3.1 Heat Treat Processor's Facilities

The approval of a facility shall be in accordance with that specified by the cognizant quality assurance organization. The procedures of the heat treating processor shall be available for review.

4.3.2 Personnel

All personnel performing heat treating, testing, inspection, and associated operations shall be trained and approved in accordance with documented Quality Assurance procedures. ARP1962 is an acceptable recommended practice.

4.4 Records

A record (written or electronic storage media), traceable to temperature recording information (chart(s) or electronic storage media) and to shop paperwork or other documentation, shall be kept for each furnace and load. The log data shall be recorded in accordance with the heat treat processor's documented procedures.

4.5 Record Retention

All production, test, and inspection records shall be kept and made available upon request of the purchaser to the cognizant quality assurance organization for at least 5 years after heat treatment, or for the duration specified by the purchaser. The records shall contain all data necessary to verify conformance to specified requirements.

4.6 Report/Certification

The heat treating processor shall furnish, with each shipment, a certified quality assurance report, traceable to the heat treat control number(s), stating that the material was processed in accordance with the requirements of the material specification. (if applicable). The report shall include: purchase order number, heat number or product identification, alloy, temper/strength designation, quantity in the shipment, and any exceptions.

5. PREPARATION FOR DELIVERY

5.1 Identification

Traceability of material or product provided to the heat treat processor shall be maintained from receipt through to the completion of processing or delivery.