SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2759D

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Superseding AMS 2759C

Heat Treatment of Steel Parts General Requirements

RATIONALE

AMS 2759D changes paragraph 3.3.1 by adding AMS 2759/11 to Table 1, 3.3.5, 3.3.5.1, 3.3.5.2, and 3.3.5.3 concerning purging, 4.2.2.3.2 concerning hardness test machines, 4.5 concerning logs, and 4.7 concerning reports.

1. SCOPE:

1.1 This specification establishes general requirements for the processes listed in 3.3.1 for heat treatment of steel parts (See 8.2.1) by users or their vendors or subcontractors.

1.2 Reference to AMS 2759 on a drawing, fabrication order, purchase order, etc constitutes a requirement to conform to the applicable provisions of the documents listed in 3.3.1 for the heat treatment of steel parts of the particular alloy described. Parts made from steels other than those specified in the detail specifications 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 conditions (temperatures, soaking times, cooling rates, etc) used by material producers, forge shops, and foundries for qualification of response to heat treatment of their products shall conform to the requirements of the specifications listed in 3.3.1.

1.4 Heat treatment of raw material by raw material producers, forge shops, or foundries should be in accordance with the material procurement specification.

1.5 Processes such as vacuum-furnace heat treating, flame hardening, induction through-hardening, austempering, martempering, and hot oil quenching are recognized heat treating processes, but their requirements are not completely covered by this specification.

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

1.6 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 which 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 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: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA and Canada), www.sae.org.

AMS 2750	Pyrometry
AMS 2759/1	Heat Treatment of Carbon and Low-Alloy Steel Parts, Minimum Tensile Strength Below 220 ksi (1517 MPa)
AMS 2759/2	Heat Treatment of Low-Alloy Steel Parts, Minimum Tensile Strength 220 ksi (1517 MPa) and Higher
AMS 2759/3	Heat Treatment of Precipitation-Hardening Corrosion-Resistant and Maraging Steel Parts
AMS 2759/4	Heat Treatment of Austenitic Corrosion-Resistant Steel Parts
AMS 2759/5	Heat Treatment of Martensitic Corrosion-Resistant Steel Parts
AMS 2759/6	Gas Nitriding and Heat Treatment of Low-Alloy Steel Parts
AMS 2759/7	Gas and Vacuum Carburizing and Heat Treatment of Carburizing-Grade Steel Parts
AMS 2759/8	Ion Nitriding
AMS 2759/9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
AMS 2759/10	Automated Gaseous Nitriding Controlled by Nitriding Potential
AMS 2759/11	Stress Relief of Steel Parts
ARP1962	Training and Approval of Heat Treating Personnel

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 A 370	Mechanical Testing of Steel Products
ASTM C 848	Young's Modulus, Shear Modulus, and Poisson's Ratio for Ceramic Whitewares by Resonance
ASTM C 1259	Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Impulse Excitation of Vibration
ASTM E 8	Tension Testing of Metallic Materials
ASTM E 8M	Tension Testing of Metallic Materials (Metric)
ASTM E 10	Brinell Hardness of Metallic Materials
ASTM E 18	Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 384	Microhardness of Materials

2.3 ANSI Publications:

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036, Tel: 212-642-4900, www.ansi.org.

ANSI/ASQC Z1.4	Sampling Procedures and Tables for Inspection by Attributes

3. TECHNICAL REQUIREMENTS:

3.1 Equipment and Pyrometry:

Thermal processing equipment and related pyrometric equipment shall be controlled in accordance with AMS 2750.

3.1.1 Heating and Refrigeration Equipment: Automatic temperature controllers and data recording instruments conforming to AMS 2750 are required on each furnace and mechanical refrigeration unit. Temperature sensors shall be located in or adjacent to each work zone. Thermocouples shall be protected, when necessary, from contamination. Instrumentation, thermocouples, test equipment, calibration equipment, load thermocouples (See 8.2.2), furnace temperature uniformity, and system accuracy shall conform to AMS 2750.

3.1.2 Quenching Equipment: Quench baths shall permit complete immersion of parts, shall provide for agitation of the quench media or the parts, shall be of sufficient volume to absorb the heat rejected by the most massive part to be quenched, and shall have a temperature indicator with a sensor in the quench media. Quenching baths shall be free from visible contamination which could detrimentally affect the process. Bath maintenance programs shall be established, and a system check shall be made, prior to production use to ensure the adequacy of the agitation system and that the system is designed to minimize susceptibility to agitation variations. When using polymers, a concentration control system shall be established prior to production use.

3.1.3 Auxiliary Equipment: Fixtures, jigs, hangers, trays, racks, snorkels, etc shall be employed, as needed, for proper handling of parts. Fixtures and fixture materials shall not cause contamination of parts and shall not reduce the heating, cooling, or quenching rates to less than required for correct hardening of parts.

3.1.4 Cleaning Equipment: Equipment shall be provided to clean parts before heat treatment, to remove oil from parts quenched in oil baths, and salt residue from parts heated or quenched in salt baths. When using polymer quenchants, a rinsing system shall be in place to remove quenchant from the parts.

3.1.5 Vacuum Equipment: Vacuum furnaces shall have a calibrated recording instrument for sensing the vacuum.

3.1.6 Servicing and Calibration of Atmosphere Control Equipment: Instrumentation used to control furnace atmosphere shall be calibrated and serviced according to manufacturer's recommendation.

3.2 Quenching Media:

3.2.1 When liquid quenching is required, oil, water, or polymer/water solutions may be used as specified for the alloy and temper indicated. The consistency of quench effectiveness shall be determined for each tank by testing initially and quarterly thereafter by one of the methods in 3.5.4 and comparing the results with those obtained previously by the same method. The heat treating facility shall establish control limits for each quenching system. If results indicate that a quenchant is outside the established limits, corrective action shall be taken and the tests repeated to verify restoration of the prior condition.

3.2.2 Problems, such as cracking and high residual stresses, due to an inappropriate quenchant or improperly designed system which is not appropriate for a particular alloy and configuration shall be avoided. Because of wide differences in quenching characteristics of different quenchants in different quenching systems, a quenchant validation procedure shall be implemented when initially establishing the quenching procedure or when changing from one quenchant to another.

3.2.2.1 When substituting a polymer/concentration for an existing oil quenchant, the quenchant validation procedure shall ensure that the polymer and concentration being substituted achieves cooling characteristics which are similar to the existing oil quenchant and that the properties being produced are equivalent to those for oil quenched parts (See 8.3).

3.2.3 Except when marquenching (See 8.2.3), the temperature of the quenchant shall be in the range 60 to 160 °F (16 to 71 °C) at the initiation of the quenching operation, and shall not exceed 200 °F (93 °C) at any time during the quenching operation, unless otherwise approved by the cognizant engineering organization (See 8.2.4). In addition, oil and polymer quenchants shall be used within the temperature range recommended by the product manufacturer.

3.2.4 Quench oil used in integral quench vacuum furnaces, where the quench chamber is below atmospheric pressure, shall be vacuum degassed at approximately the maximum recommended temperature for the oil initially and after each addition of oil.

3.2.5 Quenching from Salt Bath Furnaces: Water shall be monitored weekly to ensure salt content does not exceed 2% by weight. Polymers shall be monitored weekly to ensure salt content does not exceed 6% by weight.

3.2.6 Salt Removal: All salt residues shall be removed from parts processed in salt-baths or quenched in brine, during or immediately following quenching.

3.3 Procedure:

3.3.1 Heat Treatment: Shall be in accordance with Table 1.

TABLE 1 - Heat Treatment Procedures

Type of Steel or Process	Procedure
Carbon and Low-Alloy Below 220 ksi UTS	AMS 2759/1
Low-Alloy 220 ksi UTS and Higher	AMS 2759/2
PH and Maraging	AMS 2759/3
Austenitic	AMS 2759/4
Martensitic	AMS 2759/5
Gas Nitriding	AMS 2759/6
Gas and Vacuum Carburizing	AMS 2759/7
Ion Nitriding	AMS 2759/8
Hydrogen Embrittlement Relief (Baking) of Steel Parts	AMS 2759/9
Automated Gaseous Nitriding Controlled by Nitriding Potential	AMS 2759/10
Stress Relief of Steel Parts	AMS 2759/11

3.3.2 Cleaning: Parts shall be cleaned before heat treatment and following heat treatment operations, as necessary.

3.3.3 Corrosion Protection: Parts shall be protected from corrosion during processing and storage.

3.3.4 Racking: Parts shall be racked and supported, or otherwise oriented, primarily to ensure access of the heating, cooling, and quenching media to all surfaces of all parts and secondarily to minimize warpage.

3.3.5 Purging: Whenever the atmosphere type (e.g., neutral, carburizing, nitriding) is changed, and prior to heating of parts, remnants of the previous atmosphere shall be removed from the furnace or retort and gas supply lines. This requirement does not apply if the heat treater has documented confirmation that material removal after heat treatment will ensure that all surfaces of finished parts will be free from contamination.

3.3.5.1 The removal of the previous atmosphere shall be accomplished by purging with the replacement atmosphere at the highest temperature at which it will be used.

3.3.5.2 The purging shall be performed in accordance with a procedure which has been proved effective previously, by sensors (e.g., oxygen probe) or tests (e.g., microhardness) that are capable of detecting the presence of the previous atmosphere or the resulting contaminant.

3.3.5.3 The efficacy of the purge shall be confirmed, in conjunction with the first heat treatment load employing the new atmosphere, by the sensors or tests used to establish the procedure.

3.3.6 Loading: Parts shall not be loaded into a furnace with the temperature higher than the set temperature, unless load thermocouples are attached to the part to ensure the part temperature does not exceed the set temperature. The number, location, and method of attachment of load thermocouples shall be approved by the cognizant engineering organization.

3.3.7 Set Temperature: Control instrument(s) shall be set either at the temperature specified by the procedures listed in 3.3.1 or at an offset temperature based on the last temperature uniformity survey. The offset temperature shall be within ±10 F (±6 C) degrees of the specified set temperature unless the temperature uniformity requirement is less than ±10 F (±6 C), for which the offset temperature shall be within the uniformity range. The specific offset shall be posted on the instrument. The offset temperature shall be selected to optimize temperature distribution within the furnace so that the highest and lowest temperatures are equidistant from the specified set temperature.

3.3.8 Salt Bath Additives: Shall be limited to the salts in the bath and to additives recommended by the salt manufacturer.

3.3.9 Records: A furnace log, or equivalent documentation such as shop travellers, traceable to temperature recorder chart(s), shall be maintained.

3.4 Qualification:

3.4.1 Suppliers: Facilities performing heat treatment in accordance with this specification shall be approved as specified herein by the cognizant quality assurance organization.

3.4.2 Personnel: All personnel performing heat treating and associated operations shall be trained and approved in accordance with a procedure such as ARP1962.

3.4.3 Equipment: Equipment used for thermal processing shall be approved to the requirements of this specification and AMS 2750.

3.5 Test Methods:

The following test methods shall be used, when applicable:

3.5.1 Hardness: Shall be determined in accordance with ASTM A 370, ASTM E 10, ASTM E 18, and ASTM E 384, as applicable. The approximate conversion of tensile strength requirements to hardness shall be in accordance with ASTM A 370. Hardness tests shall be performed on the thickest section, unless otherwise specified by the cognizant quality assurance organization.

3.5.1.1 Rockwell, or similar (see 8.2.14), hardness testing machines shall be checked before the first use each day in accordance with ASTM E 18, using standard hardness test blocks for the same scale as, and within 15 points of, the hardness of the parts being tested. Brinell machines shall be checked before the first use each day, in accordance with ASTM E 10, at the loads being used. A record of the daily checks shall be maintained.

3.5.2 Tensile Properties: Testing, when required by the cognizant engineering organization, shall be in accordance with ASTM A 370 and ASTM E 8 or ASTM E 8M.

3.5.3 Salt Bath Neutrality Test: Immerse a piece of SAE 1095 carbon steel shim, nominally 0.003 inch (0.08 mm) thick, into the salt bath at operating austenitizing temperature for 10 minutes ± 1. Immediately quench the sample in water. Bend the sample until it fractures and examine the fracture surface at approximately 10X magnification. A fracture surface showing no evidence of permanent deformation (yielding or taking a set) is acceptable. If permanent deformation is noted, decarburization has occurred and corrective measures to adjust the salt bath are required.

3.5.3.1 The tests for surface contamination specified in AMS 2759/1 may be used in lieu of, and at the same testing frequency as, the salt bath neutrality test.

3.5.4 Quench Rate Control: One of the following methods shall be used for the initial and quarterly quench rate tests. The established method shall be proven to detect changes in speed of the quenchant caused by contamination, and shall be shown to be sufficiently sensitive to adequately detect differences in slow-, medium-, and fast-quench oils, and oil temperature changes of 40 °F (22 °C) degrees.

3.5.4.1 Comparative Cooling Curve Evaluation: Variation in the quenching effectiveness of an oil, water, or aqueous polymer quenchant bath shall be monitored using a suitable cooling curve evaluation procedure approved by the cognizant engineering organization.

3.5.4.2 Mechanical property tests of all quenching media shall be performed by quenching specimens of alloy steel, of appropriate hardenability and dimensions, and testing a mechanical property (e.g. hardness, strength, modulus) which varies directly or inversely with the effectiveness of quench. The specific test shall verify quenchant effectiveness by comparing the tested mechanical property results with those properties listed on the applicable drawing or in the material specification.

3.5.4.2.1 Specimen Selection for Mechanical Property Tests of all Quenching Media: Selection of the specimen dimensions/hardenability combination should be aimed at achieving approximately full hardening (e.g. 95% martensite on the surface) and significantly less hardening (e.g. less than 50% martensite plus bainite) at the center.

3.5.4.2.2 Tempering Specimen for Machining: Specimens may be tempered lightly (e.g., at 500 °F (260 °C)) after quenching to facilitate machining.

3.5.4.2.3 Testing Area: Tests may be performed on mid-radius, center, or entire section of the specimen.

3.5.4.3 Modulus: Modulus testing shall be by a dynamic (resonant frequency) method similar to ASTM C 848 or ASTM C 1259.

3.6 Additional Processes:

Parts shall not be subjected to thermal operations or straightening operations other than those specified, unless permitted by the cognizant engineering organization.

3.7 Strength Ranges:

When only a minimum tensile strength is specified and the heat treating processor has the option of selecting the tempering or aging temperature, the maximum tensile strength (converted to hardness) shall be 20.0 ksi (138 MPa) above the specified minimum for strength levels up to and including 260 ksi (1793 MPa) minimum and 25.0 ksi (172 MPa) above minimum for strength levels over 260 ksi (1793 MPa) minimum.

3.7.1 When both the minimum tensile strength and the tempering temperature are specified, the maximum strength shall be 30.0 ksi (207 MPa) above the specified minimum.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

Unless otherwise specified by the cognizant quality assurance organization, the heat treating processor shall supply all samples for processor's tests and shall be responsible for the performance of all required tests and inspections. The supplier may use his own facilities or any commercial laboratory acceptable to the cognizant quality assurance organization. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that processing conforms to specified requirements. The cognizant quality assurance organization may review heat treating records and the results of tests and inspections to verify that heat treatment conformed to specified requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Hardness (3.5.1) and tensile properties, when required, (3.5.2) are acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: The following requirements are periodic tests and, unless (1) otherwise specified by the cognizant engineering organization or (2) a reduced frequency is permitted by AMS 2750, shall be performed at the frequency specified herein on each piece of equipment in service:

4.2.2.1 Daily:

4.2.2.1.1 Salt bath neutrality test (3.5.3) of baths used to heat treat steel to minimum tensile strength of 220 ksi (1517 MPa) and higher.

4.2.2.1.2 Check of hardness testing machines (3.5.1.1).

4.2.2.2 Weekly:

4.2.2.2.1 Furnace pyrometer system accuracy test (except equipment for stress relieving and baking) as in AMS 2750.

4.2.2.2.2 Salt bath neutrality test (3.5.3) for baths used to heat treat parts to a minimum tensile strength below 220 ksi (1517 MPa).

4.2.2.2.3 Salt content monitoring of water and polymer quenchants (3.2.5).

4.2.2.3 Quarterly:

4.2.2.3.1 Calibration of furnace instruments as in AMS 2750.

4.2.2.3.2 Servicing and certification or calibration of Rockwell, or similar (see 8.2.14), and Brinell hardness test machines.

4.2.2.3.3 System accuracy tests and instrument calibration of stress relieving and baking equipment as in AMS 2750 (See 8.2.5 and 8.2.6).

4.2.2.3.4 Temperature uniformity surveys of furnaces as in AMS 2750, except for furnaces used only for annealing, stress relieving, or baking (See 8.2.7). Annually, the survey shall be at the maximum operating temperature.

4.2.2.3.5 Quench rate control tests (3.5.4).

4.2.2.4 Semi-annually: Temperature uniformity survey of annealing, stress relieving, baking, and controlled subzero transformation equipment as in AMS 2750.

4.2.2.5 Servicing and calibration of atmosphere control measuring equipment at the frequency required in 3.1.6.

4.2.2.6 Calibration of Type B and Type C instrumentation at the frequency specified in AMS 2750.

4.2.3 Preproduction Tests: The following requirements are preproduction tests and shall be performed prior to any production heat treating for each piece of equipment to be used, as applicable:

4.2.3.1 Temperature uniformity survey as in AMS 2750.

4.2.3.2 Pyrometer system accuracy test as in AMS 2750.

4.2.3.3 Instrument calibration as in AMS 2750.

4.2.3.4 Certification or calibration of hardness testing machines (3.5.1).

4.2.3.5 Certification or calibration of tensile testing machines (3.5.2).

4.2.3.6 Salt bath neutrality test (3.5.3).

4.2.3.7 Quench rate control test (3.5.4).

4.2.3.8 Calibration of atmosphere control measuring equipment (3.1.6).

4.3 Sampling and Testing:

4.3.1 For Hardness Testing:

4.3.1.1 Frequency of hardness testing shall be in accordance with Table 2. When hardness testing would be destructive or impractical to accomplish, the method for verification of correct heat treatment shall be as specified by the cognizant engineering or quality engineering organization.

TABLE 2 - Hardness Testing

Operation	Test Frequency (1)
After final operation (hardening and tempering, aging, etc) (See 8.2.8, 8.2.9 and 8.2.10).	Every part (2), (3)
After intermediate operations, when required (austenitizing and quenching, annealing, normalizing, solution heat treating, etc) (See 8.2.7, 8.2.8, 8.2.11 and 8.2.12).	One part from each lot
After thermal processing subsequent to final hardening operation (stress relieving, hot or warm straightening, baking prior to plating, etc) (See 8.2.5 and 8.2.6).	One part from each lot
After thermal processes subsequent to shot peening, plating, painting, etc (baking after plating, drying, etc).	Not required

NOTES:
1. Each detail of a weld assembly shall be considered as a separate part.
2. Statistical sampling is permitted when authorized by the cognizant quality assurance organization or when parts are subjected to 100% testing after thermal processing subsequent to final hardening operation.
3. When statistical sampling is authorized, random samples shall be selected and tested in accordance with ANSI/ASQC Z1.4 at AQL of 1.5 or less.

4.3.1.2 When heat treating standard components, such as nuts and bolts, for which the frequency of testing is specified, the requirements of the component specifications shall take precedence.

4.3.1.3 The test location shall be the thickest or heaviest section of the part which is practical to test and where the test will not be detrimental to the function of the part.

4.3.2 Lot: Shall be all parts of the same design, fabricated from the same alloy, heat treated to the same property requirements in the same furnace(s) at the same time, and presented for processor's inspection at the same time. In addition, for a continuous furnace, it shall be those parts heat treated as a continuous production run during an eight-hour shift. When testing parts after operations (e.g. stress relieving, baking, hot or warm straightening) that occur after the final step of the heat operation (e.g. tempering, aging), a lot, in addition to the above, shall consist of parts stress relieved, baked, hot or warm straightened, etc using the same equipment at the same time.

4.4 Approval:

4.4.1 Facilities: The approval of a facility shall be in accordance with the following criteria:

4.4.1.1 The heat treating processor shall have a copy of his shop procedure available for the cognizant quality assurance organizations. It shall consist of a full description of all equipment and procedures that will be used to process parts to this specification and the applicable specifications listed in 3.3.1.

4.4.1.2 All equipment shall be tested in accordance with this specification and AMS 2750.

4.4.2 Personnel: Training and approval of personnel shall be in accordance with 3.4.2.

4.5 Logs:

A record (written or electronic storage media), traceable to temperature recording information (chart(s) or electronic storage media) and to shop travelers or other documentation, shall be kept for each furnace and load. The information on the combination of documents shall include: equipment identification, approved personnel's identification, date; part number or product identification, number of parts, alloy, lot identification, AMS 2759 or other applicable specification, actual thermal processing times and temperatures used. When applicable, atmosphere control parameters, quench delay, quenchant type, polymer concentration and quenchant temperature shall also be recorded. The maximum thickness, when process parameters are based on thickness, shall be recorded and shall be taken as the minimum dimension of the heaviest section of the part. The log data shall be recorded in accordance with the heat treater's documented procedures.

4.6 Records:

Furnace logs, recorder charts, all other shop records, and all test and inspection records shall be kept available to the cognizant quality assurance organization for five years after heat treatment. The records shall contain all data necessary to verify conformance to specified requirements.