



AEROSPACE MATERIAL SPECIFICATION

AMS2759**REV. E**

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Superseding AMS2759D

Heat Treatment of Steel Parts General Requirements

RATIONALE

AMS2759E has been reaffirmed to comply with the SAE five-year review policy.

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 AMS2759 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.
- 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 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.

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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.

AMS2750	Pyrometry
AMS2759/1	Heat Treatment of Carbon and Low-Alloy Steel Parts, Minimum Tensile Strength Below 220 ksi (1517 MPa)
AMS2759/2	Heat Treatment of Low-Alloy Steel Parts, Minimum Tensile Strength 220 ksi (1517 MPa) and Higher
AMS2759/3	Heat Treatment of Precipitation-Hardening Corrosion-Resistant and Maraging Steel Parts
AMS2759/4	Heat Treatment of Austenitic Corrosion-Resistant Steel Parts
AMS2759/5	Heat Treatment of Martensitic Corrosion-Resistant Steel Parts
AMS2759/6	Gas Nitriding and Heat Treatment of Low-Alloy Steel Parts
AMS2759/7	Gas and Vacuum Carburizing and Heat Treatment of Carburizing-Grade Steel Parts
AMS2759/8	Ion Nitriding
AMS2759/9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
AMS2759/10	Automated Gaseous Nitriding Controlled by Nitriding Potential
AMS2759/11	Stress Relief of Steel Parts
AMS2759/12	Gaseous Nitrocarburizing, Automatically Controlled by Potentials
AMS2769	Heat Treatment of Parts in a Vacuum
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 / 8M	Tension Testing of Metallic Materials
ASTM E 10	Brinell Hardness of Metallic Materials
ASTM E 18	Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 384	Microindentation Hardness 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
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3. TECHNICAL REQUIREMENTS

3.1 Equipment and Pyrometry

Thermal processing equipment shall meet the requirements of AMS2750. Furnaces shall have a minimum of Type D instrumentation.

3.1.1 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 that 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.

3.1.2 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.

3.1.3 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.

3.1.4 Vacuum Equipment

Vacuum furnaces shall meet the requirements of AMS2769.

3.1.5 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 that 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 that 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	AMS2759/1
Low-Alloy 220 ksi UTS and Higher	AMS2759/2
PH and Maraging	AMS2759/3
Austenitic	AMS2759/4
Martensitic	AMS2759/5
Gas Nitriding	AMS2759/6
Gas and Vacuum Carburizing	AMS2759/7
Ion Nitriding	AMS2759/8
Hydrogen Embrittlement Relief (Baking) of Steel Parts	AMS2759/9
Automated Gaseous Nitriding Controlled by Nitriding Potential	AMS2759/10
Stress Relief of Steel Parts	AMS2759/11
Gaseous Nitrocarburizing, Automatically Controlled by Potentials	AMS2759/12
Heat Treatment of Parts in a Vacuum	AMS2769

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 that it will be used.
- 3.3.5.2 The purging shall be performed in accordance with a procedure that 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 sensors 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 sensors 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 or system accuracy test. Offsets, if used, shall meet the requirements of AMS2750.

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 travelers, 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 AMS2750.

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 and Brinell hardness testing machines shall be calibrated and verified according to ASTM E 18 and ASTM E 10 respectively.

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 / 8M (See 8.4)

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 $\pm$ 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 AMS2759/1 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) that varies directly or inversely with the effectiveness of quench.

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 conforms 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 AMS2750, shall be performed at the frequency specified herein on each piece of equipment in service. Pyrometry tests shall be performed in accordance with AMS2750.

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

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

4.2.2.3 Quarterly

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

4.2.2.3.2 Quench rate control tests (See 3.5.4).

4.2.2.4 Servicing and calibration of atmosphere control measuring equipment at the frequency required in 3.1.5.

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 Perform initial temperature uniformity survey as in AMS2750.
- 4.2.3.2 Pyrometer system accuracy test as in AMS2750.
- 4.2.3.3 Instrument calibration as in AMS2750.
- 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 that 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 AMS2750.

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, AMS2759E 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.

4.7 Report/Certification

The heat-treating processor shall furnish, with each shipment of parts, a certified quality assurance report, traceable to the heat treat control number(s), stating that the parts were processed in accordance with the requirements of AMS2759E (or other applicable specification). The report shall include: purchase order number, part number or product identification, alloy, temper/strength designation, quantity of parts in the shipment, identification of furnace(s) used, actual thermal processing times and temperatures used. When applicable, the report shall also include: atmosphere type, quenchant (including polymer concentration range), hot straightening temperature and method of straightening (e.g. press, fixtures), actual test results, (e.g., hardness, conductivity, tensile, shear etc.) and a statement of their conformance/nonconformance to requirements. This data shall be reported in accordance with the heat treater's documented procedures.