



AEROSPACE MATERIAL SPECIFICATION

AMS2773™**REV. F**Issued 1999-01
Revised 2022-04

Superseding AMS2773E

Heat Treatment
Cast Nickel Alloy and Cobalt Alloy Parts

RATIONALE

AMS2773F results from a Five-Year Review and update of this specification with the addition of ordering information, added furnace Class 5 and Type D instrumentation to pyrometry (3.1.1), added revised partial pressure and leak rate requirements to vacuum furnaces (3.1.2.2), revised amount of material removed from heating media (3.1.2.3), revised cleaning such that purchaser shall supply clean parts in prior to heat treatment (3.2.1.1), revised racking requirements regarding small parts (3.2.2), revised offset temperature selection in control instruments (3.2.3), changed start of soak for batch furnaces to align with AMS2759 (3.2.5.1), changed start of soak for vacuum furnaces to align with AMS2769 (3.2.5.2), changed start of soak for continuous furnaces such that verification is preproduction (3.2.5.3), revised re-heat treatment from being allowed twice to once (3.2.7), added cycle interruption requirements (3.2.8), clarified hardness (3.5.2), added rework and cycle interruptions to report/certification (4.7), and added note 8 to Table 3 stating tolerances for heat treatment temperatures.

NOTICE

ORDERING INFORMATION: The following information shall be provided to the heat-treating processor by the purchaser. Purchase order and/or purchaser supplied documents shall specify not less than the following:

- AMS2773F
- Quantity of parts
- Part number or part identity
- Material (alloy) designation of parts, including foundry heat/lot number and heat treatment condition
- Heat treating operations required, including:
 - Final heat treatment condition required (see 1.2.2)
- Processing variables not defined in or different from AMS2773 requirements, such as:
 - Processing temperatures, times, and other parameters
 - Allowance for straightening (see 3.2.6)
 - Post straightening thermal operations requirements (see 3.2.6)
 - Optional, any pre-cleaning and post-cleaning requirements (see 3.2.1.1, 3.2.1.2)

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Documents

Document Sharing Hub

- Post heat treatment corrosion protection requirements, if applicable
- Any restriction to options allowed within this specification (e.g., salt bath only, polymer quenchant only)

1. SCOPE

1.1 Purpose

This specification specifies the engineering requirements for heat treatment, by part fabricators (users) or their vendors or subcontractors, of parts made of cast nickel or cobalt alloys and of fabricated assemblies in which cast nickel or cobalt alloys are the primary structural components. This specification is not intended to provide requirements for heat treating operations that are a responsibility of the casting supplier in meeting the requirements of the casting commodity specification.

1.2 Application

1.2.1 Alloys

Detailed heat treating instructions are specified for the age-hardenable (precipitation-hardenable) and non-age-hardenable alloys listed in 8.2. However, this specification also may be used for alloys other than those listed in 8.2 provided that temperatures, soaking times, and cooling requirements are specified by the cognizant engineering organization.

1.2.2 Heat Treatments

Heat treatments covered by this specification are as follows:

- Homogenization (see 2.5.6)
- Solution treating (see 2.5.7)
- Stabilization (see 2.5.9)
- Precipitation hardening (see 2.5.10)
- Stress relief (see 2.5.8)

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 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 processes 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 +1 724-776-4970 (outside USA), www.sae.org.

AMS2750 Pyrometry

AMS2769 Heat Treatment of Parts in a Vacuum

ARP1820 Chord Method of Evaluating Surface Microstructural Characteristics

ARP1962 Training and Approval of Heat-Treating Personnel

SAE J1086 Numbering Metals and Alloys

See Appendix A for a listing of those AMS material specifications referenced in this document.

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

ASTM E10 Brinell Hardness of Metallic Materials

ASTM E18 Rockwell Hardness Metallic Materials

ASTM E140 Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

ASTM E384 Microindentation Hardness of Materials

2.3 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

BB-H-1168 Helium, Technical

MIL-A-18455 Argon, Technical

MIL-PRF-27201 Propellant, Hydrogen

MIL-PRF-27401 Propellant Pressurizing Agent, Nitrogen

MIL-PRF-27407 Propellant Pressurizing Agent, Helium

2.4 CGA Publications

Available from Compressed Gas Association, Inc., 4221 Walney Road, 5th Floor, Chantilly VA 20151-2923, Tel: 703-788-2700, www.cganet.com.

CGA G-5.3 Commodity Specification for Hydrogen

CGA G-9.1 Commodity Specification for Helium

CGA G-10.1 Commodity Specification for Nitrogen

CGA G-11.1 Commodity Specification for Argon

2.5 Definitions

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

2.5.1 PARTS

Usually identified by a part number, parts are produced from raw castings in accordance with requirements of a drawing and are usually tested by nondestructive techniques only. They are heat treated by a fabricator/user, or his designee, to meet requirements of a drawing. The requirements are usually conveyed by a purchase order, fabrication outline, and/or heat treating specification. Parts, at the time of heat treatment, may resemble raw castings.

2.5.2 LOT

Shall be all parts of the same nominal configuration, of the same alloy, processed at the same time, and heat treated as a heat treatment batch.

2.5.3 LOAD SENSOR

A sensor attached to and in direct contact with the heaviest section of a part or representative sample. There should be no gap between the sensor and the part. It should be shielded against furnace radiation and protected against contamination from the furnace atmosphere or heating medium.

2.5.4 SET OR OFFSET TEMPERATURE

The temperature at which controlling instruments are set to cause the working zone of the furnace to operate within required temperature tolerance.

2.5.5 COGNIZANT ORGANIZATION

The engineering organization responsible for the design of the parts, or its allied quality assurance organization, or a designee of these organizations.

2.5.6 HOMOGENIZATION

A high temperature heat treatment designed to promote solid state diffusion within the casting in order to reduce or eliminate chemical segregation.

2.5.7 SOLUTION HEAT TREATMENT

A high temperature heat treatment designed to place certain carbides and intermetallic compounds into solid solution.

2.5.8 STRESS RELIEVING

A heat treatment used to remove or reduce stresses in strain-hardened or welded alloys.

2.5.9 STABILIZATION HEAT TREATMENT

An intermediate temperature precipitation heat treatment used with many age-hardening nickel alloys to cause a precipitation of discontinuous chromium carbides at grain boundaries prior to a lower temperature aging heat treatment which will cause a fine gamma-prime precipitation within the grains. This two-step precipitation results in an optimization of tensile and creep-rupture properties.

2.5.10 PRECIPITATION HEAT TREATMENT

An intermediate temperature heat treatment causing hardening and strengthening of the alloy by the precipitation of intermetallic compounds and, in some instances, of carbides from supersaturated solid solutions.

2.5.11 AIR COOLING

The rate at which the parts, separated from one another sufficiently to allow free movement of air between them, would cool to room temperature after being removed from the furnace and placed in ambient air without forced motion of the air.

2.5.12 RAPID AIR COOLING

The rate at which the parts, separated from one another sufficiently to allow free movement of air between them, would cool to room temperature after being removed from the furnace and placed in shop air with rapid motion of the air forced over the parts by a fan or blower.

2.5.13 THICKNESS

The minimum specified dimension of the heaviest section of the part.

3. TECHNICAL REQUIREMENTS

3.1 Equipment

3.1.1 Pyrometry

Shall be in accordance with AMS2750

3.1.1.1 Furnaces shall be Class 5 or better in accordance with the uniformity tolerance required by the heat treatment being performed. (See Table 3, note 8.)

3.1.1.2 Instrumentation shall be Type D or better.

3.1.2 Furnaces

3.1.2.1 Temperature Uniformity

Shall be in accordance with AMS2750.

3.1.2.2 Vacuum Furnaces

Shall be in accordance with AMS2769.

3.1.2.2.1 Furnaces shall be operated at pressures not higher than 10 microns of mercury unless argon, helium, hydrogen, or compatible mixtures thereof, is used to provide a partial pressure. Partial pressures may be used whenever necessary to avoid surface alloy depletion by sublimation of high vapor pressure elements such as aluminum and chromium. Argon or helium conforming to 3.1.2.3.1, or a mixture of the two, may be used to achieve partial pressures whenever necessary to avoid surface alloy depletion by sublimation of high vapor pressure elements.

3.1.2.2.2 Leak rate shall be in accordance with AMS2769.

3.1.2.3 Heating Media

Protective atmospheres shall be used whenever heat treating temperature is above 1600 °F (871 °C) unless parts will have a minimum of 0.020 inch (0.51 mm) of surface material removed from all surfaces after heat treatment to eliminate high temperature atmospheric effects, such as oxidation, alloy depletion, and carburization. Acceptable protective atmospheres include argon, helium, hydrogen, vacuum, and vacuum with partial pressure of any of these three gases. In addition, for non-age-hardening alloys, neutral salt baths and exothermic gas atmospheres are acceptable protective atmospheres when approved by the cognizant engineering organization (see 2.5.5). Direct fired furnaces shall be controlled so that there is no direct flame impingement on the parts.

3.1.2.3.1 Argon, Helium, and Hydrogen Gases

Shall meet the composition requirements of MIL-A-18455 (argon), CGA G-11.1, Grade C (argon), MIL-PRF-27407 (helium), CGA G-9.1, Grade L, minimum (helium), BB-H-1168, Grade A (helium), or MIL-PRF-27201 or CGA G-5.3 (Grade B) (hydrogen), as applicable. The dew point of the gas shall be -60 °F (-51 °C) or lower as the gas enters the furnace. Atmospheres of any of these gases in the furnace work zone shall have sufficient purity to avoid contamination or degradation of any part surface which will not have surface material removed after heat treatment.

3.1.2.3.2 Vacuum and Partial Pressure Atmospheres

Shall be sufficient to avoid contamination or degradation of any part surface which will not have surface material removed after heat treatment.

3.1.2.3.2.1 Cooling may be accelerated by back-filling with argon or helium conforming to 3.1.2.3.1 or with nitrogen conforming to either MIL-PRF-27401, Grade C or CGA G-10.1, Grade L, or combinations thereof, meeting the dew point requirements of 3.1.2.3.1.

3.1.2.3.3 Salt Baths

Acceptable only for non-age-hardening alloys and, when approved by the cognizant engineering organization, shall be neutral with respect to the alloy being treated so as to avoid contamination or degradation of any part surfaces which will not be machined after heat treatment.

3.1.2.3.4 Exothermic Atmospheres

Acceptable only for non-age-hardening alloys and, when approved by the cognizant engineering organization, shall be produced by the combustion of fuel gas in air, shall be neutral to slightly reducing with respect to the parts being treated, and shall be sufficiently low in sulfur content to avoid contamination or degradation of any part surfaces which will not have surface material removed after heat treatment.

3.1.3 Auxiliary Equipment

Fixtures, jigs, hangers, trays, racks, etc., shall not cause contamination of the surface of parts and shall not reduce the heating, cooling, or quenching rates below those required for proper heat treatment.

3.1.4 Cooling

Shall be provided to cool parts according to the heat treatment requirements specified for each alloy. Acceptable cooling media may include air, oil, water, water-polymer solutions, salt, brine (nominally 10% by weight NaCl), argon, helium, hydrogen, nitrogen, and vacuum. The medium selected shall not contaminate or degrade any part surface which will not be machined after heat treatment. When air cooling (AC) (see 2.5.11) or rapid air cooling (RAC) (see 2.5.12) is specified, cooling media shall be used which will provide protection, if required, to avoid contamination or degradation of finished surfaces; cooling rates shall be achieved that will be equivalent to, or faster than, rates that would be achieved by AC or RAC, as specified.

3.1.4.1 Quenching

Quenching baths shall permit complete immersion of parts and free circulation of the quenchant adjacent to all surfaces of parts. Equipment shall agitate or circulate the quenchant and/or the parts.