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)

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS2773F/

- 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.

3.2 Procedures

3.2.1 Cleaning

3.2.1.1 Prior to Heat Treatment

Parts shall be in a clean condition before heat treatment.

3.2.1.1.1 The purchaser shall supply clean parts to the processor or specify the cleaning method prior to heat treatment, to the processor. Parts shall be visually inspected to verify freedom from grease, dirt, oil, corrosion, and corrosion preventive coatings. Use of magnification as a referee for part inspection is permitted.

3.2.1.1.2 Following heat treatment operations, parts shall be cleaned when specified. Post heat treatment cleaning is not required unless specified.

3.2.1.2 After Heat Treatment

Parts which have been heat treated in molten salt or cooled in oil, molten salt, brine, or water-polymer solution shall be thoroughly cleaned to remove all residues of these materials.

3.2.2 Racking

Parts shall be racked to ensure uniform heating and cooling throughout the load. Parts shall not be nested unless tests with load thermocouples have demonstrated that the arrangement will not affect uniformity of heating and cooling and will not reduce the cooling rate below minimum requirements. Small parts (see 3.2.2.1) may touch but shall not be nested in a manner that prevents free access of the cooling media to most surfaces.

3.2.2.1 For small parts, the maximum thickness of layers, and minimum spacing between layers, shall be 1 inch (25 mm).

3.2.3 Control Instruments

Shall be set either at the set temperature (see 2.5.4) specified or at the offset temperature (see 2.5.4) based on the most recent temperature uniformity survey. The offset temperature shall be within 5 °F (3 °C) for precipitation treatments, and 10 °F (6 °C) for other treatments, of the specified set temperature and shall be posted on the instrument or programmed into the control system when a programmable system is in use. The offset temperature shall be selected to optimize the temperature distribution within the furnace so that the highest and lowest temperatures are within the uniformity tolerance required for the heat treatment.

3.2.3.1 The posting of the offset temperature shall include, or consist of, a statement of both the “desired” temperature and the corresponding “set” temperature, e.g., “When 1000 °F is desired, set at 1004 °F.”

3.2.4 Heat Treatment

Shall be performed as follows unless an alternate treatment has been specified by purchase order or by the cognizant engineering organization:

3.2.4.1 The specified solution and stress-relief treatment for the non-age-hardening alloys shall be performed in accordance with Table 1. Soaking times from Table 2 shall be used when not specified in Table 1. The specified homogenization, solution, precipitation, and stress relief treatments for age-hardening alloys shall be performed in accordance with Table 3. Tolerances for the soaking times for both aging-hardening and non-age-hardening alloys shall be as shown in Table 4.

Table 1 - Heat treatment of non-age-hardening[1] cast nickel alloy and cobalt alloy parts

Casting Alloy	Applicable AMS	Purchased Condition[2]	Solution Set Temperature[3]	Stress Relief Set Temperature[3]
INCONEL®[4] Alloy 625	AMS5401 AMS5402	As cast	2100 °F (1149 °C)[5] 1 hour - AC	1800 °F (982 °C) 2 hours - AC
Alloy B	AMS5396	As cast	2150 °F (1177 °C) RAC	
Alloy C	AMS5388	As cast	2225 °F (1218 °C) RAC	
Alloy X	AMS5390	As cast	2150 °F (1177 °C) RAC	1800 °F (982 °C) 2 hours - AC
STELLITE®[6] Alloy 31	AMS5382	As cast	Not applicable	1600 °F (871 °C) 2 hours - AC

Notes:
(1) Although normally considered to be non-age-hardening, these alloys, after solution heat treatment, are subject to some hardening upon exposure to temperatures in the approximate range of 1200 to 1600 °F (649 to 871 °C).
(2) Purchased condition is the condition as specified in the applicable AMS.
(3) AC = air cool; RAC = rapid air cool (see 3.1.4).
(4) INCONEL® is a registered trademark of Huntington Alloys Corporation.
(5) Solution heat treatment of 2175 °F (1191 °C) shall be used for parts of this alloy when specified by the cognizant engineering organization.
(6) STELLITE® is a registered trademark of Kennametal, Inc.

Table 2A - Soaking time for non-age-hardenable nickel alloy and cobalt alloy parts, inch/pound units

Diameter or Thickness of Maximum Section Inches	Soaking Time (see 3.2.5)
Up to 0.025, incl	10 minutes
Over 0.025 to 0.050, incl	15 minutes
Over 0.050 to 0.100, incl	20 minutes
Over 0.100 to 0.250, incl	25 minutes
Over 0.250 to 0.500, incl	45 minutes
Over 0.500 to 1.00, incl	1 hour
Over 1.00 to 1.50, incl	1 hour, 15 minutes
Over 1.50 to 2.00, incl	1 hour, 30 minutes
Over 2.00 to 2.50, incl	1 hour, 45 minutes
Over 2.50 to 3.00, incl	2 hours

Table 2B - Soaking time for non-age-hardenable nickel alloy and cobalt alloy parts, SI units

Diameter or Thickness of Maximum Section Millimeters	Soaking Time (see 3.2.5)
Up to 0.64, incl	10 minutes
Over 0.64 to 1.27, incl	15 minutes
Over 1.27 to 2.54, incl	20 minutes
Over 2.54 to 6.35, incl	25 minutes
Over 6.35 to 12.70, incl	45 minutes
Over 12.70 to 25.4, incl	1 hour
Over 25.4 to 38.1, incl	1 hour, 15 minutes
Over 38.1 to 50.8, incl	1 hour, 30 minutes
Over 50.8 to 63.5, incl	1 hour, 45 minutes
Over 63.5 to 76.2, incl	2 hours

Table 3 - Heat treatment of age-hardenable cast nickel alloy and cobalt alloy parts

Casting Alloy	Applicable AMS	Purchased Condition[1]	Solution Set Temperature[2][8]	Precipitation Set Temperature[2][8]	Other Treatments Set Temperature[2][8]
INCONEL® Alloy 713[5]	AMS5377	As cast	Not applicable	Not applicable	Stress relief 1600 °F (871 °C) Hold 2 hours - AC
INCONEL® Alloy 718[5]	AMS5383	Homogenization and solution heat treated	Select temperature in the range 1750 to 1800 °F (954 to 982 °C) Hold 1 hour minimum - AC	1325 °F (718 °C) Hold 8 hours Furnace cool to 1150 °F (621 °C) and hold at 1150 °F (621 °C) for total precipitation time of 18 hours - AC	Homogenization[3] 2000 °F (1093 °C) Hold 1 to 2 hours - AC
IN-738 C & LC	AMS5410	As cast	2050 °F (1121 °C) Hold 2 hours - AC	1550 °F (843 °C) Hold 24 hours - AC	
MAR-M-246®[6]	None	As cast		1550 °F (843 °C) Hold 50 hours - AC	
MAR-M-247®[6]	None	As cast		1600 °F (871 °C) Hold 20 hours - AC	
Rene' 41 Alloy	AMS5399	Solution heat treated	1950 °F (1066 °C) Hold for 3 hours minimum - RAC	1400 °F (760 °C) Hold 16 hours minimum - AC	
UDIMET® Alloy 500[7]	AMS5384 Noncurrent	Solution and precipitation heat treated	2100 °F (1149 °C) Hold 4 hours - AC - plus 1975 °F (1079 °C) Hold 4 hours - AC	1400 °F (760 °C) Hold for 16 hours - AC	

Notes:
(1) Purchased condition is the condition as specified in the applicable AMS. When no AMS is specified, purchased condition is typical of other specification systems.
(2) AC = air cool; RAC = rapid air cool (see 3.1.4).
(3) Parts shall be solution and precipitation heat treated following homogenization.
(4) When welding is completed before precipitation heat treatment, the solution heat treatment temperature shall be used for post-weld stress relief.
(5) INCONEL® is a registered trademark of Huntington Alloys Corporation.
(6) Mar-M® is a registered trademark of Lockheed Martin Corporation.
(7) UDIMET® is a registered trademark of Special Metals Corporation.
(8) Solution temperature tolerance is ±25 °F (±14 °C). Precipitation temperature tolerance is ±20 °F (±11 °C). Stress relief temperature greater than 1550 °F (843 °C) tolerance is ±25 °F (±14 °C). Stress relief temperature equal to and less than 1550 °F (843 °C) tolerance is ±20 °F (±10 °C). Homogenization temperature tolerance is ±25 °F (±14 °C).

Table 4 - Tolerance for the soaking times in Tables 1, 2, and 3 for heat treatment of nickel alloy and cobalt alloy parts

Soaking Time Specified	Tolerance, Plus Only
Up to 16 hours, incl	30 minutes
Over 16 hours	2 hours

3.2.4.1.1 Parts of age-hardening alloys shall be heat treated to the precipitation hardened condition. When a stabilization heat treatment is also specified for age-hardening alloys, the stabilization treatment shall be applied to solution treated parts before precipitation treatment.

3.2.4.1.2 Where temperature ranges are specified in Tables 1 and 3, it is the responsibility of the heat treatment processor to select, for each heat of material, the specific temperature and time, within the ranges specified, which will produce heat treated parts meeting all technical requirements of the drawing and applicable material specification.

3.2.4.2 Other Alloys Not Listed in 8.2

Heat treatments of cast parts made of alloys not covered herein, shall be as specified by the purchase order or the cognizant engineering organization. This information shall include the heat treatment name (e.g., solution, precipitation), the set temperature, the soaking time, and the quenchant or cooling medium.

3.2.4.3 Assemblies of Castings and Wrought Alloys

Heat treatment of cast parts fabricated with wrought alloys in a single assembly shall be the heat treatment designated by this specification for the cast alloy.

3.2.5 Start of Soaking Time

3.2.5.1 Batch Furnaces

3.2.5.1.1 When only furnace control sensors are used, soaking time starts when temperature indicated by the furnace control instrument recovers to within 5 °F (3 °C) of the set heat treating temperature.

3.2.5.1.2 When furnace control sensors and recording thermocouples are used, soaking time starts when the temperature indicated by all recorded sensors reaches the required temperature tolerance applicable to the set heat treating temperature. See Table 3, note 8.

3.2.5.1.3 When load thermocouples are used, soaking time starts when the part temperature reaches the required temperature tolerance for the set heat treating temperature. See Table 3, note 8.

3.2.5.2 Vacuum Furnace

Shall be in accordance with AMS2769.

3.2.5.3 Continuous Furnaces

Shall be operated so that all part temperatures are within the allowed range (the range described by the specified set temperature and the tolerance specified in Table 3, note 8) for the specified time. Conformance to this requirement shall be verified in preproduction using load thermocouples in a load representative of the weight and traverse speed of the parts to be heat treated.

3.2.6 Straightening After Heat Treatment

Shall be performed only when the straightening procedure and any subsequent stress-relief are approved by the cognizant engineering organization.

3.2.7 Re-Heat Treatment

Parts may be re-solution heat treated and re-precipitation heat treated one time without cognizant engineering organization approval. There shall be evidence in the heat treat records of re-solution and/or re-precipitation heat treatments that is retained in the producer's quality system.

3.2.8 Cycle Interruptions

If the precipitation, stabilization, or stress relief cycle is interrupted due to power loss or furnace malfunction that causes the furnace temperature to drop below the required setpoint tolerance, the cycle can be continued to complete the required soak time. For example, if power is lost 1 hour and 20 minutes into an 8 hour precipitation cycle, the parts can be re-heated to the precipitation temperature and continued for 6 hours and 40 minutes in order to complete the 8 hour cycle. In no cases can the cumulative precipitation time exceed the maximum time tolerance (for example, 8 hour cycle allow +30 minutes, the cumulative precipitation time cannot exceed 8 hours and 30 minutes). Only one such interruption is allowed per cycle. Further interruptions or exceeding the time tolerance requires reworking via re-solution treatment (see 3.2.7).

3.3 Qualification

Facilities performing heat treatment in accordance with this specification shall be approved by the cognizant organization (see 2.5.5). Personnel performing or directing the performance of heat treatment in accordance with this specification shall be approved in accordance with ARP1962 or other established procedures acceptable to the cognizant organization.

3.4 Properties After Heat Treatment

3.4.1 Surface Contamination

3.4.1.1 The heat treatment processor shall assume surfaces will not be machined after heat treatment unless the minimum amount of surface material to be removed after heat treatment is determined.

3.4.1.2 Surfaces of parts which are not to have surface material removed after heat treatment shall have no carburization, sulfidation, nitriding, nor intergranular oxidation resulting from the heat treating operations; evidence of such contamination shall be a continuous or general condition in the microstructure at the surface determined by metallurgical examination in accordance with 3.5.1. On surfaces which are to have material removed after heat treatment, the depth of any of these conditions shall not exceed the depth of surface material to be removed in finishing the part.

3.4.2 Hardness

Parts shall conform to hardness requirements specified on the engineering drawing or purchase order.

3.4.2.1 If hardness requirements are not specified on the engineering drawing or purchase order, age-hardening alloys conforming to one of the AMS specifications listed in Table 5 shall meet the hardness specified in Table 5 following precipitation treatment.

3.4.2.2 If hardness is not specified on the engineering drawing or purchase order, or in Table 5, parts shall conform to the hardness requirements of the applicable material specification when the material specification contains hardness requirements for the heat treatment condition represented by the parts.

Table 5 - Hardness requirements for age-hardenable cast nickel alloy and cobalt alloy parts in the precipitation heat treated condition

Alloy	Applicable AMS	Hardness Requirement(1)
INCONEL® Alloy 718	AMS5383	34 to 44 HRC
Rene' 41 Alloy	AMS5399	30 HRC minimum
UDIMET® Alloy 500	AMS5384	30 HRC minimum

Notes:
(1) Hardness requirements are shown as HRC, the same as used in the specified AMS material specification. Equivalent hardness (see 8.3) determined by another type of hardness testing is satisfactory, providing the alternate testing conforms to 3.4.2, 3.5.2, and 4.4.2 of this specification.

3.5 Test Methods

The following shall be used when applicable unless otherwise specified by the cognizant engineering organization:

3.5.1 Surface Contamination

Testing shall be by metallurgical examination, at approximately 500X magnification, of etched specimens prepared in accordance with ASTM E3. The chord method described in ARP1820 may be used to enhance this examination.

3.5.2 Hardness

Shall be determined in accordance with ASTM E10, ASTM E18, or ASTM E384, as applicable. Unless otherwise specified by the cognizant quality assurance organization, hardness tests shall be performed on parts except when the parts are not of suitable size or shape, or when the test will be detrimental to the function of the part; in these cases, suitable sample material which represents the parts shall be supplied to the heat treatment processor by purchaser for hardness tests.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

Unless otherwise specified by the cognizant organization (see 2.5.5), the heat treatment processor shall be responsible for the performance of all tests and inspections specified herein. The processor may use its own facilities or any commercial laboratory acceptable to the cognizant organization.

4.1.1 The procuring activity reserves the right to perform any surveillance, tests, or inspection of parts and to review heat treatment records and results of processor's tests and inspections to verify that the heat treatment conformed to specified requirements.

4.2 Records

Shall be kept available to purchaser for not less than 5 years after heat treatment. The records shall contain all data necessary to verify conformance to requirements of this specification.

4.3 Classification of Tests

4.3.1 Acceptance Tests

For age-hardenable alloys, if hardness requirements are specified (see 3.4.2), hardness is an acceptance test and shall be performed on each part unless a sampling plan is authorized by the cognizant organization (see 2.5.5).

4.3.2 Periodic Tests

Surface contamination is a periodic test and shall, unless otherwise authorized by the cognizant organization (see 2.5.5), be performed monthly on each furnace, except as provided in 4.3.2.1, for each type of atmosphere used in each furnace when heat treating temperature is above 1600 °F (871 °C) and parts have less than 0.008 inch (0.20 mm) finishing stock on any surface.

4.3.2.1 Periodic surface contamination tests are not required on vacuum furnaces operating under 10 microns (μm) pressure except as provided in 4.3.2.2.

4.3.2.2 Surface contamination tests shall also be performed whenever parts which have less than 0.008 inch (0.20 mm) finishing stock on any surface, and which have been heat treated at a temperature above 1600 °F (871 °C), show abnormal surface discoloration after heat treatment. The cognizant engineering organization is responsible for defining "abnormal surface discoloration."

4.3.3 Preproduction Tests

Surface contamination (3.4.1) is a preproduction test when heat treating temperature is above 1600 °F (871 °C) and parts have less than 0.008 inch (0.20 mm) finishing stock on any surface. Preproduction tests shall be performed prior to, or on, the first production lot (see 2.5.2) heat treated in each type of furnace equipment and for each type of atmosphere to be used in each furnace type.

4.4 Test Samples

4.4.1 Surface Contamination Tests (3.5.1)

4.4.1.1 For preproduction surface contamination tests (4.3.3), sample material of the same alloy representing the parts shall be supplied to the heat treatment processor by purchaser, or destructive testing of a part shall be authorized by purchaser.

4.4.1.2 For periodic surface contamination tests (4.3.2), sample material shall be prepared in accordance with 4.4.1.2.1 and be either the same alloy as the production parts to be heat treated or shall be an alloy selected from Table 6.

Table 6 - Periodic surface contamination test alloys

Waspaloy®(1) UNS No. N07001	Alloy X-750 UNS No. N07750	Alloy 718 UNS No. N07718
AMS5544	AMS5542	AMS5596
AMS5704	AMS5598	AMS5597
AMS5706	AMS5667	AMS5662
AMS5707	AMS5668	AMS5663
AMS5708	AMS5670	AMS5664
AMS5709	AMS5671	
	AMS5747	

Notes:
(1) Waspaloy® is a registered trademark of United Technologies Corporation.

4.4.1.2.1 Prior to furnace exposure, at least one surface shall be machined or ground. The test samples shall be exposed to the heat treating atmosphere at the maximum temperature, or higher, and for the maximum time, or longer, required for heat treating the production parts.

4.4.2 Hardness tests (3.5.2) shall be performed nondestructively on parts except when the parts are not of suitable size or shape, or when the test will be detrimental to the function of the part; in these cases, suitable sample material which represents the parts shall be supplied to the heat treatment processor by purchaser for hardness tests.

4.5 Approval of Heat Treatment Processors

Shall be accomplished by the cognizant organization (see 2.5.5) and will normally be based on the following:

4.5.1 Approval of the heat treatment processor's shop procedure document, which shall include a full description of all equipment and procedures that will be used to meet requirements of this specification and AMS2750.

4.5.2 Competence of heat treatment processor's personnel (see 3.3).

4.6 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, AMS2773F 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.