AEROSPACE MATERIAL SPECIFICATION

AMS2801™	REV. D

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Revised 2024-03

Superseding AMS2801C

Heat Treatment of Titanium Alloy Parts

RATIONALE

AMS2801D is a limited revision which revises the racking requirement for fasteners and small parts (see 3.3.2.2) and adds a new Table 7 to allow higher processing temperature for Beta alloys with related changes to Hydrogen Pick-Up (see 3.4.1) and Surface Contamination (see 3.4.2) provisions. Subsequent table numbers have been revised based on the addition of Table 7.

NOTICE

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

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

- AMS2801D
- Quantity of parts
- Size of parts
- Part number
- Material alloy designation of parts
  - Including mill heat/lot number, if applicable
  - Beta transus temperature, if it is required to be known for processing
- Heat-treat operations required, including:
  - Heat-treat condition, as delivered
  - Heat-treatment condition required
  - Tensile requirement, if applicable
  - Minimum stock removal after heat treatment

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/AMS2801D

- Processing variables not defined or different from the specification
  - Processing temperatures, times, and other parameters
  - Allowance for straightening
  - Post straightening thermal operations requirements
  - Pre-cleaning and post-cleaning requirements
  - Post heat-treatment protection requirements
  - Any restriction to options allowed within this specification
- If removal of surface contamination after heat treatment is to be performed by the heat-treatment processor (see 3.3.4)
- Surface contamination removal method and parameters, if it is to be performed by the heat-treatment processor
- Additional ordering information as required

1. SCOPE

1.1 Purpose

This specification establishes the engineering requirements for the heat treatment of titanium and titanium alloy parts. Heat treatment of raw material by raw material producers, forge shops, or foundries shall be in accordance with the material procurement specification AMS-H-81200.

1.2 Heat Treatments

Heat treatments covered by this specification are stated in Table 1.

Table 1 - Applicable heat treatments

Anneal	Beta Solution Treated and Overaged
Stress Relief	Solution Treat
Age	Beta Solution Treat
Overage	Solution Treat and Age
Cold Worked and Aged	Solution Treat and Over Age

1.3 Alloys

Titanium and titanium alloys are covered by this specification are stated in Table 2.

Table 2 - Titanium and titanium alloys

Commercially Pure	Alpha alloys	Alpha-Beta alloys	Beta alloys
Ti40	5Al-2.5Sn	6Al-4V	13V-11Cr-3Al
Ti55	5Al-2.5Sn ELI	6Al-4V ELI	3Al-8V-6Cr-4Mo-4Zr
Ti70	6Al-2Cb-1Ta-0.8Mo	6Al-6V-2Sn	15V-3Al-3Cr-3Sn
	8Al-1Mo-1V	3Al-2.5V	10V-2Fe-3Al
		6Al-2Sn-4Zr-2Mo	
		6Al-2Sn-4Zr-6Mo	

1.3.1 Other Alloys and Heat Treatments

This specification may be used for the heat treatment of parts made from alloys other than those in Table 2, provided that temperatures, times, and quenchants are specified by the cognizant engineering organization.

1.4 Processes Not Covered by This Specification

This specification does not cover selective heat treatments (induction, flame, laser, etc.) nor the use of thermal processing required to facilitate shaping or forming of titanium parts.

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

AMS4901 Titanium Sheet, Strip, and Plate, Commercially Pure, Annealed, 70.0 ksi (485 MPa)

AMS-H-81200 Heat Treatment of Titanium and Titanium Alloys

AS7766 Terms Used in Aerospace Metals Specifications

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: 610-832-9585, www.astm.org.

ASTM E3 Preparation of Metallographic Specimens

ASTM E8/E8M Tension Testing of Metallic Materials

ASTM E407 Microetching Metals and Alloys

ASTM E1447 Determination of Hydrogen in Reactive Metals and Reactive Metal Alloys by Inert Gas Fusion with Detection by Thermal Conductivity or Infrared Spectrometry

2.3 CGA Publications (Compressed Gas Association)

Available from CGA, 14501 George Carter Way, Suite 103, Chantilly, VA 20151, Tel: 703-788-2700, www.cganet.com.

CGA G-9.1 Commodity Specification for Helium

CGA G-11.1 Commodity Specification for Argon

2.4 Order of Precedence

In the event of a conflict between the text of this document and the references cited herein, the text of this document shall take precedence. Nothing in this document, however, shall supersede applicable laws and regulations, unless a specific exemption has been obtained.

2.5 Terms used in AMS are defined in AS7766.

2.5.1 Parts

Finished and semi-finished parts heat treated by the user during the fabrication process.

2.5.2 Thickness

The thickness is the minimum dimension of the heaviest section of the part.

3. TECHNICAL REQUIREMENTS

3.1 Pyrometry

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

3.2 Furnace Equipment

All heating, quenching and other processing equipment used for thermal treating shall be capable of producing conforming parts.

3.2.1 Furnace classes are as defined in AMS2750.

3.2.1.1 Furnace classes for annealing, stress relieving, solution treating, or beta solution treating shall be Class 5 or better.

3.2.1.2 Furnace class for aging and overaging shall be Class 3 or better except as noted in 3.2.1.2.1.

3.2.1.2.1 The furnace shall be Class 2 or better for parts made from the following five alloys when the temperature is 1025 °F (552 °C) or lower: 6Al-6V-2Sn, 13V-11Cr-3Al, 15V-3Cr-3Al-3Sn, 10V-2Fe-3Al, and 3Al-8V-6Cr-4Mo-4Zr.

3.2.2 Atmospheres

Allowable environments during heat treatment are inert gases argon or helium, or mixtures thereof, vacuum, and air. When removal of surface contamination from the heat-treated part is not feasible, argon, helium, or mixtures thereof, or vacuum environment shall be used. Protective coatings may be used to avoid or minimize the detrimental effects of heating in air when approved by the cognizant engineering organization (see 3.3.4.2).

3.2.2.1 Inert Atmospheres

Argon equivalent or having greater purity than CGA G-11.1, Grade C, or helium equivalent or having greater purity than CGA G-9.1, Grade L, shall be circulated within the furnace as necessary to protect all surfaces of the parts. The gas dew point when measured at the gas inlet of the furnace shall be -60 °F (-51 °C) or lower. Furnace ducts and zones containing parts shall be sealed as to prevent contamination of any parts to the degree that they are rendered nonconforming to specified material requirements.

3.2.2.2 Vacuum

3.2.2.2.1 Vacuum furnaces and processing shall be in accordance with AMS2769.

3.2.2.2.2 Cooling may be accelerated by back-filling with inert gas conforming to 3.2.2.1.

3.2.2.3 Prohibited Atmospheres

Gas mixtures resulting from the combustion in air of hydrocarbons (gas or oil), endothermic, exothermic, hydrogen, and dissociated ammonia atmospheres are prohibited from being used during any heat-treatment operation.

3.2.3 Furnace Purging

Prior to heat treatment of parts, each furnace that has contained an atmosphere unacceptable for heat treating titanium and titanium alloys (see 3.2.2.3) shall be purged with air or inert gas, as applicable.

3.2.3.1 The volume of purging air or inert gas introduced shall be at least six times the volume of the furnace chamber. During purging, the minimum temperature within the chamber shall be the intended soaking temperature. When air or inert gas purging is impractical, the furnace temperature shall be set to a minimum of 200 °F (111 °C) above the intended soaking temperature and be held at that temperature for a minimum of 4 hours. Following purging or elevated temperature soak, the furnace shall be stabilized at the required temperature, loaded with a production load, and the load then heated and soaked, as applicable. Following heat treatment and any subsequent cleaning, pickling, or other process that may introduce hydrogen contamination, specimens shall be taken from the load and examined for conformance with hydrogen and surface contamination requirements of 3.4.1 and 3.4.2.

3.2.3.2 Purging Prior to Introducing Inert Gas

Unless otherwise specified, furnaces shall be loaded, purged with a volume of air or inert gas at least six times the volume of the furnace chamber, and subsequently filled with argon or helium. The load shall then be heated and soaked as applicable.

3.2.4 Auxiliary Equipment

Auxiliary equipment such as fixtures, jigs, hangers, trays, racks, belts, etc., shall be used, as necessary. This equipment shall not reduce the heating, cooling, or quenching rates below those required for proper heat treatment and shall not cause surface contamination of finished part surfaces. All auxiliary equipment contacting parts shall be made of heat-resistant metal such as stainless steel or nickel base alloys. Nickel bearing heat-resistant metals shall not be used in contact with finished part surfaces above 1700 °F (927 °C). The use of ceramic, carbon or other suitable nonreactive material is also permitted, with the requirement that the surface contamination specimen per 4.3.4 be excised at the contact point where the material contacts the nonreactive material.

3.2.5 Quenching Facilities and Media

All heat-treatable titanium alloys, except alloys that can be cooled at a rate of furnace cool, or air cool, or faster, shall be quenched by complete immersion in water, oil, or polymer, as applicable. Quenching and handling facilities shall be located such that contact between the quenchant, and parts occurs within the time required for compliance of Ti-6Al-4V and Ti-6Al-4V ELI alloy as specified in Table 3. For other alloys, quench delay times shall be as necessary to develop required properties. Use of molten salt baths for quenching is prohibited (see 8.9 and 8.10).

Table 3 - Quench delay time [(1)(2)]

Nominal Thickness, Inches (mm)	Maximum Delay Time (Seconds)
Up to 0.25 (6.4), excl	6
0.25 (6.4) to 1.00 (25.4), excl	8
1.00 (25.4) to 3.00 (76.2), excl	10
3.00 (76.2) and over	30

(1) Quench delay time begins when the furnace door starts to open and ends when the last corner of the load is immersed in the quenchant. In bottom-quench air furnaces, the quench delay time starts when the parts emerge from the work zone or when the work zone temperature drops below the minimum solution temperature, whichever comes first.

(2) Times shown apply to Ti-6Al-4V and Ti-6Al-4V ELI.

3.2.5.1 Quenching Baths

Shall be of sufficient size to permit complete immersion of parts and free movement of the quench medium adjacent to all surfaces of parts. Equipment shall be provided for agitation or circulation of the quench medium and/or the parts. The volume of quenchant, and any auxiliary cooling equipment, shall be sufficient to maintain the quenchant below 100 °F (38 °C) during a water quench or below 120 °F (49 °C) during a polymer quench, or 60 to 160 °F (16 to 71 °C) during an oil quench.

3.2.6 Continuous Furnaces

When continuous furnaces are operated below 1700 °F (927 °C), they shall be controlled to ensure that parts meet surface contamination requirements of the final part configuration.

3.3 Procedures

3.3.1 Cleaning

Prior to heat treatment, part surfaces shall be free from lubricants, halogen compounds, and other foreign matter that will cause surface contamination. Halogen compounds (see 8.10) and methanol shall not be used to degrease parts unless the parts are subsequently cleaned using an alkaline solution or an acid pickle (see 8.10). Surfaces of parts and auxiliary equipment shall be clean and free of dirt, water, oil, grease, paint, ink, crayon markings, die pick-up, fingerprints, and other foreign material. After cleaning and prior to heat treatment, personnel handling parts shall wear clean gloves that ensure no handling residue is left on the parts.

3.3.1.1 For parts where all surfaces have metal removed after heat treatment, such that all surface contamination is removed, handling parts with gloves is not required.

3.3.2 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 distortion (see 8.9).

3.3.2.1 Parts, other than rivets, bolts, nuts, and other small parts, shall not be nested unless tests with load thermocouples have established the necessary additional soaking time required and have demonstrated that the arrangement will not affect uniformity of heating and cooling nor impede the adequacy of quenching.

3.3.2.2 Rivets, bolts, nuts, and other small parts, with maximum thickness of 0.5 inch (13 mm) may be processed in baskets provided the maximum thickness of each layer does not exceed 1 inch (25 mm) and the spacing between layers is at least 1 inch (25 mm).

3.3.3 Heat Treatment

3.3.3.1 Annealing

Shall consist of soaking for 2 hours ± 15 minutes at 1300 °F (704 °C) and air or furnace cooling with the following exceptions:

3.3.3.1.1 Parts made from beta alloys and parts which have been solution treated (and not aged) shall not be annealed.

3.3.3.1.2 Parts made from 6Al-6V-2Sn alloy shall be cooled to 1000 °F (538 °C) at a rate not to exceed 300 °F (167 °C) per hour, then air and/or furnace cooled.

3.3.3.1.3 Parts made from 5Al-2.5Sn alloy shall be annealed for 2 hours ± 15 minutes at 1500 °F (816 °C) and air or furnace cooled.

3.3.3.2 Beta Annealing

When beta annealing or beta solution heat treatment is specified, parts shall be soaked at a temperature that is 50 °F ± 25 °F (28 °C ± 14 °C) above the known beta transus temperature of the heat of material. The soaking time shall be as stated in Table 5, followed by cooling at a rate equivalent to air cooling or faster. Furnace cooling is not permitted. Water quenching shall not be performed unless specified in the contract or on the drawing. When water quenching after beta annealing or beta solution heat treatment is specified, Ti-6Al-4V, Ti-6Al-4V ELI, and Ti-6Al-6V-2Sn alloys shall be given a second anneal between 1350 °F and 1400 °F (732 °C and 760 °C) for 1 to 4 hours.

3.3.3.3 Stress Relieving

Shall consist of soaking for 2 hours ± 15 minutes at 1100 °F (593 °C) and air or furnace cooling with the following exceptions:

3.3.3.3.1 Parts made from beta alloys and any parts which have been solution heat treated (and not aged) shall not be stress relieved.

3.3.3.3.2 For aged parts, the stress relieving temperature shall be 50 °F (28 °C) below the aging temperature. Cooling rate shall be air cool or faster below 850 °F (454 °C).

3.3.3.4 Solution Heat Treating

Shall be performed in accordance with Tables 4 and 5.

Table 4 - Solution heat treatment, soak temperatures, and quench requirements

Alloy	Set Temperature °F	Set Temperature °C	Quench(2)(5)
Alpha Alloys			
8Al-1Mo-1V	1825	996	(1)
Alpha-Beta Alloys			
6Al-4V sheet	1725	941	water or polymer
6Al-4V ELI	1725	941	water or polymer
6Al-4V other	1750(4)	954(4)	water or polymer
6Al-6V-2Sn	1625	885	water or polymer
6Al-2Sn-4Zr-2Mo	1770	966	(1)
6Al-2Sn-4Zr-6Mo	1600	871	(1)
Beta Alloys			
13V-11Cr-3Al	1400	760	(1)
3Al-8V-6Cr-4Mo-4Zr	1500	816	(1)
10V-2Fe-3Al(3)	Beta Transus -50	Beta Transus -28	(1)
15V-3Cr-3Al-3Sn	1450	788	(1)

(1) a. For thicknesses under 0.5 inch (12.7 mm) - Air cool or faster.
b. For thicknesses from 0.5 to 2 inches (12.7 to 51 mm) - Air, oil, polymer, or water except (1) air shall not be used for 8Al-1Mo-1V or 6Al-2Sn-4Zr-2Mo and (2) air shall not be used for forgings of 13V-11Cr-3Al, 3Al-8V-6Cr-4Mo-4Zr, or 15V-3Cr-3Al-3Sn.
c. For thicknesses over 2 inches (51 mm) - Water.

(2) Inert gas back-fill may be substituted for air cool in vacuum and inert atmosphere furnaces.

(3) The beta transus temperature will be furnished to the heat treater (see Ordering Information).

(4) When mechanical property requirements are specified (e.g., as is usual for fasteners), an alternate set temperature within the range of 1650 to 1775 °F (899 to 968 °C) and oil quenching may be used. If sampling and testing are not specified along with the mechanical properties, the use of the alternate temperature shall be validated by testing not less than two specimens, heat treated with each lot of parts, from the same heat and lot of material.

(5) Quench delay time shall not exceed the time in Table 3.

Table 5 - Solution heat-treatment soak times

	6Al-4V	6Al-6V-2Sn	13V-11Cr-3Al, 10V-2Fe-3Al, 6Al-2Sn-4Zr-2Mo, 8Al-1Mo-1V, 6Al-2Sn-4Zr-6Mo	3Al-8V-6Cr-4Mo-4Zr, 15V-3Cr-3Al-3Sn
Thickness[2] Inches	Minimum Soaking Time[3] Minutes			
up to 0.100	15	20	60	30
0.101 - 0.200	16	21	61	31
0.201 - 0.300	17	22	62	32
0.301 - 0.400	18	23	63	33
0.401 - 0.500	19	24	64	34
0.501 - 0.600	20	25	65	35
0.601 - 0.700	21	26	66	36
0.701 - 0.800	22	27	67	37
0.801 - 0.900	23	28	68	38
0.901 - 1.000	24	29	69	39
1.001 - 1.500	44	49	89	59
1.501 - 2.000[1]	64	69	109	79

[1] For thicknesses greater than 2.000 inches, add 20 minutes for each additional 1/2 inch or fraction thereof.
[2] Thickness is the minimum dimension of the heaviest section of the part.
[3] The maximum soak time shall be no more than twice the minimum.

3.3.3.5 Aging

Shall be performed in accordance with Table 6. Environment during cooling after aging shall be compatible with the heating environment.

Table 6 - Aging treatments[4]

Alloy	Temper[3][4]	Set Temperature °F	Set Temperature °C	Soaking Time Hours[1]
		Alpha Alloys		
8Al-1Mo-1V	STA1100	1100	593	8
		Alpha-Beta Alloys		
6Al-4V	STA900	900	482	8
6Al-4V	STOA1300	1300	704	4
6Al-6V-2Sn	STA1000	1000	538	2.5
6Al-2Sn-4Zr-2Mo	STA1100	1100	593	8
6Al-2Sn-4Zr-6Mo	STA1100	1100	593	6
		Beta Alloys		
13V-11Cr-3Al	STA800	800	427	10
13V-11Cr-3Al	CWA800[2]	800	427	10
3Al-8V-6Cr-4Mo-4Zr	STA925	925	496	20
3Al-8V-6Cr-4Mo-4Zr	CWA1000[2]	1000	538	6
10V-2Fe-3Al[3]	STA925	925	496	8
10V-2Fe-3Al[3]	STA975	975	524	8
15V-3Cr-3Al-3Sn	STA950	950	510	8

[1] Soaking times shown are for material up to 0.10 inch (2.5 mm) thick. Add 20 minutes for each additional 1/2 inch (12.7 mm) or fraction thereof. The thickness is the minimum dimension of the heaviest section of the part. Tolerance for soaking time shall be plus 0.5 hour or 5%, whichever is greater than zero.
[2] Cold worked instead of solution heat treated.
[3] When no temper designation is specified, the STA 925 temper (see 8.3) shall be used.
[4] When mechanical property requirements are specified, other aging treatments (including those used by the material producer to confirm response to heat treatment) may be used to meet requirements. If sampling and testing are not specified along with the mechanical properties, any adjustment of the time or temperature shall be validated by testing not less than two specimens from the same heat and lot of material heat treated with each lot of parts.

3.3.3.6 Start of Soak

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

3.3.3.6.2 When furnace control sensors and recording thermocouples are used, soaking time starts when the temperature indicated by all recorded sensors reaches the minimum of the required temperature tolerance applicable to the set heat-treating temperature.

3.3.3.6.3 When load thermocouples are used, soaking time begins when the part temperature reaches the minimum of the required temperature tolerance for the set heat-treating temperature.

3.3.4 Descaling

3.3.4.1 Descaling shall be performed on all parts heat treated in air at a set temperature greater than 1000 °F (538 °C) in air. Sufficient material shall be removed to ensure there is no surface contamination on any surfaces.

3.3.4.2 Protective Coatings

The use of coatings to protect against scaling and to ease scale removal is allowed when approved by the cognizant engineering organization.

3.4 Properties

Unless otherwise stated in the applicable material specification, the following tests shall be performed:

3.4.1 Hydrogen Pick-Up

For parts heated in air at a set temperature greater than the temperature stated in Table 7, or after purging of atmospheres whenever the equipment has been operated previously using atmospheres defined in 3.2.2.3, which could contaminate parts, hydrogen pick-up shall not exceed 25 ppm from the hydrogen level determined prior to processing when tested in accordance with ASTM E1447. Parts heat treated in vacuum or in an inert atmosphere do not require hydrogen pick-up testing.

Table 7 - Test temperature for hydrogen pickup and surface contamination

Alloy Group(1)	Temperature
Commercially Pure	1000 °F (538 °C)
Alpha Alloys	1000 °F (538 °C)
Alpha-Beta Alloys	1000 °F (538 °C)
Beta Alloys	1200 °F (649 °C)

(1) See Table 2 for alloys in groups.

3.4.1.1 Rework of Parts with Hydrogen Pick-Up

Parts found to have hydrogen pick-up in excess of 25 ppm resulting from heat treatment may have the pick-up reduced to an acceptable level by heating the entire lot of parts in a vacuum furnace conforming to 3.2.2.2.1. Such heating shall not result in overaging of parts. Heating by resolutioning and aging shall only be performed when authorized by the cognizant engineering organization. Records of all such heating shall be maintained and submitted to the purchaser along with the certification test report. Hydrogen contamination testing shall also be performed after the purging of atmospheres whenever the equipment has been operated previously using atmospheres defined in 3.2.2.3 which could contaminate parts (see 3.2.3.1).

3.4.2 Surface Contamination

Surface contamination is only applicable for parts heated at a set temperature greater than the temperature stated in Table 7.

3.4.2.1 The surfaces of machined, ground, blasted, or acid-pickled parts shall not exhibit the effects of absorbed oxygen or nitrogen to the degree that the surface contamination of the part exceeds the levels specified as determined in accordance with the bend test requirement of AMS4901 or by metallographic examination (see 4.3.3 and 4.3.4).

3.4.2.2 Specimens that are heat treated in vacuum or inert gas atmosphere furnaces shall be free from surface contamination as determined in accordance with the bend test requirement of AMS4901, or by metallographic examination (see 4.3.3 and 4.3.4). Parts heat treated in vacuum or in an inert atmosphere that exhibit no evidence of discoloration need not be tested for surface contamination unless nonmetallic fixturing is used (see 3.2.5).

3.4.2.3 Surface contamination testing shall be performed after the purging of atmospheres whenever the equipment has been used previously to heat treat using atmospheres, such as endothermic, dissociated ammonia, etc., which could contaminate titanium parts. The degree of surface contamination shall not exceed the levels specified as determined in accordance with the bend test requirement of AMS4901 or by metallographic examination (see 4.3.3 and 4.3.4).

3.4.3 Tensile Properties

When tensile testing is specified, specimens prepared and tensile tested in accordance ASTM E8/E8M shall exhibit properties as specified in the applicable material specification. The rate of strain during tensile testing shall be set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ±0.002 in/in/min (±0.002 mm/mm/min) through the 0.2% offset yield strain.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

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

4.2 Classification of Tests

4.2.1 Acceptance Tests

Hydrogen pick-up (see 3.4.1) and surface contamination (see 3.4.2) are acceptance tests and shall be performed on each lot of parts. Tensile properties (see 3.4.3) when specified is an acceptance test.

4.2.2 Periodic Tests

There are no periodic tests.

4.2.3 Preproduction Tests

Hydrogen pick-up (see 3.4.1) and surface contamination (see 3.4.2) tests are preproduction tests and shall be performed on specimens or parts that have been exposed to the highest processing temperature and for each type of atmosphere used for each heat-treatment furnace, and when the cognizant engineering organization deems confirmation testing necessary.

4.3 Sampling and Testing

4.3.1 Sampling shall be as specified.

4.3.2 Lot

A 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 the processor's inspection at the same time. When testing parts after operations (e.g., stress relieving, baking, or hot or warm straightening) that occur after the final step of the heat operation (e.g., 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.

4.3.3 Specimens

4.3.3.1 Surface Contamination Test Specimens

Specimens for surface contamination testing shall be of suitable dimensions and shall be removed from parts where configuration and dimensions permit. Where such removal is impossible, specimens shall be taken from a sample piece of appropriate dimensions and of the same alloy as the part that is being heat treated and that has been heat treated along with the parts they represent.

4.3.3.2 Hydrogen Pick-up Test Specimens

4.3.3.2.1 Specimens shall be made from AMS4901 material and shall be nominally 0.020 inch (0.51 mm) thick by 1 inch (25 mm) square. When authorized by the cognizant engineering organization specimen may be excised from a part.

4.3.3.2.2 For heat-treat loads containing small parts (e.g., fastener components), such parts may be substituted for specimens.

4.3.4 Test for Surface Contamination

Parts or specimens selected in accordance with 4.3.3, as applicable, shall be prepared in accordance with ASTM E3, etched according to ASTM E407 in a suitable solution, and examined at 400X or higher magnification. A photomicrograph of the surface shall be taken and stored as part of the record. Alternatively, specimens of appropriate dimensions shall be tested in accordance with the bend test requirement of AMS4901.

4.4 Approval

4.4.1 Heat-Treat Processor’s Facilities

The approval of a facility shall be in accordance the requirements of the cognizant quality assurance organization. The procedures used by the heat-treating processor shall be available for review.

4.4.2 Personnel

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

4.5 Records

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

4.6 Record Retention

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