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400 COMMONWEALTH DRIVE, WARRENDALE, PA 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 2728

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HEAT TREATMENT OF WROUGHT COPPER BERYLLIUM ALLOY PARTS

1. SCOPE:

1.1 Purpose: This specification establishes the requirements for heat treatment of wrought copper beryllium parts (See 8.1.1) by users or by their vendors or subcontractors.

1.2 Application: This specification is applicable to parts made from the following alloys: UNS C17000, UNS C17200, UNS C17300, UNS C17500, and UNS Cl7510 (See 8.2).

1.2.1 The heat treat parameters (temperatures, soaking times, cooling rates, etc) used by material producers and forge shops for qualification of response to heat treatment of their products shall conform to the requirements of this specification.

1.2.2 Heat treatment of raw material by raw material producers or forge shops shall be in accordance with the material procurement specification.

1.2.3 Vacuum-furnace heat treating is a recognized heat treating process but its equipment requirements are not covered by this specification.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications and Aerospace Recommended Practices shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2750 - Pyrometry

2.1.2 Aerospace Recommended Practices:

ARP 1820 - Chord Method of Evaluating Surface Microstructural Characteristics

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E3 - Preparation of Metallographic Specimens
ASTM E8 - Tension Testing of Metallic Materials
ASTM E10 - Brinell Hardness of Metallic Materials
ASTM E18 - Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E384 - Microhardness of Materials

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Standards:

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

3. TECHNICAL REQUIREMENTS:

3.1 Equipment and Pyrometry: Thermal processing equipment and related pyrometric equipment shall be controlled in accordance with AMS 2750.

3.1.1 Heating Equipment: High temperature furnaces with or without controlled atmosphere are acceptable for solution heat treating. Salt baths shall not be used for solution treatments. A muffle furnace shall be used for solution treating in fuel fired furnaces with an air atmosphere. Circulating-atmosphere type furnaces, with or without controlled atmospheres, and salt bath type furnaces are acceptable for precipitation hardening. Still air oven type furnaces are not permitted for low temperature age hardening.

3.1.2 Temperature Controls and Measurement: Automatic temperature controllers and data recorders conforming to AMS 2750 are required on each furnace. Temperature sensors shall be located in or adjacent to each work zone. Thermocouples shall be protected from contamination. Instrumentation, thermocouples, test equipment, calibration equipment, load thermocouples (See 8.1.2), furnace temperature uniformity, and system accuracy shall conform to AMS 2750.

3.1.2.1 Furnace Temperature Uniformity: Requirements for solution heat treating (See 8.1.3) shall be ±25°F (±15°C), and for precipitation hardening (See 8.1.4) shall be ±10°F (±5°C).

3.1.3 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 kept clean. Racks, baskets, trays, or other containers may be used provided that the container construction will permit the quench medium to simultaneously reach all parts.

3.1.4 Auxiliary Equipment: Fixtures, jigs, hangers, trays, racks, 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 heat treating of parts.

3.1.5 Cleaning Equipment: Equipment shall be provided to clean parts before heat treatment and to remove salt from parts heated in salt baths.

3.2 Heating and Cooling Environment:

3.2.1 Atmospheres: Shall be controlled so as not to react with the parts being heat treated. Materials that could attack or contaminate shall not contact parts.

3.2.1.1 Solution Treating Atmosphere: Parts shall be solution treated in either air or protective atmospheres. Acceptable protective atmospheres for finished machined surfaces are exothermic, argon, helium, nitrogen, hydrogen, blends of these gases, and vacuum (See 3.2.1.1.2). Endothermic atmosphere is not acceptable for parts with finish machined surfaces. For scale-free or discoloration free parts, an air atmosphere should be avoided.

3.2.1.1.1 Unless specifically informed that the part will be machined all over, the heat treating processor shall heat treat the parts as if some surfaces will not have subsequent metal removal and, therefore, when solution heat treating, shall heat treat using air or protective atmosphere.

3.2.1.1.2 Vacuum: Is permitted for UNS C17000, UNS C17200, and UNS C17300 at 1450°F (790°C), but is not permitted for UNS C17500 and UNS C17510 at 1700°F (925°C).

3.2.1.2 Aging Atmosphere: Parts shall be aged in air or protective atmospheres. Acceptable protective atmospheres for aging are the same as for solution treating (3.2.1.1), and neutral salt bath.

3.2.2 Quenching Media: Cold water baths shall be used. The water temperature shall not exceed 95°F (35°C) during operating use. For parts over 5 in. (125 mm) in nominal thickness, quenching may be done in water not warmer than 150°F (65°C) to minimize quench cracking.

3.3 Procedure:

3.3.1 Cleaning: Parts shall be vapor degreased before heat treatment operations. Parts aged in salt shall be cleaned after heat treatment to remove salt residue.

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

3.3.3 Racking: Parts shall be racked and supported, or otherwise oriented, to ensure access of the heating, cooling, and quenching media to all surfaces of every part.

3.3.4 Loading: Parts shall not be loaded into a furnace with the temperature higher than the set temperature.

3.3.4.1 When load thermocouples are required, the cognizant engineering organization shall determine the number, location, and method of attachment.

3.3.5 Set Temperature: Control instrument (s) shall be set at the temperature specified herein. If an offset temperature based on the last temperature uniformity survey is approved by the cognizant engineering organization, it shall be within 5°F (3°C) of the specified set temperature and shall be posted on the instrument. The offset temperature shall be selected so as to optimize temperature distribution within the furnace so that the highest and lowest tempertures are equidistant from the specified set temperature. If an offset temperature is used, a load thermocouple is required.

3.3.6 Soaking: Heating shall be controlled in such manner that either the heating medium or the part temperature, as applicable, is maintained at the set temperature and for the soak time specified herein. Soaking shall commence when all control, indicating, and recording thermocouples reach the specified set temperature or, if load thermocouples are used, when the part temperature reaches the minimum of the furnace uniformity tolerance at the set temperature. The determination of the commencement of soak time based on using either load or control thermocouples on a job shall not be changed once established, unless approval by the cognizant quality assurance agency is granted for changing the method, i.e. either from a load thermocouple to the control thermocouple or vice versa.

3.3.7 Solution Heat Treat (Solution Annealing): Shall be accomplished by heating to and soaking at the following temperatures for the time specified in Table I:

Alloy No. UNS C17000, UNS C17200, and UNS C17300: 1450°F (790°C)

Alloy No. UNS C17500, UNS C17510: 1700°F (925°C)

The solution heat treat condition is designated as Condition A.

Temperature uniformity shall be ± 25°F (± 15°C).

3.3.7.1 Quench: Shall be accomplished in cold water within 60 sec after removal of parts from furnace.

3.3.8 Precipitation Harden: Shall be accomplished by heating to and soaking at a set temperature within the following temperature range for the time specified in Table II.

Alloy No. UNS C17000, UNS C17200 and UNS C17300: 600° - 625°F (315° - 330°C).

Alloy No. UNS C17500 and UNS C17510: 875° - 925°F (470° - 495°C).

Parts may be air cooled or quenched. The conditions before and after precipitation hardening are given in Table II. The temperature uniformity shall be ±10°F (±5°C).

3.3.9 Stress Relief: When specified by the cognizant engineering organization, stress relieve by heating at a set temperature in the range 300° - 350°F (150° - 180°C) for not less than 30 minutes.

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

TABLE I

SOAK TIMES FOR SOLUTION HEAT TREATING (1)

Thickness Range (2)		Soak Times (3) (4)	
Inches	Millimetres	Minimum	Maximum
		hr min	hr min
Up to 0.005, excl (5)	up to 0.12, excl (5)	2	6
0.005 to 0.010, incl (5)	0.12 to 0.25, incl (5)	3	9
Over 0.010 to 0.030, incl (5)	Over 0.25 to 0.75, incl (5)	6	15
Over 0.030 to 0.090, incl (5)	Over 0.75 to 2.25, incl (5)	10	30
Over 0.090 to 0.250, incl	Over 2.25 to 6.25, incl	20	40
Over 0.250 to 0.50, incl	Over 6.25 to 12.50, incl	45	1 30
Over 0.50 to 1.00, incl	Over 12.50 to 25.00, incl	1	2
Over 1.00 to 1.50, incl	Over 25.00 to 37.50, incl	1 15	2 30
Over 1.50 to 2.00, incl	Over 37.50 to 50.00, incl	1 30	3
Over 2.00 to 2.50, incl	Over 50.00 to 62.50, incl	1 45	3 30
Over 2.50 to 3.00, incl	Over 62.50 to 75.00, incl	2	4
Over 3.00 to 3.50, incl	Over 75.00 to 87.50, incl	2 15	4 30
Over 3.50 to 4.00, incl	Over 87.50 to 100.00, incl	2 30	5
Over 4.00 to 4.50, incl	Over 100.00 to 112.50, incl	2 45	5 30
Over 4.50 to 5.00, incl	Over 112.50 to 125.00, incl	3	6
Over 5.00 to 8.00, incl	Over 125.00 to 200.00, incl	3 30	7
Over 8.00	Over 200.00	(6)	(7)

(1) Solution heat treatment of fabricated parts is not recommended.

(2) Thickness is the minimum dimension of the most massive section of the part.

(3) Soak time commences as specified in 3.3.6.

(4) In all cases, the parts shall be held for sufficient time to ensure that the center of the most massive area has reached temperature and the necessary solutioning and homogenization have taken place.

(5) Solution heat treatment of cold worked product in these size ranges is not recommended because it destroys basic characteristics, can cause severe loss of dimensional form, and causes severe distortion problems.

(6) 4 hr plus 30 min. for every 3 in. (75 mm) or increment of 3 in. (75 mm) greater than 8 in. (200 mm).

(7) Double the minimum time.

TABLE II

PRECIPITATION HARDENING TIMES AND CONDITIONS

Material Form	Alloy	Temper Before Precipitation Harden	Minimum Time, Hour (1)	Temper After Precipitation Harden
Strip	UNS C17000	A	3	AT
	UNS C17200	1/4H	2	1/4HT
		1/2H	2	1/2HT
		H	2	HT
Strip	UNS C17500	A	3	AT
	UNS C17510	1/2H	2	1/2HT
		H	2	HT
Plate, Rod, and Bar	UNS C17000	A	3	AT
	UNS C17200	H	2	HT
	UNS C17500			
	UNS C17510			
Forgings	UNS C17000	A	3	AT
	UNS C17200			
	UNS C17500			
	UNS C17510			
Wire	UNS C17000	A	3	AT
	UNS C17200	1/4H	2	1/4HT
	UNS C17300	1/2H	2	1/2HT
	UNS C17500	3/4H	2	3/4HT
	UNS C17510	H	2	HT

(1) Maximum time shall be 1/2 hr more than minimum specified.

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 at leadman and foreman level responsible for heat treatment in accordance with this specification shall be approved as specified in 4.4.2. There shall be at least one approved person working on each shift.

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

3.5 Properties:

3.5.1 Hardness: Parts shall conform to Table III.

3.6 Test Methods: The following test methods shall be used, when applicable.

3.6.1 Hardness: Shall be determined in accordance with ASTM E10, ASTM E18, and ASTM E384, as applicable.

3.6.1.1 Rockwell hardness testing machines shall be checked daily, when used, in accordance with ASTM E18, and ASTM E384, as applicable, using standard hardness test blocks for the same scale as, and within 10 points of, the hardness of the parts being tested. A record of the daily checks shall be maintained.

3.6.2 Tensile Properties: Testing, when required by the cognizant engineering organization, shall be in accordance with ASTM E8.

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

3.7 Additional Processes: Parts shall not be subject to thermal operations or straightening operations other than those specified, unless permitted by the cognizant engineering organization.

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 tests and inspections. Results of such tests shall be reported to the cognizant quality assurance organization as required by 4.7. The supplier may use his own facilities or any commercial laboratory acceptable to the cognizant quality assurance organization. The purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that processing conforms to the requirements of this specification. The cognizant quality assurance organization may review heat treating records and the results of tests and inspections to verify that heat treatment conformed to all requirements of this specification.

TABLE III

HARDNESS AFTER PRECIPITATION HARDENING

Alloy	Temper	Thickness, Inch	Thickness, Millimetres	Rockwell Hardness, Minimum C	Rockwell Hardness, Minimum 30N
UNS C17000	AT	All	All	33	53
	1/4HT	All	All	35	55
	1/2HT	All	All	37	57
	3/4HT	All	All	38	58
	HT	Up to 3/16, incl	Up to 4.80, incl	39	59
		Over 3/16 to 1, incl	Over 4.80 to 25.00, incl	35	--
		Over 1	Over 25.00	34	--
UNS C17200 and UNS C17300		All	All	36	56
	1/4HT	All	All	38	58
	1/2HT	All	All	39	59
	3/4HT	All	All	39	59
	HT	Up to 3/16, incl	Up to 4.80, incl	40	60
		Over 3/16 to 1, incl	Over 4.80 to 25.00, incl	39	--
		Over 1	Over 25.00	34	--
				B	30T
UNS C17500 and UNS C17510		All	All	92	77
	1/4HT	All	All	94	78
	1/2HT	All	All	95	79
	3/4HT	All	All	95	79
	HT	All	All	96	80

4.1.1 Responsibility for Inspection of Direct Government Orders: Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the government. The government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for hardness (3.6.1) and, when required, tensile properties (3.6.2) are classified as acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Tests to determine conformance to the following requirements are classified as periodic tests and, unless otherwise specified by the cognizant engineering organization, shall be performed at the frequency specified herein on each piece of equipment in service.

4.2.2.1 Daily:

4.2.2.1.1 Check of hardness testing machines (3.6.1.1).

4.2.2.2 Weekly:

4.2.2.2.1 Furnace pyrometer system accuracy test as in AMS 2750.

4.2.2.3 Quarterly:

4.2.2.3.1 Calibration of furnace instruments as in AMS 2750.

4.2.2.3.2 Service and certification of hardness test machines.

4.2.2.3.3 Temperature uniformity surveys of furnaces as in AMS 2750. Annually, the survey shall be at the maximum operating temperature.

4.2.2.4 Servicing and calibration of atmosphere control measuring equipment at the frequency required in 3.6.3.

4.2.3 Preproduction Tests: Tests to determine conformance to the following requirements are classified as preproduction tests and shall be performed prior to any production heat treating for each piece of equipment to be used.

4.2.3.1 Temperature uniformity survey as in AMS 2750.

4.2.3.2 Pyrometer system accuracy tests as in AMS 2750.

4.2.3.3 Instrument calibration as in AMS 2750.

4.2.3.4 Certification of hardness testing machines (3.6.1).

4.2.3.5 Certification of tensile testing machines (3.6.2).

4.2.3.6 Calibration of atmosphere control measuring equipment (3.6.4).

4.3 Sampling:

4.3.1 For Hardness Testing:

4.3.1.1 Hardness testing shall be performed on every part except as permitted by 4.3.1.1.1, 4.3.1.1.2, and 4.3.1.1.3.

4.3.1.1.1 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 assurance organization.

4.3.1.1.2 Statistical sampling is permitted when authorized by the cognizant quality assurance organization.

4.3.1.1.2.1 When statistical sampling is authorized, random samples shall be selected and tested in accordance with MIL-STD-105 at acceptance quality level (AQL) of 1.5 or less.

4.3.1.1.3 When heat treating standard components for which the frequency of testing is specified, the requirements of the component specification shall take precedence.

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

4.3.2 Lot : Shall be all parts of the same design, fabricated from the same alloy, heat treated 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 8-hr shift.

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 organization. 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 2.1.1.

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

4.4.2 Personnel: Approval of heat treatment personnel by the processing facility's quality assurance organization shall be in accordance with the following three criteria: