SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS2728 | REV. C

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Superseding AMS2728B

Heat Treatment of Wrought Copper Beryllium Alloy Parts

RATIONALE

AMS2728C results from a Limited Scope Ballot to correct errors present in revision B (3.1.2.2, 3.1.5.1, 3.3.6, 3.3.7, 4.2.2).

1. SCOPE

1.1 Purpose

This specification establishes the requirements for heat treatment of wrought copper beryllium parts (See 1.2.2 and 8.2.1) 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 C17510 (See 8.4).

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 producers or forge shops shall be in accordance with the material procurement specification.

1.3 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 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 vendor 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.

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

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS2728C

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AMS2750 Pyrometry

AMS2769 Heat Treatment of Parts in Vacuum

ARP1917 Clarification of 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 E 3 Preparation of Metallographic Specimens

ASTM E 8/E 8M Tension Testing of Metallic Materials

ASTM E 10 Brinell Hardness of Metallic Materials

ASTM E 18 Rockwell Hardness of Metallic Materials

ASTM E 384 Knoop and Vickers Hardness of Materials

3. TECHNICAL REQUIREMENTS

3.1 Equipment

3.1.1 Pyrometry

Shall conform to AMS2750.

3.1.2 Furnaces

3.1.2.1 Solution heat treating furnaces shall be a minimum of Class 2 (±10 °F or ±6 °C)

3.1.2.2 Precipitation hardening furnaces shall be a minimum of Class 2 (± 10 °F or ±6 °C)

3.1.2.3 Stress Relieving furnaces shall be a minimum of Class 5 (±25 °F or ±14 °C)

3.1.2.4 Vacuum furnaces used to perform processes in this specification shall be in accordance with AMS2769.

3.1.3 Heating Media

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 age hardening.

3.1.4 Racks and Fixtures

Shall not cause contamination of product and shall not reduce the heating, cooling, or quenching rates to less than required for correct heat treating. Design and construction shall preclude entrapment of quenchant and minimize deformation or other damage to product.

3.1.5 Quenching Equipment

3.1.5.1 Equipment shall be provided for quenching in water and for measuring and recording water temperature. Provisions shall be made for mechanical or hydraulic agitation of the quenching medium and/or agitation of the product and for cooling of the water as necessary to conform with 3.1.5.3.

3.1.5.2 Air agitation shall not be used.

3.1.5.3 Quench tanks shall be located in proximity to solution heat treating furnaces so that the quench delay times listed in Table 2 can be achieved. The delay time is measured from the time the furnace door starts to open until complete immersion of the load in quenchant.

3.1.5.4 The quenchant volume shall be sufficient to prevent the quench tank temperature from rising to a temperature greater than the limit established in 3.2.2.

3.1.6 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 are exothermic, argon, helium, nitrogen, hydrogen, blends of these gases, and vacuum (See 3.2.1.1.2). Endothermic atmosphere is not acceptable. To minimize discoloration 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 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 Age Hardening Atmosphere

Parts shall be aged in air or protective atmospheres. Acceptable protective atmospheres for age hardening 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 130 °F (46 °C) during operating use.

3.3 General Procedures

3.3.1 Cleaning

Parts shall be cleaned before heat treatment operations. Parts aged in salt shall be cleaned after heat treatment to remove salt residue.

3.3.2 Discoloration Protection

Parts shall be protected from discoloration by keeping dry before and after processing.

3.3.3 Racking and Spacing

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. Racking orientation shall include measures to minimize part distortion or damage during the heating and quenching process.

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 Soaking

Heating shall be controlled in such a 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.

3.3.6 Solution Heat Treat (Solution Annealing)

Shall be accomplished by heating to and soaking at the following temperatures for the time specified in Table 1:

Alloy No. UNS C17000, UNS C17200, and UNS C17300: 1450 °F ± 10°F (790 °C ± 6°C)

Alloy No. UNS C17500, UNS C17510: 1700 °F ± 10°F (925 °C ± 6°C)

The solution heat treat condition is designated as TB00 (formerly Condition A).

3.3.6.1 Quench

Shall be accomplished in cold water (See 3.2.2) within the quench delay times listed in Table 2.

3.3.7 Precipitation Harden

Shall be accomplished by heating to and soaking at the following temperatures, as applicable, for the time specified in Table 3:

Alloy No. UNS C17000, UNS C17200 and UNS C17300: 612 °F ± 10°F (330 °C ± 6°C).

Alloy No. UNS C17500 and UNS C17510: 925 °F ± 10°F (495 °C ± 6°C).

Parts may be air cooled or quenched. The conditions before and after precipitation hardening are given in Table 3.

3.3.8 Stress Relief

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

3.3.9 Records

A furnace log, or equivalent documentation such as shop travelers, traceable to temperature recorder chart(s) shall be maintained (See 4.5).

TABLE 1 - SOAK TIMES FOR SOLUTION HEAT TREATING (1)

Thickness Range (2) inches	Thickness Range (2) millimeters	Soak Times (3)(4) Minimum		Soak Times (3)(4) Maximum	
		hours	minutes	hours	minutes
Up to 0.090, incl (5)	Over 0.75 to 2.25, incl (5)		(6)		(6)
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		20		40
Over 0.50 to 1.00, incl	Over 12.50 to 25.00, incl		20		40
Over 1.00 to 1.50, incl	Over 25.00 to 37.50, incl		30	1	
Over 1.50 to 2.00, incl	Over 37.50 to 50.00, incl		30	1	
Over 2.00 to 2.50, incl	Over 50.00 to 62.50, incl		30	1	
Over 2.50 to 3.00, incl	Over 62.50 to 75.00, incl		30	1	
Over 3.00 to 3.50, incl	Over 75.00 to 87.50, incl		30	1	
Over 3.50 to 4.00, incl	Over 87.50 to 100.00, incl		30	1	
Over 4.00 to 4.50, incl	Over 100.00 to 112.50, incl		30	1	
Over 4.50 to 5.00, incl	Over 112.50 to 125.00, incl		30	1	
Over 5.00 to 8.00, incl	Over 125.00 to 200.00, incl		45	1	15
Over 8.00	Over 200.00		(6)		(6)

(1) Solution heat treatment of fabricated parts is not recommended.
(2) Thickness is the minimum dimension of the most massive section of the product.
(3) This table applies when a load thermocouple (See 8.2.2) is used. Soak time commences as specified in 3.3.6.
(4) Product shall be held for sufficient time to ensure that the center of the most massive area has reached temperature.
(5) Solution heat treatment of cold worked product in these size ranges is not recommended because it can cause distortion with loss of dimensional form.
(6) Solution heat treatment of product in these size ranges is not recommended because of the risk of grain growth beyond the allowable size in the appropriate AMS specification.

TABLE 2 - MAXIMUM QUENCH DELAY TIMES FOR SOLUTION HEAT TREATING

Minimum Thickness (1) inches	Minimum Thickness (1) millimeters	Maximum Time (2) seconds
Over 0.090 to 0.25, incl	Over 2.25 to 6.25, incl	5
Over 0.25 to 0.50, incl	Over 6.25 to 12.5, incl	7
Over 0.50 to 1.00, incl	Over 12.5 to 25.0, incl	10
Over 1.00 to 1.50, incl	Over 25.0 to 37.5, incl	12
Over 1.50 to 2.00, incl	Over 37.5 to 50.0, incl	14
Over 2.00 to 2.50, incl	Over 50.0 to 62.5, incl	16
Over 2.50 to 3.00, incl	Over 62.5 to 75.0, incl	18
Over 3.00 to 3.50, incl	Over 75.0 to 87.5, incl	20
Over 3.50 to 4.00, incl	Over 87.5 to 100, incl	22
Over 4.00 to 4.50, incl	Over 100 to 112.5, incl	24
Over 4.50 to 5.00, incl	Over 112.5 to 125, incl	26
Over 5.00 to 8.00, incl	Over 125 to 200, incl	30

1. Minimum thickness is the minimum dimension of the thinnest section of any product in the load.
2. The maximum quench delays specified may be exceeded provided tests made within the past 12 months have demonstrated that product temperatures do not decrease by more than 100 °F (47 °C) from the appropriate furnace set temperature.

TABLE 3 - PRECIPITATION HARDENING TIMES AND CONDITIONS

Material Form	Alloy	Temper Before Precipitation Harden (2)		Minimum Time, Hours (1)	Temper After Precipitation Harden (2)	
Strip	UNS C17000	TB00	(A)	3	TF00	(AT)
	UNS C17200	TD01	(1/4H)	2	TH01	(1/4HT)
		TD02	(1/2H)	2	TH02	(1/2HT)
		TD04	(H)	2	TH04	(HT)
Strip	UNS C17500	TB00	(A)	3	TF00	(AT)
	UNS C17510	TD02	(1/2H)	2	TH02	(1/2HT)
		TD04	(H)	2	TH04	(HT)
Plate, Rod, and Bar	UNS C17000	TB00	(A)	3	TF00	(AT)
	UNS C17200	TD04	(H)	2	TH04	(HT)
	UNS C17500					
	UNS C17510					
Forgings	UNS C17000	TB00	(A)	3	TF00	(AT)
	UNS C17200					
	UNS C17500					
	UNS C17510					
Wire	UNS C17000	TB00	(A)	3	TF00	(AT)
	UNS C17200	TD01	(1/4H)	2	TH01	(1/4HT)
	UNS C17300	TD02	(1/2H)	2	TH02	(1/2HT)
	UNS C17500	TD03	(3/4H)	2	TH03	(3/4HT)
	UNS C17510	TD04	(H)	2	TH04	(HT)

1. Maximum time shall be 1/2 hour more than minimum specified.
2. Former temper designation terminology shown in parenthesis.

3.4 Qualification

3.4.1 Suppliers

Facilities performing heat treatment in accordance with this specification shall be approved by the cognizant quality assurance organization as specified herein.

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 AMS2750.

3.5 Properties

3.5.1 Hardness

Parts shall conform to Table 4.

TABLE 4 - HARDNESS AFTER PRECIPITATION HARDENING

Alloy	Temper (1)		Thickness Inch	Thickness Millimetres	Rockwell Hardness, Minimum	
					HRC	HR 30N
UNS C17000	TF00	(AT)	All	All	33	53
	TH01	(1/4HT)	All	All	35	55
	TH02	(1/2HT)	All	All	37	57
	TH03	(3/4HT)	All	All	38	58
	TH04	(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	TF00	(AT)	All	All	36	56
	TH01	(1/4HT)	All	All	38	58
	TH02	(1/2HT)	All	All	39	59
	TH03	(3/4HT)	All	All	39	59
	TH04	(HT)	Up to 3/16, incl	Up to 3/16, incl	40	60
			Over 3/16 to 1, incl	Over 3/16 to 1, incl	39	--
			Over 1	Over 1	34	--
					HRB	HR 30T
UNS C17500 and UNS C17510	TF00	(AT)	All	All	92	77
	TH01	(1/4HT)	All	All	94	78
	TH02	(1/2HT)	All	All	95	79
	TH03	(3/4HT)	All	All	95	79
	TH04	(HT)	All	All	96	80

1. Former temper designation terminology shown in parenthesis.

3.6 Test Methods

The following test methods shall be used, when applicable.

3.6.1 Hardness

Rockwell, Brinell, and microhardness testing machines shall be calibrated and verified according to ASTM E 18, ASTM E 10, and ASTM E 384 respectively.

3.6.2 Tensile Properties

Testing, when required by the cognizant engineering organization, shall be in accordance with ASTM E 8/E 8M.

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 be responsible for the performance of all tests and inspections. Parts required for testing shall be supplied by the customer. Results of such tests shall be reported to the cognizant quality assurance organization as required by 4.7. The processor 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 specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Hardness (3.6.1) and, when required, tensile properties (3.6.2) are acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests

The following requirements are periodic tests and, unless (1) otherwise specified by the cognizant engineering organization or (2) a reduced frequency is permitted by AMS2750, shall be performed at the frequency specified herein on each piece of equipment in service. Pyrometry tests shall be performed in accordance with AMS2750. Hardness testing machines shall be checked in accordance with ASTM E 10, ASTM E 18 or ASTM E 384, as applicable.

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

4.2.3 Preproduction Tests

The following requirements are preproduction tests and shall be performed prior to any production heat treating for each piece of equipment to be used.

4.2.3.1 Certification of tensile testing machines (3.6.2).

4.2.3.2 Calibration of atmosphere control measuring equipment (3.6.3).

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 Table 5.

TABLE 5 - ACCEPTANCE SAMPLING PLAN (1)

Lot Size	Sample Size	Lot Size	Sample Size
Up to 8	All	1201 to 3200	35
9 to 90	8	3201 to 10 000	38
91 to 150	12	10 001 to 35 000	46
151 to 280	19	35 001 to 150 000	56
281 to 500	21	150 001 and over	64
501 to 1200	27		

1. If any of the parts do not meet the minimum hardness, test 100% and accept those meeting the requirements

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-hour period.