SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

AMS 2678

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Furnace Brazing of Parts in a Vacuum Atmosphere

RATIONALE

AMS 2678 is a new specification to cover vacuum furnace brazing.

1. SCOPE

1.1 Purpose

This specification covers the requirements and procedures for the brazing of parts in a very low pressure gas which referred to as “vacuum” herein.

1.2 Application

This process provides general requirements and practices for vacuum brazing carbon and alloy steels, corrosion resistant steels, precipitation hardening alloys, nickel and cobalt-based alloys, aluminum alloys, and titanium alloys, but usage is not limited to such applications. For specific brazing requirements, the applicable AMS, AWS, or other engineering specification should be referenced.

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 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 supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been canceled 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 724-776-4970 (outside USA), www.sae.org.

AMS 2750	Pyrometry
AMS 2769	Heat Treatment of Parts in a Vacuum
ARP1962	Certification of Heat Treating Personnel

2.2 NFPA Publications

Available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471 or www.nfpa.org.

NFPA 86D Standard for Industrial Furnaces Using Vacuum as an Atmosphere

3. TECHNICAL REQUIREMENTS

3.1 Furnace Equipment

The furnace components shall not deleteriously affect material processed during a normal production run which can occur from vaporization or chemical reaction between the furnace components and the parts or gases used to maintain partial pressure in the furnace. See also 3.5.3.1.

3.1.1 Vacuum System

The vacuum pumping system shall have sufficient pumping capacity to evacuate the furnace to a pressure within the recommended range for the materials being processed, and to maintain the required pressure during the entire brazing process, including periods when a partial pressure is maintained using a controlled flow of inert gas.

3.1.1.1 Vacuum Sensing Equipment

The vacuum furnace shall be equipped with at least one gauge capable of sensing and recording the pressure in the vacuum heating chamber of the furnace. Vacuum sensing equipment shall be calibrated in accordance with the manufacturer's specification. Gauge types in Table 1 are recommended for the pressure ranges shown.

TABLE 1 - PRESSURE VERSUS RECOMMENDED GAUGE TYPE

Pressure (Microns)	Gauge
1 to 10^{3}	Thermocouple or Pirani
10^{-6} to 1	Hot filament ionization
10^{-4} to 10	Cold cathode ionization

3.1.1.2 Vacuum Gauge Calibration

The method of vacuum gauge calibration shall be in accordance with the manufacturer's specification and shall be acceptable to the purchaser. For furnaces used for processing materials at pressures of 1 micron or lower, vacuum gauges shall be calibrated every three months; otherwise, vacuum gauges shall be calibrated at least annually, unless conditions necessitate more frequent calibrations. Alternatively, a frequency may be established by periodic testing and agreed to by the purchaser.

3.1.1.3 Leak Rate

Testing for gas leakage shall be performed at ambient or elevated temperature. Initial leak rate shall be determined after closing the vessel and evacuating to at least 50 microns. After reaching the initial evacuation level set point for the process being performed, all valves to the vessel chamber shall be closed, the initial pressure recorded, and a second reading of pressure made a minimum of 15 minutes after the first reading. Leak rate shall then be determined by dividing the rise in pressure (difference between final and initial readings) by the time in hours. Leak rate shall be expressed as microns per hour. Permissible leak rate shall be in accordance with AMS 2769 or as specified by the purchaser.

3.1.1.4 If the leak rate test fails, the furnace may be baked out as specified in 3.1.1.5 and retested.

3.1.1.5 Bake-Out Cycle

The furnace shall be subjected to a bake-out (clean up) cycle monthly or when one or more of the following conditions occurs:

The furnace fails a periodic leak rate test as in 3.1.1.3.
After cycles where aluminum brazing filler metals are used and other filler metal brazing cycles are to follow.
Before running titanium base metals or filler metals containing titanium.

3.1.1.5.1 The bake-out cycle shall be carried out at a minimum of 50 °F (28 °C) above the brazing temperature to be used on the next series of brazing cycles.

3.1.1.5.2 Bake-out shall be for a period of one hour minimum at the lowest achievable furnace pressure and until the pressure is within the brazing range specified by the cognizant engineering organization or no change in pressure is observed over a period of 30 minutes.

3.1.1.5.3 Following the bake-out period, the furnace shall be cooled to a temperature lower than the brazing temperature, and the leak rate measured using the method in 3.1.1.3.

3.1.2 Pyrometry shall conform to AMS 2750.

3.1.2.1 Thermocouples

Thermocouple types K, N, and Nickel-Nickel Molybdenum shall be suitably protected by enclosing them in metal or ceramic sheaths, and shall be of a type compatible with the range of temperatures and vacuum conditions used. They shall be of a suitable size and located in such a way that the sheaths receive direct radiation from the heating elements and furnace walls.

3.1.2.1.1 The thermocouple types shown in Table 2 shall be used in vacuum for furnace control or temperature uniformity test measurements unless otherwise approved by the cognizant engineering organization.

TABLE 2 - THERMOCOUPLE TYPES VERSUS MAXIMUM OPERATING TEMPERATURE

Type	Maximum Temperature °F	Maximum Temperature °C
K (Chromel-Alumel)	2200(1)	1204
N (Nicrosil-Nisil)	2200(1)	1204
Nickel - Nickel/Molybdenum	2300	1260
S, R (Platinum/Rhodium - Platinum/Rhodium)	2600	1427
B (Platinum/Rhodium - Platinum/Rhodium)	3100	1704
Tungsten -Tungsten/Rhenium	4000	2204

Note:
(1) These thermocouples shall be discarded or recalibrated after being exposed to any of the following service conditions: five (5) brazing cycles or accumulation of 5 hours service at or above 2100 °F (1149 °C) or ten (10) brazing cycles or accumulation of 10 hours service between 2000° F (1093 ° C) and 2100 °F (1149 °C) or, for cycles below 2000 °F (1093 °C), the applicable requirement of AMS 2750 shall apply.

3.1.2.1.2 When used in metal or other sheathes, the processor shall ensure that no chemical reaction between the sheath or insulation in contact with the thermocouple and the thermocouple wire can occur.

3.1.3 Quenching

Furnaces having quenching capability shall be equipped with cooling means sufficient for the material, components, load and process being performed.

3.1.3.1 Gas Quenching

When gas quenching is specified, it shall be accomplished by backfilling the furnace with a gas that has no detrimental metallurgical effects on the material being processed or on the furnace equipment. The system and the pressure of the backfill gas selected shall be capable of cooling the parts at a rate sufficient to meet the material property requirements specified by the cognizant engineering organization.

3.1.3.1.1 When gas quenching is specified, the load shall be vacuum-cooled to below the solidus of the braze alloy before the furnace is backfilled for quenching.

3.1.3.2 Cooling

Where slow cooling is required following the brazing step, vacuum cooling or cooling with a partial pressure of inert gas is permitted. Controlled cooling using a programmed heat input is permitted provided load thermocouples are used to measure the actual load temperature during the cooling period. Load thermocouples must be shielded by the load. Alternatively, working thermocouples may be used to control the cooling by establishing the load cooling time in preproduction testing (3.5.2).

3.1.3.3 Use for Heat Treatment

When the braze heating/cooling cycle is to be used to accomplish part of a heat treatment process, the furnace must also meet the requirements of the applicable heat treat specification.

3.2 Partial Pressure Atmospheres

To minimize metal evaporation, partial pressures may be used.

3.2.1 Hydrogen shall only be used as a partial pressure gas with the approval of the cognizant engineering organization.

3.2.1.1 The use of hydrogen in a vacuum furnace shall be in accordance with NFPA Standard 86D.

3.2.2 When partial pressures are used to maintain chamber pressures above 100 microns, diffusion pumps shall be isolated from the main vacuum chamber to prevent backstreaming.

3.3 Outgassing

If the pressure rises during the heat-up cycle to a level such that either the partial pressure control set point is exceeded, causing the inert gas used to maintain such pressure to stop flowing or the vacuum level needed to maintain diffusion pump operation is exceeded, excessive outgassing is occurring. In this instance, the furnace shall be held at a constant temperature, or the heating rate reduced until the pressure and vacuum requirements are re-established.

3.4 Cleaning

Parts, fixtures and materials other than flux or paste, charged into the heating chamber shall be free of ingredients or contaminants which might evaporate and react with the material being brazed or the furnace components. Handling of cleaned parts and fixtures shall be such as to prevent contamination prior to charging into the furnace.

3.4.1 Drying of Paste

Parts assembled with braze paste shall be dried prior to being placed in the vacuum furnace.

3.5 Brazing shall be performed in accordance with the requirements of the applicable brazing specification and as follows:

3.5.1 Part Loading

Parts and fixtures shall be arranged in the furnace to promote uniform heating and cooling, and when quenching is required, to permit uniform circulation of the quench medium.

3.5.1.1 Parts shall be arranged so that braze filler metal cannot contact components of the furnace, fixtures, or thermocouples. When ceramic or other materials are used to separate parts, or fixtures from parts, they shall be of a type compatible with the brazing conditions and shall not interfere with uniform heating or cooling of the parts.

3.5.2 Load Thermocouples

One or more load thermocouples shall be used for procedure qualification. The thermocouples shall be located in the portions of the load that are predicted to be the last to attain the desired temperature. The thermocouples may be attached to the outer surface of the parts. If a thermocouple is placed in a hole to measure the core or interior of the part being processed, the thermocouple or end of the sheath or well shall make intimate contact with the surface at the bottom of the hole. To avoid errors due to conduction along the length of the thermocouple, the minimum depth of insertion of the thermocouple shall be at least ten times the diameter of the thermocouple.

3.5.2.1 Bare load thermocouples (unsheathed) may be used, provided they are used for only one brazing cycle and then discarded. Thermocouple types shall be selected to ensure that no chemical reaction with the material being brazed or the braze filler metal can occur.

3.5.2.2 In the event a load thermocouple fails, the run need not be aborted as long as another thermocouple continues to record the correct temperature.

3.5.2.3 Once a load has been qualified with load thermocouples, subsequent loads can be run without load thermocouples provided adequate records detailing the number of parts and distribution in the first qualified load are kept on file, and provide that subsequent loads have an equal or fewer number of parts in the load, and the distribution of the parts is the same as the distribution in the first load.

3.5.2.4 When use of load thermocouples is impractical, such as with two or three chamber oil- or gas-quench furnaces, tests shall be conducted to establish the correct heat-up time for the load.

3.5.3 Fixturing

Part fixtures shall provide adequate support and positioning of parts to promote uniform heating and cooling.

3.5.3.1 Fixture materials shall be of adequate strength to support the parts being brazed, and shall not react with the material being brazed or the braze filler metals. In particular, fixture/material combinations that readily form eutectics are not permitted.

3.5.4 Braze filler metals shall be selected in accordance with the applicable brazing specification or the drawing or the specific requirements of the cognizant engineering organization.

3.5.4.1 Braze filler metal shall be selected to avoid excessive vaporization such that joint properties or braze filler metal melting range are outside engineering specifications.

3.5.4.2 Soak time at the brazing temperature shall be selected to avoid composition change due to vaporization or excessive diffusion to the extent that joint properties are caused to be outside engineering specifications.

3.6 Surface Discoloration

Unless otherwise specified by the cognizant engineering organization, surface discoloration from the braze material shall not be a cause for rejection.

3.7 Brazed joint quality shall be as specified in the applicable brazing specification or the drawing, or if none are indicated therein, as specified by the cognizant engineering organization.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The brazing processor shall be responsible for performance of all required tests and inspections. Purchaser reserves the right to perform any confirmatory testing and inspection deemed necessary to ensure that processing conforms to specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Test

Braze joint quality (3.7) is an acceptance test and shall be performed as required by the cognizant quality assurance organization.

4.2.2 Periodic Tests

Vacuum gauge calibration (3.1.1.2) and leak rate (3.1.1.3) are periodic tests. Vacuum gauge calibration shall be performed at a frequency selected by the processor unless frequency of testing is specified by purchaser. Leak rate shall be performed weekly unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests

All pyrometry tests (section 3.1.2) including temperature uniformity survey, pyrometry system accuracy, and instrument calibration in accordance with AMS 2750; vacuum gauge calibration (3.1.1.2) and leak rate (3.1.1.3) are preproduction tests and shall be performed prior to production on each piece of equipment (furnace) and when a change is made to a procedure upon which approval was based (4.3) that could affect the acceptability of the brazed parts and when purchaser deems confirmatory testing to be required.

4.3 Approval of brazing processors shall be accomplished by the cognizant engineering or quality assurance organization based on the following:

4.3.1 Approval of the Braze Processor's Process

Manufacturing and quality assurance procedures and process control documents that shall be used to meet the requirements of this specification.

4.3.2 Competence of the Braze Processor's Personnel

Personnel performing or directing the performance of brazing in accordance with this specification shall be approved in accordance with ARP1962 or other established procedures.

4.4 Records shall be kept available to the purchaser for not less than five years after brazing. The records shall contain all data necessary to verify conformance to the requirements of this specification.