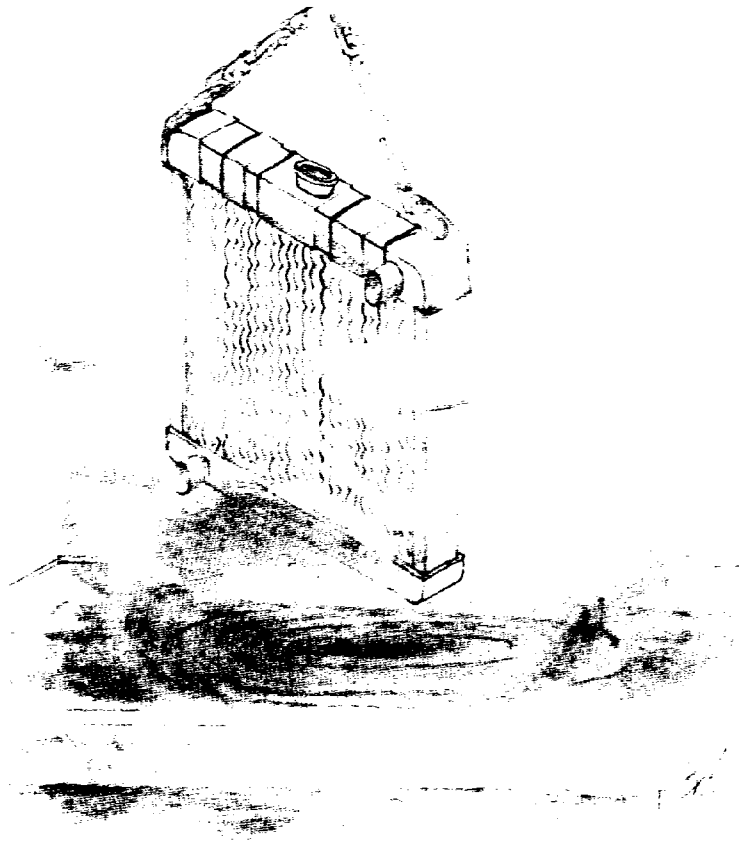


ANSI/AWS C3.7-93
An American National Standard

Specification for Aluminum Brazing



American Welding Society

Keywords — Aluminum, aluminum brazing, furnace brazing, quality control, inspection of brazed joints, brazing materials, brazing equipment, classification of brazed joints, brazed joint defects, nondestructive testing, furnace brazing procedure, braze joint defects

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An American National Standard

Approved by
American National Standards Institute
September 22, 1992

Specification for Aluminum Brazing

Prepared by
**AWS Committee on Brazing
and Soldering**

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This specification presents minimum fabrication, equipment, material, process procedure requirements and defect limits for the brazing of aluminum by all of the processes commonly used; atmosphere furnace, vacuum furnace, and flux processes. Its purpose is to standardize aluminum brazing requirements for all applications where brazed aluminum joints of assured quality are required. It provides criteria for classifying aluminum brazed joints based on loading and the consequences of failure and quality assurance criteria defining the limits of acceptability of each class. The specification defines acceptable brazing equipment, materials and procedures, as well as the required inspection for each class of joint.



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This standard is subject to revision at any time by the AWS Brazing and Soldering Committee. It must be reviewed every five years and if not revised, it must be either reapproved or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS Brazing and Soldering Committee and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS Brazing and Soldering Committee to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 550 N.W. LeJeune Road, P. O. Box 351040, Miami, Florida 33135.

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Foreword

(This Foreword is not a part of ANSI/AWS C3.7-93, *Specification for Aluminum Brazing*, but is included for information purposes only.)

This specification is one of a series prepared at the request of the Aerospace Manufacturers Association and a number of others to replace MIL-B-7883. This military specification covered all brazing processes and had become obsolete as these had proliferated and the technology had become more complex. Attempting to cover all on the diverse brazing processes in one concise, easily understood document was found to be impossible, and therefore a series of four independent specifications on brazing were written, all in the same format. They are torch brazing, furnace brazing, induction brazing, and aluminum brazing. It was decided to subdivide the technology in this way based upon a survey of production brazing applications conducted by the AWS Committee on Brazing and Soldering. This showed that these would cover the vast majority of brazing done in the United States today.

The fifth specification in the series is the *Recommended Practices for Ultrasonic Inspection of Brazed Joints*. In the preparation of the four brazing specifications it was found that no such document existed which could be referenced by them to provide specific criteria and requirements for the application of this important new technology to brazed joints.

Comments and suggestions for the improvement of this specification are welcome. They should be sent to the Secretary, Brazing and Soldering Committee, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

Official interpretations of any of the technical requirements of the specification may be obtained by sending a request, in writing to the Managing Director, Technical Services Division, American Welding Society. A formal reply will be issued after it has been reviewed by appropriate personnel following established procedures.

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Specification for Aluminum Brazing

1. Scope

This specification presents minimum fabrication and quality requirements for brazing of aluminum and aluminum alloys. Its purpose is to standardize brazing process requirements and control braze joint quality for all applications where braze joints of assured quality are required. This document states minimum requirements for processes and products with the minimum of explanatory information so that sources of ambiguity are reduced. It assigns responsibility for the ultimate quality of the brazed product to a single organization, and permits that organization to modify requirements if appropriate to the application. It requires proper documentation of any such modification.

2. Classification of Brazed Joints

2.1 Introduction. Brazed joints are classified in this specification based on two criteria; the designed loads and the consequences of failure. It is the responsibility of the Organization Having Quality Responsibility (see section 6, Definitions) to realistically evaluate both of these factors and assign the proper classification. This classification controls which inspection methods and acceptance limits are required. However, all joints, regardless of class, are expected to be manufactured by the most suitable methods to the best possible quality.

2.2 Class A Joints. Class A joints are those subjected to high or cyclical stresses, or both, the failure of which could result in significant risk to persons or property, or could result in a significant operational failure.

2.3 Class B Joints. Class B joints are those subjected to low or moderate noncyclical service stresses, the failure of which could result in significant

risk to persons or property, or could result in a significant operational failure.

2.4 Class C Joints. Class C joints are those subjected to moderate or low noncyclical service stresses, the failure of which would have no significant detrimental effect.

2.5 No Class Specified. When no class is specified on the engineering drawing or other applicable document approved by the Organization Having Quality Responsibility, Class A requirements shall apply. However, because of the confusion that can result, all engineering drawings referencing this specification should state the class of the brazed joint in the braze joint symbol. Symbols shall be per ANSI/AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*.¹

3. Applicable Documents

The following documents are a part of this specification, as referenced by this specification. Unless otherwise specified by the Organization Having Quality Responsibility, the revision of these documents in force at the time a contract or purchase order is issued shall be used:

(1) ASTM E230 *Electromotive Force (EMF) Tables for Standardized Thermocouples*²

(2) ANSI/AWS A2.4 *Symbols for Welding, Brazing and Nondestructive Testing*

(3) ANSI/AWS B2.2 *Standard for Brazing Procedure and Performance Qualification*

1. Available from the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135.

2. Available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

(4) ANSI/AWS A3.0 *Standard Welding Terms and Definitions*

(5) ANSI/AWS A5.8 *Specification for Filler Metals for Brazing*

(6) ANSI/AWS C3.8 *Recommended Practices for Ultrasonic Inspection of Brazed Joints*

(7) MIL-STD-6866 *Inspection, Penetrant*³

(8) MIL-STD-453 *Inspection, Radiographic*

(9) MIL-STD-105 *Sampling Procedures and Tables for Inspection of Attributes*

4. Process Requirements

4.1 Process Description. Aluminum is brazed using techniques which overcome the tendency to form very stable oxides. These include brazing in molten flux bath, torch brazing with fluxes, brazing in an atmosphere furnace with special fluxes, and brazing in vacuum or inert gas furnaces. Fluxless processes use either elemental magnesium, magnesium containing filler metal, or magnesium bearing base metals to getter available oxygen in the vacuum retort and to reduce the oxide film present on the aluminum surface. The magnesium modifies the wetting and alloying characteristics of the standard aluminum filler metals making them significantly more aggressive as well as making the base metal more susceptible to filler metal penetration. Because the melting points of the base metal and filler metal are usually very close together, temperature control requirements are much more restrictive than is common in the brazing of other metals.

4.2 Equipment

4.2.1 General Furnace Requirements. All furnaces and molten salt baths used in the brazing of aluminum shall have automatic temperature controlling and recording devices in good working order capable of controlling the temperature of the furnace or bath to the requirements of this specification. They shall have adequate heating capacity to accomplish uniform heating of the workload at the rate required to prevent both thermal distortion of the assemblies and liquation of the filler metal. They shall be properly maintained in good working order.

3. Available from Standardization Document Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, phone (215)699-3321.

4.2.2 Temperature Measurement and Control Instruments. In closed, batch-type furnaces and molten flux baths, suitable instruments and thermocouples shall be provided to measure and control the temperature of assemblies being brazed. The instrument shall be of the potentiometer type capable of measuring, recording, and providing a permanent record of the temperature through the entire brazing thermal cycle. In furnaces with multiple heating zones, the instrumentation shall be provided for each zone. All instruments used to measure the temperature of assemblies being brazed or to control furnace or bath temperature shall have an indicated temperature accuracy range of not more than ± 0.5 percent of the maximum for which the furnace or bath is qualified over the entire operating range. The indicated temperature accuracy of the instrument shall be determined in accordance with the equipment manufacturer's recommendations using a known electromotive force input traceable to the National Institute of Standards and Technology.⁴ All instruments shall be calibrated at least monthly or whenever repairs or modifications are made to them. Instruments used exclusively to protect the furnace or bath from over-temperature accidents are not subject to the requirements of this clause.

4.2.2.1 Work load control thermocouples shall be of a type listed in ASTM E230, *EMF Tables for Standardized Thermocouples*. They shall be recalibrated by comparison to a calibrated test instrument traceable to the National Institute of Standards and Technology at least monthly and replaced as required.

4.2.2.2 Work zone control thermocouples shall be of a type listed in ASTM E230. They shall be recalibrated by comparison to a calibrated test instrument traceable to the National Institute of Standards and Technology at least monthly and replaced as required.

4.2.3 Atmosphere Controlling Instruments

4.2.3.1 Electronic dewpoint measurement instruments shall be calibrated in accordance with the manufacturer's recommendations against ref-

4. National Institute of Standards and Technology, Office of Standard Reference Materials, Building 202, Room 206, Gaithersburg, Maryland 20899.

erence devices traceable to the National Institute of Standards and Technology. Such gages shall be calibrated before initial use and at least once per month when in use.

4.2.3.2 Vacuum Measuring Devices. Thermocouple gages shall be used to measure pressure higher than 10^{-3} Torr. Suitable electronic gauges shall be used to measure pressures of 10^{-3} Torr, or less. These gauges shall be so mounted as to measure the pressure within the vacuum chamber of the furnace. Suitable instruments for reading and recording the pressure shall be provided. These instruments and gauges shall be calibrated in accordance with the manufacturer's recommendations against reference standards traceable to the National Institute of Standards and Technology. They shall be so calibrated before initial use and at least once every three months when in use.

4.2.4 Temperature Qualification. All furnaces and flux baths shall be qualified for temperature uniformity and control prior to initial use for production brazing. All furnaces and molten flux baths used in the brazing of aluminum, including preheat furnaces, shall be requalified at least every three months. They shall be requalified after any repairs or alterations which might affect temperature control or uniformity [e.g. new heating elements, new control thermocouple(s), replacement of shielding]. Requalification is not required when the repair or alteration has previously been documented not to affect the temperature control or uniformity of the furnace or flux bath.

4.2.4.1 Uniformity tests of furnaces shall be conducted using a typical production atmosphere or vacuum level. All tests of furnace or flux baths shall be conducted using new or recalibrated thermocouples. The temperature-measuring equipment shall meet the requirements of 4.2.2. Instruments used to control the furnace or bath during production brazing shall not be used to monitor the qualification thermocouples.

A minimum of two thermocouples shall be used to determine the temperature uniformity of furnaces or baths having a work-zone volume of 10 cubic feet (0.28 cubic meter) or less. A minimum of 9 thermocouples, or 1 thermocouple per 25 cubic feet (0.70 cubic meter) of working zone, whichever gives the greater number of thermocouples, shall be used to determine the uniformity of furnaces or baths having a work zone larger than 10 cubic feet

(0.28 cubic meter). No more than 40 thermocouples shall be required to determine the temperature uniformity of the work zone of any furnace or bath. The thermocouples shall be symmetrically distributed within the work zone.

Qualification shall be performed at the normal brazing temperature or 1100°F if the furnace or bath is used at multiple temperatures. The temperature of all furnace test and control thermocouples shall be recorded at intervals of no more than five minutes starting at not less than 200°F (111°C). Temperature measurement and recording shall continue at least 30 minutes after the furnace or bath has reached thermal equilibrium to determine the recurrent temperature pattern of the furnace or flux bath. The results of the test shall be posted at the furnace or flux bath and shall include the date of testing, due date of next test, the size of the work zone, and the results of the tests including the location within the work zone of the hottest and coldest areas.

4.2.4.2 Molten flux-bath qualification procedures shall be performed at the beginning of every operating day to assure the brazing capability of the bath. A suitable braze sample shall be assembled and brazed to a procedure approved by the Organization Having Quality Responsibility. The brazed joint produced shall be smooth, continuous, and shall show adequate braze filler metal flow as specified by that procedure. Failure to meet these requirements shall require suitable corrective action and successful retest before the use of the bath for production brazing. The results of the daily qualification test shall be documented.

4.2.4.3 Temperature uniformity requirements are as follows:

(1) **Aluminum Brazing Furnaces.** Before thermal equilibrium has been reached, no temperature reading shall vary from the temperature for which the furnace is being qualified by more than $\pm 20^\circ\text{F}$ ($\pm 12^\circ\text{C}$). After thermal equilibrium has been reached, the temperature measured by any test thermocouple shall not vary from the selected furnace control temperature by more than $\pm 5^\circ\text{F}$ ($\pm 3^\circ\text{C}$).

(2) **Aluminum Preheat Furnaces.** Before thermal equilibrium has been reached, no temperature reading shall vary from the temperature for which the furnace is being qualified by more than $\pm 20^\circ\text{F}$ ($\pm 12^\circ\text{C}$). After thermal equilibrium has been reached, the temperature measured by any test

thermocouple shall not vary from the selected furnace control temperature by more than $\pm 10^\circ\text{F}$ ($\pm 6^\circ\text{C}$).

(3) Molten Flux Baths. Flux baths used for brazing aluminum base metals having solidus temperature of 1120°F (604°C), or greater, shall have temperature uniformity throughout the working zone within $\pm 10^\circ\text{F}$ ($\pm 6^\circ\text{C}$) of the controller set point. Flux baths used for brazing aluminum base metals having solidus temperature of less than 1120°F (604°C) shall have temperature uniformity throughout the working zone within $\pm 5^\circ\text{F}$ ($\pm 3^\circ\text{C}$) of the controller set point.

4.2.5 Furnace Operational Requirements

4.2.5.1 Atmosphere furnaces shall be suitable for the intended purpose and in good working order. The gas supply and purification system (if any) shall be capable of supplying atmosphere gases in accordance with the approved brazing procedure (see 4.5).

4.2.5.2 Vacuum furnaces for fluxless brazing of aluminum shall be suitable for the intended purpose, in good working order, and shall comply with the following performance requirements. Temperature within the working zone shall be controlled within $\pm 5^\circ\text{F}$ ($\pm 3^\circ\text{C}$) of the set temperature. A cold and previously outgassed furnace shall have total leakage (i.e., real leakage plus virtual leakage) of no more than 20 microns per hour when the vacuum chamber is isolated from the pumping system after being evacuated to 5 microns. Leak rate shall be measured over a time period of no less than 30 minutes. Such a leak rate test shall be done at least once a week, or whenever there is reason to suspect that an unacceptable leak rate exists. A cold outgassed furnace shall be capable of reaching a vacuum of 10^{-5} Torr in a time as specified in the brazing procedure (see 4.5). It shall have the capability of backfilling with inert gas after evacuation to 10^{-4} Torr when required by the brazing procedure (see 4.5). The inert gas shall have a dewpoint at the entry point to the furnace retort no higher than -90°F (-68°C). Suitable provision shall be made for measurements of the dewpoint.

4.2.5.3 Atmosphere furnaces for the brazing of fluxed aluminum assemblies shall be suitable for the intended purpose and in good working condition. The temperature of the working zone shall be

controlled to within 5°F (3°C) of the set temperature. Suitable means shall be provided to control the furnace atmosphere composition and dewpoint. Products of combustion shall not access the brazing chamber, to in any way impinge on the assemblies being brazed. Furnance atmospheres, the means to be used to control them, and the limits to which they are to be controlled shall be specified by the approval brazing procedure (see 4.5).

4.2.5.4 Preheat furnaces shall be in good working order and suitable for the intended purpose. Combustion-type furnaces shall not impinge combustion products onto the work. The temperature in the working zone shall be controlled within 10°F (6°C) of the set temperature.

4.2.5.5 Molten flux baths used for the brazing of aluminum shall be in good working condition and suitable for the intended purpose. They shall be electrically heated and the temperature of the bath shall be controlled within the range of 1050°F to 1160°F (565°C to 627°C).

4.2.6 Fixtures. Fixtures shall be made of suitable materials which are stable at the brazing temperature and do not contaminate the flux, atmosphere, base metal, or brazing filler metal. The fixtures shall be designed to allow for thermal expansion of the components being brazed. To the greatest extent possible, the fixtures shall control the components at points or along lines of contact. All fixtures, racks and baskets used in aluminum brazing with fluxes shall be made of corrosion resistant materials such as nickel-based stainless steels or inconel. Fluxless fixtures use similar materials for their high strength to weight properties at elevated temperatures.

4.3 Aluminum Brazing Materials

4.3.1 Filler Metals. Filler metals shall be as specified on the engineering drawing.

4.3.2 Fluxes. Fluxes shall be compatible with the base and filler metals which are specified by the engineering drawing. Fluxes shall remove oxides and prevent their reformation during the brazing operation. They shall promote the flow of filler material and its wetting onto the base metal surfaces of the joint. Acceptable flux(es) shall be specified by the approved brazing procedure (see 4.5).

4.3.3 Cleaning Materials. Cleaning materials shall not leave any residues which interfere with the wetting or flow of the filler metal or contaminate the flux or filler metal. Chemical cleaning solutions which cause damage to the base metals shall not be used.

4.3.4 Braze Stopoff. Braze stopoff materials, if used, shall be suitable for the intended purpose and compatible with the base metal(s), filler metal(s), fluxes, and furnace atmosphere. In certain applications, residues from stopoff materials can produce unacceptable contamination of the product. If any doubt exists, permission of the Organization Having Quality Responsibility should be obtained prior to use.

4.4 Process Requirements

4.4.1 Cleaning. Components to be brazed shall be free of oil, grease, paint, dirt, scale or other foreign substances that can interfere with the brazing process, or contaminate the braze joint. Burrs shall be removed as required to permit proper assembly and filler metal flow.

4.4.2 Clearance. In assemblies for aluminum brazing where the filler metal is in the form of cladding on the base metals, or where filler metal tape or foil is used, the base and filler metals shall be in intimate contact. In assemblies where the filler is preplaced adjacent to the joint, the clearance between the joint surfaces of the base metals shall be 0.001 to 0.003 in. (0.025 to 0.075 mm) unless otherwise specified by the engineering drawing.

4.4.3 Assembly. Components shall be assembled and held in place by suitable fixtures per 4.2.6. Assembly by fusion or resistance tack welding or by tabs or rivets shall be specified by the approved brazing procedure (see 4.5).

Fixturing and assembly techniques which keep the braze joint clearance from closing during brazing shall not be used for fluxless (i.e., vacuum aluminum brazing), although such techniques are acceptable when external filler metal placement and flux are used. Vent and drain holes in components shall be as specified on the engineering drawing.

4.4.4 Application of Filler Metal. Sufficient filler metal in the form specified on the engineering drawing shall be preplaced in, or adjacent to, the joint in sufficient quantity to produce a satisfac-

tory brazed joint. On joints having one end inaccessible to visual inspection, the filler shall be placed at the blind end of the joint or in the joint prior to assembly. Binders used in filler metal slurries shall not leave harmful residues or in any way interfere with filler metal flow.

4.4.5 Application of Flux. Flux shall be applied in the form and quantity, and by the method specified in the approved brazing procedure. The quantity and location of placement shall be such as to produce a satisfactory brazed assembly.

4.4.6 Application of Stopoff. Braze stopoff materials shall be applied in quantities and locations as necessary to control filler metal flow in order to meet the requirements of the engineering drawing. It shall not be applied in such a manner that the braze joint surfaces or filler metal are contaminated.

4.4.7 Maintenance of Molten Flux Baths. Flux baths shall have sludge removed from the sides and bottom of the tank by suitable means prior to any additions of flux to the bath and at least once per week when in operation. In addition, at the beginning of each day of operation, the bath shall be dehydrated by repeatedly immersing sheets or coils of clean AA 1100 or AA 3003 aluminum. When this aluminum is free of visual surface contamination upon removal from the bath (i.e., light gray in color), brazing shall commence. This treatment shall also be performed immediately after flux is added to the bath prior to the commencement of brazing. The chemical composition of the flux shall be analyzed by suitable techniques at least once a month and maintained within the limits recommended by the manufacturer of the flux. The pH of the flux shall be measured at least once a week by suitable means and shall be maintained between 6.4 and 7.0. Baths not maintained to these requirements shall not be used to braze assemblies to this specification, and assemblies brazed in them shall be rejected.

4.4.8 Procedure for Nonvacuum Furnace Brazing. Components cleaned and assembled to the requirements of this specification shall be placed in the furnace in such a manner that the atmosphere can readily reach all surfaces. They shall be heated to the required temperature in the shortest possible time after temperature stabilization, if stabilization is required, by the approved brazing proce-

ture. Assemblies shall be cooled in a suitable manner to prevent cracking, reduce residual stresses, and accomplish any heat treatment required by the engineering drawing. Procedures shall be qualified and documented per 4.5.

4.4.9 Procedure for Dip Brazing. Components cleaned and assembled to the requirements of this specification shall be preheated in a suitable furnace to a temperature 50°F to 100°F (30°C to 60°C) below the solidus temperature of the brazing filler metal until the entire assembly has reached this temperature. The assembly shall then be removed from the preheat furnace and immediately lowered into the molten flux bath at a uniform rate such that the positioning of the parts and filler metal is not disturbed. The temperature of the bath shall not exceed the solidus of the base metal. Assemblies shall remain in the bath until melting and flow of the filler is complete. Removal shall be at a uniform rate such that neither the components nor filler metal are disturbed before solidification is complete. Assemblies shall be hung over the bath until all draining of flux has ceased. Assemblies shall be cooled in a suitable manner to prevent cracking, reduce residual stresses, and accomplish any post braze heat treatment required by the engineering drawing. Procedures shall be qualified and documented per 4.5.

4.4.10 Flux Removal. All residual fluxes shall be removed by suitable means after brazing until the requirements of 5.4.3.4 are met.

4.4.11 Procedure for Aluminum Fluxless Brazing. Assemblies cleaned and assembled to the requirements of this specification shall be vacuum brazed to a cycle as required by the engineering drawing or documents referenced by it, or to a procedure qualified and documented in accordance with 4.5.

4.4.12 Torch Brazing. Torch brazing is normally controlled by visual indicators related to process variables. Since these indicators are developed through experience related to outcome as opposed to specific measured values, torch brazing has been excluded from the sections of this specification on process description and control. The balance of the specification beginning with paragraph 4.4.6 may be applied.

4.5 Brazing Procedure Qualification. Brazing procedures, equipment, and operators shall be qualified in accordance with AWS B2.2, *Standard for Brazing Procedure and Performance Qualification*, 4.2 and 5.4.1, or as required by the Organization Having Quality Responsibility. Such qualifications shall be documented and approved in writing. Modification of such procedures requires written approval of the Organization Having Quality Responsibility before use.

4.6 Safety and Health. Brazing fluxes, filler metals, filler metal binders, furnace atmospheres, molten flux baths and other components of aluminum brazing processes may be toxic or hazardous, or both. It is mandatory that all aluminum brazing operations be conducted so that all relevant federal, state, and local government safety and health requirements are met. Refer to ANSI Z49.1, *Safety in Welding and Cutting*, for further information.

5. Quality Assurance Provision

5.1 Responsibility for Inspection. Unless otherwise specified in the contract or purchase order, the organization performing a brazing operation is responsible for the performance of all inspections of the product of that brazing operation. This requirement includes a system of quality control and documentation which assures, and can prove, that all required operations and procedures were done. Suppliers may use their own facilities or any other facility acceptable to the Organization Having Quality Responsibility for the final product. However, the Organization Having Quality Responsibility shall retain the right to perform or witness the required tests, or to perform any other tests necessary to assure that the brazed assemblies conform to the requirements of this specification and of the engineering drawing.

5.2 Responsibility for Compliance. All products must meet all requirements of this specification except where deviation is specifically approved, in writing, by the Organization Having Quality Responsibility or is part of the engineering drawing. The inspections required shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in this specification shall not relieve a contractor of the responsibility of ensuring that all products or supplies which are produced under this

specification meet all contractual obligations. The use of inspection sampling systems (see 5.4.4) does not authorize the shipment of known defective material, nor does it obligate any person or organization to accept defective material.

5.3 Sequence of Inspection and Manufacturing Operations. Brazed joints may be inspected at the assembly or subassembly level, provided the entire joint is accessible for inspection. Parts requiring postbrazing heat treatment shall be inspected after heat treatment has been completed unless otherwise specified on the engineering drawing. When brazed joints are inspected in process, prior to machining of joint edges, reinspection shall be required after machining to assure that the brazed joint has not been damaged in the machining operations. Final flux residue testing per 5.4.3.4 shall be performed after all machining operations of the brazed joint have been completed.

5.4 Required Inspections of Brazed Joints

5.4.1 Metallurgical inspection for excessive magnesium/silicon diffusion into base metals shall be performed as part of the process qualification procedure for all brazed aluminum joints. A microsection through the joint shall be prepared and etched by suitable means, and examined at magnification of 100X. Evidence of intergranular attack or excessive grain growth further than 0.006 in. (0.15 mm) into the base metal shall be unacceptable. The brazing procedure shall be modified, as required, to eliminate the attack. Assemblies brazed in accordance with the modified procedure shall be inspected to and shall meet the requirements of this paragraph. This test shall be repeated periodically if so specified by the Organization Having Quality Responsibility.

5.4.2 All Brazed Joints. All brazed joints shall be visually inspected to the acceptance criteria specified in 5.5.

5.4.3 Class A and Class B Brazed Joints. Class A and Class B brazed joints shall be either radiographically or ultrasonically inspected to determine the area of the joint surfaces actually brazed and to detect internal defects unless the requirements of 5.4.3.3 are met. Choice of process is optional, except for the criteria given in 5.4.3.1 and 5.4.3.2. However, ultrasonic inspection generally is the preferred process for inspecting brazed joints. Acceptance criteria shall be as specified in 5.5.

5.4.3.1 Radiographic inspection shall be performed in accordance with MIL-STD-453, *Radiographic Inspection*. Brazed joints shall be radiographically inspected only when the following configuration and process requirements are met. Ultrasonic inspection shall be required when any one of these criteria are not met except as specified in 5.4.3.3:

(1) The clearance between the joint surfaces at assembly must be 4%, or more, of the total thickness of the base metals at the joint.

(2) The configuration of the assembly must permit proper film placement.

5.4.3.2 Ultrasonic inspection shall be performed in accordance with the latest edition of ANSI/AWS C3.8, *Recommended Practices for Ultrasonic Inspection of Brazed Joints*. Ultrasonic inspection shall be performed only when the following configuration and process criteria are met. Radiographic inspection shall be required when any of these criteria are not met except as specified in 5.4.3.3.

(1) The surface through which the sonic pulse enters the material shall be parallel to the joint faces, and the part must be processed so that all filler metal runover is removed prior to ultrasonic inspection.

(2) A suitable ultrasonic reference standard shall be available. It shall be identical to the assemblies it represents as to joint configuration, joint clearance, and filler material. The reference standard shall have defects of known size and location suitable for calibrating the ultrasonic apparatus.

(3) The ultrasonic apparatus shall produce a joint facsimile suitable for making quantitative measurements of the percentage of the brazed joint actually bonded and for documenting the testing of the assembly.

5.4.3.3 Certain specialized brazed components may not be inspectable by radiographic or ultrasonic techniques. In such cases, alternate inspection techniques and acceptance limits shall be as specified in writing by the Organization Having Quality Responsibility. That organization is responsible for the suitability of the final product for service and the suitability of the brazed joints. If no such inspection techniques or limits have been specified in writing, all requirements of this specification shall be met.

5.4.3.4 Flux Removal Test. All aluminum components brazed using flux shall be tested for

flux and flux residues after flux removal. This test shall consist of rinsing the assembly with deionized or distilled water such that all areas of the component are flushed and collecting a representative sample of this rinse water. Five percent by weight aqueous solution of silver nitrate equal to one percent of the total volume of the sample shall then be added to it in a suitable clean glass container. Any evidence of a precipitate shall be cause for rejection. Other test methods may be used as alternates with the written approval of the Organization Having Quality Responsibility if they are shown to be capable of dependably detecting chloride ion concentrations five parts per million, or less. Any assemblies so tested and rejected shall be recleaned by suitable means to remove the flux and flux residues, retested, and must meet the requirements of this paragraph prior to acceptance.

5.4.4 Sample Inspection Plans

5.4.4.1 Class C Joints. Class C joints may be inspected using sample plans in accordance with MIL-STD-105, *Sampling Procedures and Tables for Inspection of Attributes*.

5.4.4.2 Class B Joints. Class B joints shall be inspected using a sample plan in accordance with MIL-STD-105 only with the written permission of the Organization Having Quality Responsibility and if all of the following criteria are met.

(1) Sampling techniques are based upon the assumption all of the products in a given batch or lot are identical. In most cases, each lot will be a single furnace load or a single shift's or less, production of a molten flux bath made from identical detail parts identically processed.

(2) Proof of such identical processing, therefore, is a precondition for approval of sample inspection plans. Such proof shall be presented in writing to the Organization Having Quality Responsibility prior to the use of such sample plans.

5.4.4.3 Class A Joints. Class A joints require inspection of every unit. No sample plans shall be used.

5.4.4.4 Lot Size and Sampling. A random sample shall be selected from each inspection lot in accordance with MIL-STD-105, AQL of 2. 5% defects and inspected in accordance with this specification. Lot sizes for purposes of sampling shall consist of all brazed parts of the same design or

kind manufactured by the same process from identical details, identically prepared during one continuous period, and submitted for acceptance at the same time.

5.4.5 Additional Nondestructive Tests

5.4.5.1 Fluorescent or dye penetrant inspection techniques in accordance with MIL-STD-6866, *Penetrant Inspection*, should be used only on assemblies on which the brazed joint has been subjected to machining stresses to determine if the joint has not been cracked by those stresses. Penetrant inspection is not suitable for inspecting braze joint fillets.

5.4.5.2 Additional nondestructive tests may be required by the Organization Having Quality Responsibility at its discretion. In such cases, the minimum limits for acceptance shall be clearly defined in writing by that organization.

5.4.5.3 Destructive test of assemblies or samples shall be performed as required for process qualification or corrective action. Destructive testing of samples or sample parts shall not be substituted for any nondestructive tests required by this specification except as part of an approved sampling plan in accordance with the requirements of this specification or as part of an inspection procedure complying with 5.4.3.3.

5.5 Acceptance Criteria. Unless otherwise specified by the engineering drawing, or a document referenced by it, the following are the minimum acceptance criteria for inspection of aluminum brazed joints. Any assembly failing to meet these minimum requirements shall be rejected.

5.5.1 Surface Defects

5.5.1.1 Porosity open to the surface shall be confined to the fillet and shall not penetrate into the brazed joint proper (see section 6, Definitions).

5.5.1.2 Cracks are unacceptable.

5.5.1.3 Evidence of braze filler attack of the base metal (e.g., undercutting or erosion) is unacceptable if it has penetrated into the base metal more than 5% of its thickness on Class A joints and 15% for Class B and Class C joints.

5.5.1.4 Failure of the filler metal to melt completely is unacceptable. However, filler residue is acceptable on assemblies brazed by a fluxless process as long as evidence of filler metal flow is visible.

5.5.1.5 Voids which are continuous across the joint between two opposite joint edges are unacceptable.

5.5.1.6 If the edge of the joint opposite that to which filler metal is applied is visible after brazing, filler metal shall be present at that edge of the joint, at least locally. Lack of such evidence of braze filler metal penetration is unacceptable. When the assembly configuration makes inspection of the edge opposite that to which filler metal was applied impossible, this requirement shall not apply.

5.5.1.7 Evidence of flux or flux residue is unacceptable (see 5.4.3.4).

5.5.1.8 Quality of workmanship shall be such that the assemblies are suitable for the intended purpose and that surfaces are free of excess braze filler material which could interfere with later operations or the function of the product.

5.5.2 Internal Defects

5.5.2.1 Radiographic film or ultrasonic facsimiles of Class A joints shall show the total measured unbrazed or unbonded area of the joint does not exceed 20% of the total joint area. The width of the largest void or unbonded area shall not exceed 60% of the width total joint. No area of void or unbond which is 40% of the width of the joint in width or larger shall extend closer to the edge of the joint than 20% of the joint width.

5.5.2.2 Radiographic film or ultrasonic facsimiles of Class B joints shall show the total measured unbrazed or unbonded area of the joint does not exceed 30% of the total joint area. The width of the largest void or unbonded area shall not exceed 70% of the total joint width. No such area which is 60% of the width, or larger, shall extend closer to the joint edge than 15% of the joint width.

5.6 Rework

5.6.1 Joints brazed with flux may be reworked by rebrazing by the original, qualified procedure (see 4.5), using the same filler metal, twice without

the specific, written approval of the Organization Having Quality Responsibility, unless otherwise specified by that organization. If, after having been rebrazed twice and inspected to the requirements of 5.4 and 5.5, the assembly is still not acceptable, or if a brazing process or filler metal other than that specified by the qualified procedure is to be used, or if disassembly of the brazed assembly is required, written prior approval of the procedures to be used shall be obtained from the Organization Having Quality Responsibility.

5.6.2 Rebrazing of rejected joints brazed by fluxless processes shall only be done with the prior written approval of the Organization Having Quality Responsibility and with a rebrazing procedure qualified to the requirements of 4.5.

6. Definitions

Braze Joint. The total area, as defined by the engineering drawing, of the faying surfaces to be joined by brazing and the fillets which form at the edges of that area.

Braze Joint Proper. The total area, as defined by the engineering drawing, of the faying surfaces to be joined by brazing, excluding any fillets which form at the edges of that area.

Braze Symbol. The symbol on the engineering drawing designating the location, class, and configuration of the brazed joint. Such symbols shall be in accordance with the latest edition of ANSI/AWS A2.4, *Standard Symbols for Welding, Brazing and Nondestructive Examination*.

Braze Wetting. Filler metal should be smooth, adherent, and exhibiting no evidence of repulsion of the filler metal by the base metal surface.

Lack of Bond or Unbond. A condition in a brazed joint where filler metal is present between the joint faces, but does not adhere or form a metallurgical bond with the base metal. It most commonly occurs when filler metal is preplaced between contaminated joint faces. In many cases, it is only nondestructively detectable by ultrasonic inspection.

Organization Having Quality Responsibility. The organization responsible to the ultimate user of the product for the quality of the product and its suit-

ability for the intended use. This will usually be the manufacturer and marketer of the final product in commercial business and the prime contractor in government procurement. Although such organizations may subcontract brazing and related operations to others, they cannot delegate the ultimate responsibility for the service suitability of the product of those or any other operations.

Surface Porosity. A roughened or spongy appearance, or open pore on the surface of the braze fillet. Such pores are not sharply linear or cracklike in shape. It is confined to the surface of the fillet and does not progress into the braze joint proper.

Void. An area of a braze joint proper which is not completely filled with filler metal.

AWS Brazing and Soldering Documents

AWS Designation	Title
BRH	Brazing Handbook
SM	Soldering Manual
A2.4	Standard Symbols for Welding, Brazing, and Nondestructive Testing
B2.2	Standard for Brazing Procedure and Performance Qualification
C3.2	Standard Method for Evaluating the Strength of Brazed Joints in Shear
C3.3	Recommended Practices for Design, Manufacture, and Inspection of Critical Brazed Components
C3.4	Specification for Torch Brazing
C3.5	Specification for Induction Brazing
C3.6	Specification for Furnace Brazing
C3.7	Specification for Aluminum Brazing
C3.8	Recommended Practices for Ultrasonic Inspection

For additional information, contact the Order Department, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.