

AWS-C3.4

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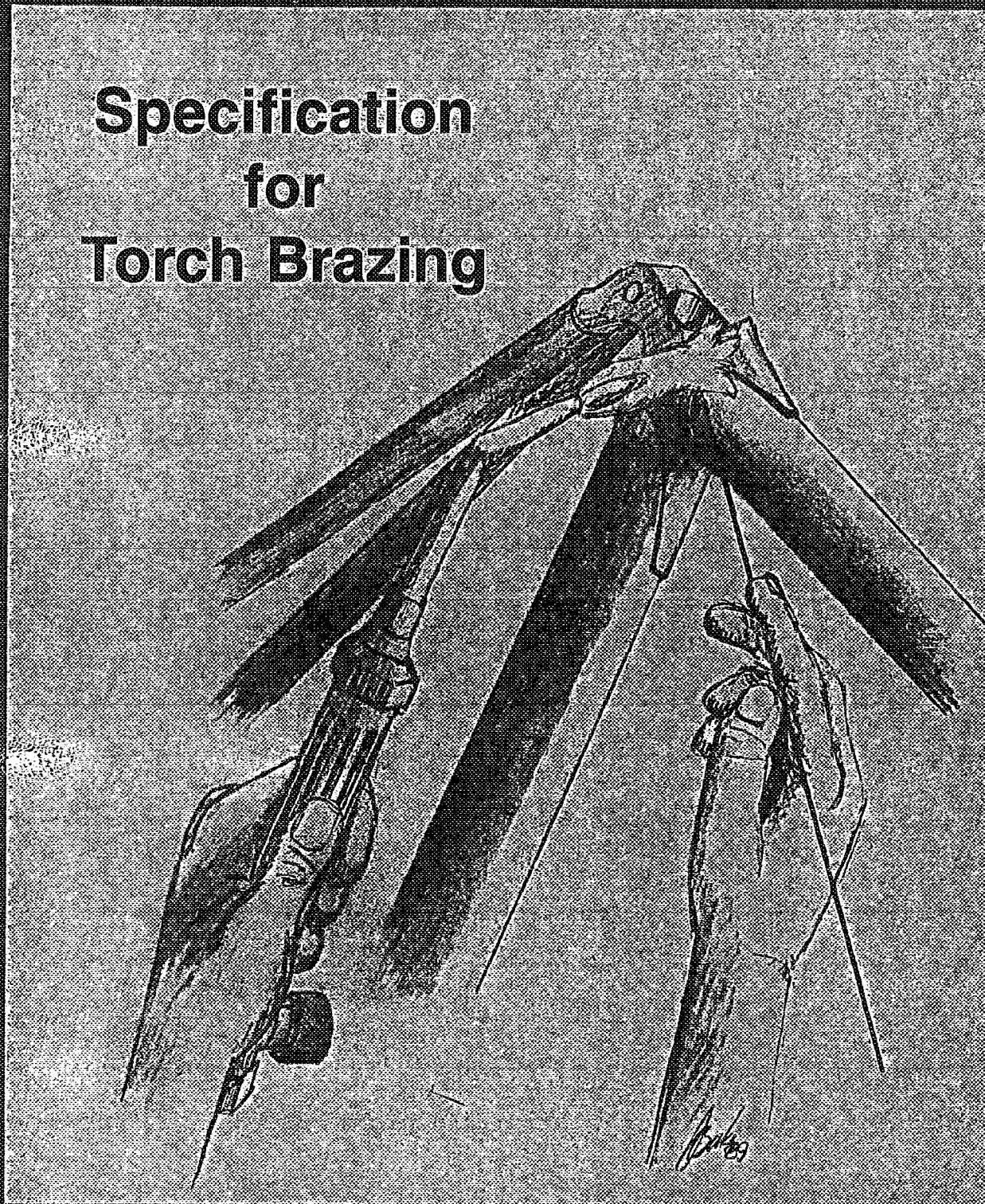
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An American National Standard

Specification for Torch Brazing



American Welding Society

Keywords—Torch brazing, quality control, inspection, brazing materials, brazing equipment, classification, defects, nondestructive testing, procedure

ANSI/AWS C3.4-90
An American National Standard

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March 16, 1990

Specification for Torch 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 provides minimum fabrication, equipment, material, process procedure requirements, and defect limits for the torch brazing of steels, copper, copper alloys, and heat and corrosion resistant alloys. It provides criteria for classifying torch 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 torch brazing equipment, materials, and procedures, as well as the required inspection for each class of joint.



American Welding Society

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Foreword

(This Foreword is not a part of ANSI/AWS C3.4-90, *Specification for Torch 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 such processes had proliferated, and the technology had become more complex. Attempting to cover all of 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 on 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. The survey showed that the four individual categories would cover the vast majority of brazing done in the United States today. An additional document, which will be the fifth in the series, is the *Recommended Practices for Ultrasonic Inspection of Brazed Joints*. In the preparation of the first 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 Technical Director, American Welding Society. A formal reply will be issued after the request has been reviewed by appropriate personnel following established procedures.

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Specification for Torch Brazing

1. Scope

This specification presents minimum fabrication and quality requirements for torch brazing steels, stainless steels, copper, copper alloys, and heat and corrosion resistant metals. Its purpose is to standardize torch 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 modifications.

2. Classification of Brazed Joints

2.1 Method of Classification. Torch brazed joints are classified in this specification based on two criteria: the designed loads they must carry and the consequences of their failure. It is the responsibility of the Organization Having Quality Responsibility (see section 6, Definitions) to evaluate both of these factors and assign the proper classification. This classification controls which inspection methods and limits are required. However, all joints, regardless of class, are expected to be manufactured by the most suitable methods to provide the required quality.

2.2 Class A Joints. Class A joints are those joints 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 joints 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 joints 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 (see section 6, Definitions), Class A requirements shall apply. However, because of the confusion which can result, all engineering drawings referencing this specification should state the class of the brazed joint in the braze joint symbol. Symbols shall be in accordance with the latest edition of ANSI/AWS A2.4, *Symbols for Welding, Brazing, and Nondestructive Examination*.¹

3. Applicable Documents

The following documents form a part of this specification, as referenced by this specification. Unless otherwise specified by the Organization Having

1. AWS standards may be obtained from the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

Quality Responsibility, the revision of these documents in force at the time a contract or purchase order is issued shall be used.

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

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

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

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

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

(6) ANSI/ASC Z49.1, *Safety in Welding and Cutting*²

(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 Equipment. In torch brazing, heat is produced by a controlled fuel gas flame. The fuel gas; e.g., acetylene, propane natural gas, may be combusted with air, compressed air, or oxygen. The specific combination selected is dependent on the amount of heat required to bring the particular components to the brazing temperature in the required time. Equipment shall be suitable in design and construction for the particular application, in good working condition, and adequately maintained to assure continuing compliance with this specification. It shall be capable of producing a neutral or reducing flame and shall produce uniform heating of the components being brazed. Manual, semi-automatic, or fully automatic equipment may be used depending on the particular application. In automatic systems, multiple heat stations may be used to progressively raise the part temperature.

4.1.1 Flux Application Equipment. Flux application equipment shall be suitable for the intended purpose and shall be in good working order. It shall keep

the flux mixture homogenous, maintain consistency, and apply the flux to the proper locations in the required amounts.

4.1.2 Fixtures. Fixtures, if used, shall be designed and made so that they do not adhere to the parts being joined or otherwise interfere with the brazing process. Fixtures shall support the assembly during the entire cycle, have thermal expansion characteristics suitable for the application, and shall maintain the components being brazed in the proper dimensional relationships as specified by the engineering drawing.

4.2 Materials

4.2.1 Filler Metals. The filler metal to be used shall be specified on the engineering drawing, or accompanying documents, and shall meet the requirements of ANSI/AWS A5.8, *Specification for Filler Metals for Brazing*, unless otherwise specified by the engineering drawing or accompanying documents. (There are filler metal/base metal combinations that can cause severe service problems under certain circumstances; e.g., nickel base alloys brazed with silver bearing filler metals and iron base alloys brazed with silver or copper base filler metals containing high phosphorous. Care should therefore be used to assure that the filler metal selected is metallurgically compatible with the base metal.)

4.2.2 Fluxes. Fluxes shall be compatible with the base and filler metals specified by the engineering drawing. Acceptable flux, or fluxes, shall be defined by the qualified torch brazing procedure (see 4.4). Fluxes shall remove oxides and prevent their reformation during the brazing operation. They shall promote the flow of the molten filler metal and its wetting onto the base metal surfaces of the joint.

4.2.3 Cleaning Materials. Cleaning materials shall leave no residue which will interfere with the wetting or flow of the filler metal. For example, aluminum oxide, silica, or zirconia blast cleaning media shall not be used on components to be brazed. Chemical cleaning solutions which are detrimental to the base metal shall not be used.

4.3 Procedure Requirements

4.3.1 Cleaning. The mating joint surfaces and adjacent areas of components to be brazed shall be free of oil, grease, paint, oxides, dirt, scale, or any

2. May be obtained from the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

3. MIL-STD documents may be obtained from the Naval Publications and Forms Ctr., 5801 Tabor Ave., Philadelphia, Pennsylvania 19120 [Phone 215-697-3321].

foreign substances that can interfere with the brazing process or contaminate the brazed joint. Burrs shall be removed as required to permit proper assembly and filler metal flow.

4.3.2 Joint Clearance. Joint clearance between mating surfaces to be torch brazed shall be 0.001 to 0.004 in. (0.025 to 0.100 mm) at room temperature or as required to provide this clearance at the brazing temperature or in the case of dissimilar metals; unless otherwise specified on the engineering drawing.

4.3.3 Accessibility. Joints to be torch brazed in place shall be accessible for proper preparation, assembly, heating, flux and filler application, cooling, flux removal, and for the proper performance of all required inspections. Inaccessibility is not grounds for the waiver of any requirement of the engineering drawing or of this specification.

4.3.4 Application of Filler Metal. Filler metal may be applied to the joint prior to brazing in the form of paste or preformed shapes, or added during brazing as wire or rod. Filler metals shall be so placed or applied as to be drawn onto the joint surfaces by capillary action during brazing. Preplacement of filler metal between the joint surfaces of Class A or Class B joints shall only be permitted where ultrasonic inspection is used to assure proper bonding of the joint as specified. Filler metal quantity shall be sufficient to yield satisfactory joints without build-up on the adjacent surfaces which might interfere with part function.

4.3.5 Application of Flux. Flux shall be applied in the form of paste, powder, liquid, vapor, slurry, or as coating on filler metal wire or rod. Quantity and location of flux shall be such as to yield a satisfactory brazed joint and adequately protect adjacent areas from oxidation.

4.3.6 Application of Stop Off. Braze stop off materials shall be applied in the quantities and locations necessary to control filler metal flow as required to meet the engineering drawing. It shall be applied so as to avoid contamination of either the braze joint surfaces or preplaced filler metal.

4.3.7 Brazing Cycle. Parts shall be heated to bring the joint uniformly to the brazing temperature. Overheating shall be avoided. The heating and the application of the filler metal shall cause it to flow toward the hottest area of the joint. The flux shall not be

removed from the assembly by the force of the flame. The assembly shall be heated so that it is held at the brazing temperature for the minimum time needed to produce a satisfactory joint and avoid adverse metallurgical effects. After brazing, the assembly shall be cooled so that cracking of the filler or base metals does not occur, and residual stresses are minimized.

4.3.8 Safety and Health. Torch brazing fluxes and filler materials, particularly those containing cadmium, give off hazardous fumes during the brazing cycle. It is mandatory that torch brazing operations be properly and adequately ventilated or that operators be provided with adequate breathing apparatus, or both, as required to assure that all relevant federal, state, and local government safety and health requirements are met. In addition, there are other hazards involved in torch brazing, such as those relating to the use of corrosive fluxes and potentially explosive gases. Refer to ANSI Z49.1, *Safety in Welding and Cutting*, for information on these and other safety and health problems which must be controlled during torch brazing.

4.3.9 Post Brazing Operations. Post braze heat treatments shall be performed as required by the engineering drawing. Residual flux, salts, and stop off shall be removed by suitable means. No post braze cleaning or passivation treatments (e.g., nitric acid passivation of silver or copper brazed assemblies), which will dissolve filler metal or result in any adverse effects to the base or filler metals shall be used.

4.4 Qualification. Brazing procedures, equipment, and operators shall be qualified in accordance with the latest edition of ANSI/AWS B2.2, *Brazing Procedure and Performance Qualification*, or as required by the Organization Having Quality Responsibility. Such qualification shall be documented and approved in writing by the Organization Having Quality Responsibility. Modification of such procedures requires written approval by the Organization Having Quality Responsibility prior to use.

5. Quality Assurance Provisions

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 that all required operations and procedures were completed, and which documents the results of all inspection operations. 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 the engineering drawing.

5.2 Responsibility for Compliance. All products shall 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 assuring that all products or supplies which the contractor produces under this specification meet all contractual obligations. The use of inspection sampling systems (see 5.4.2) 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. Torch brazed joints may be inspected at the assembly or subassembly level, provided the entire joint is accessible for inspection. Parts requiring post braze 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.

5.4 Required Inspections of Brazed Joints. All brazed joints shall be visually inspected to the acceptance criteria given in 5.5. Class C joints require visual inspection only.

5.4.1 Class A and Class B Brazed Joints. Class A and Class B brazed joints, except as specified in 5.4.1.3 and 5.4.1.4, shall be either radiographically or ultrasonically inspected to determine the area of the joint surfaces actually brazed and to detect internal defects. Choice of process is optional, except for

the criteria given in 5.4.1.1 and 5.4.1.2. Acceptance criteria shall be as specified in 5.5, unless otherwise specified on the engineering drawing.

5.4.1.1 Radiographic inspection shall be performed in accordance with MIL-STD-453. Brazed joints shall only be radiographically inspected when the following configuration and process requirements are met:

(1) The clearance between the joint surfaces at assembly must be 2% or more of the total thickness of the base metals at the joint.

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

(3) All filler metal shall have entered the joint proper by capillary action during the braze cycle; i.e., no filler metal was preplaced between the joint faces prior to the brazing heat cycle. This does not preclude the preplacement of filler metal adjacent to the joint faces or in slots machined adjacent to the joint proper.

Ultrasonic inspection shall be required if one or more of these requirements are not met.

5.4.1.2 Ultrasonic inspection shall be performed in accordance with ANSI/AWS C3.8, *Recommended Practice for Ultrasonic Inspection of Brazed Joints*. Ultrasonic inspection shall only be performed when the following configuration and process criteria are met:

(1) The surface through which the sonic pulse enters the material shall be parallel to the joint surfaces, and the part must be processed so that filler metal runover onto this surface 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 the joint configuration, base metal(s) joint clearance, and filler material. It shall have defects of known size and location suitable for calibrating the ultrasonic apparatus.

(3) Ultrasonic facsimiles may be required at the discretion of the Organization Having Quality Responsibility.

Radiographic inspection shall be required when one or more of these requirements are not met.

5.4.1.3 Leak and pressure testing of Class A and B tube and pipe joints to the following requirements may be substituted for radiographic and ultrasonic inspection of Class A and Class B sleeve type joints in tube or pipe assemblies 1 in. (25.4 mm) or

less in outer diameter if approved in writing by the Organization Having Quality Responsibility.

(1) Class A joints shall be air pressure tested at an internal pressure and by procedures specified in writing by the Organization Having Quality Responsibility. They shall then be helium leak tested, and leakage of not more than 3.0×10^{-5} cc/second shall be detected with a suitable mass spectrograph leak detector in good working condition calibrated as specified by the manufacturer.

(2) Class B joints shall be air pressure tested at an internal pressure and by procedures specified in writing by the Organization Having Quality Responsibility. No leakage shall be allowed.

(3) Internal pressure test fixtures and devices shall be suitable for the intended purpose and shall be adequately shielded to prevent injury to persons in the case of catastrophic failure during pressure testing.

5.4.1.4 Certain specialized brazed components may not be inspectable by radiographic or ultrasonic techniques and may be unsuitable for leak or pressure testing in accordance with 5.4.1.3.

In such cases, specialized inspection techniques and acceptance limits shall be as specified in writing by the Organization Having Quality Responsibility. That organization is responsible for the suitability for service of the final product and of the selected inspection techniques to verify the suitability of the brazed joints. If no such special inspection techniques and acceptance limits have been specified in writing, all requirements of this specification shall be met.

5.4.2 Sample Inspection Plans

5.4.2.1 Class C joints may be inspected using sample plans in accordance with MIL-STD-105, Inspection Level II, AQL 2.5, using single sample plan for normal inspection.

5.4.2.2 Class B joints may be inspected using a sample plan in accordance with MIL-STD-105, as in 5.4.2.1, only with the written permission of the Organization Having Quality Responsibility and if both of the following criteria are met:

(1) Sampling techniques are based upon the assumption that all of the products in a given batch or lot are identical; i.e., represent one population. Proof must therefore be provided that the entire process, including the preprocessing of the components from which the assemblies were made, was controlled and that all assemblies within one lot are from one

identically processed population. Such proof shall be presented in writing to the Organization Having Quality Responsibility as a precondition to the granting of permission for sample testing; otherwise the use of sampling techniques shall not be approved, and 100% inspection is required.

(2) No operation critical to the quality of the brazed joint shall be directly dependent upon the skill or care of an operator, except when a written record of the actual process variables controlled by the operator is automatically produced, i.e., sample inspection of Class B manual torch brazes is prohibited unless temperature monitoring and recording equipment is used to assure that all parts are processed identically, and the recordings produced are a part of the quality records of each part lot.

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

5.4.2.4 Lot Size and Sampling. When applicable, (see 5.4.2.1 and 5.4.2.2) a random sample shall be selected from each inspection lot in accordance with MIL-STD-105, AQL of 2.5%, 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 similar details, prepared by the same procedures during one continuous period and submitted for acceptance at the same time.

5.4.3 Additional Nondestructive Tests

5.4.3.1 Fluorescent or dye penetrant inspection techniques in accordance with MIL-STD-6866 should only be used on assemblies where the brazed joint has been subjected to machining stresses to assure that the joint has not been damaged in machining. These inspection techniques are not suitable for the inspection of braze fillets because they routinely give false positive results.

5.4.3.2 Additional nondestructive tests may be specified by the Organization Having Quality Responsibility at its discretion.

5.4.3.3 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 inspection procedure complying with 5.4.1.4.

5.5 Acceptance Criteria. Unless otherwise specified by the engineering drawing or document referenced by it, the following are the minimum acceptance criteria for inspection of brazed joints. Any assembly failing to meet these minimum requirements shall be rejected. (See section 6, Definitions)

5.5.1 Surface Defects

5.5.1.1 Porosity open to the surface is acceptable if it is confined to the fillet and shall not penetrate into the brazed joint proper (see Section 6, Definitions). For limits of porosity penetrating the braze joint, see 5.5.2.

5.5.1.2 Cracks or crack-like indications are unacceptable.

5.5.1.3 Evidence of braze filler attack of the base metal is unacceptable, if it has penetrated into the base metal more than 10% of the total thickness of the thinnest component of the brazed joint.

5.5.1.4 Failure of the filler metal to melt completely is unacceptable.

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

5.5.1.6 Evidence of braze filler penetration through the joint is required; i.e., filler metal shall be present at all edges of the joint. Lack of such evidence of braze filler metal penetration is unacceptable. This requirement shall not apply in cases where the edge of the joint opposite the edge to which filler material is applied is not accessible for inspection, due to the configuration of the assembly.

5.5.1.7 Evidence of flux or flux residue, is unacceptable.

5.5.2 Internal Defects

5.5.2.1 Class A Joints. Radiographic film or ultrasonic facsimiles of Class A joints shall show the total measured void, or unbonded area, of the joint does not exceed 15% of the total joint area. The width of the largest void or unbonded area shall not exceed 60% of the total joint width. No such area which is wider than 40% of the width of the joint, or larger, shall extend closer to the edge of the joint than 20% of the joint width.

5.5.2.2 Class B Joints. Radiographic film or ultrasonic facsimiles of Class B joints shall show that the total measured void, or unbonded area, of the joint does not exceed 25% 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 wider than 60% of the width of the joint, or larger, shall extend closer to the joint edge than 15% of the joint width.

5.6 Rework. Brazed joints may be reworked by rebrazing by the original, qualified procedure 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, the assembly still is not acceptable, or if a brazing process or filler metal other than that approved by the qualified procedure is to be used, or if disassembly of the brazed assembly is required, prior written approval of the procedures to be used shall be obtained from the Organization Having Quality Responsibility. If it is necessary to change the brazing process or filler metal to accomplish the rework, the new procedure shall be qualified as specified in 4.4.

6. Definitions

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

Braze Symbol. This is 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, *Symbols for Welding, Brazing, and Nondestructive Examination*.

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.

Void. Any area of the braze joint proper which is not completely filled with filler material.

Lack of Bond or Unbond. A condition in a brazed joint where although filler metal is present between the joint faces, the filler metal 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.

Surface Porosity. A roughened or spongy appear-

ance or open pores on the surface of the braze fillet. Such pores are not sharply linear or crack-like in shape. It is confined to the fillet and does not progress into the braze joint proper.

Braze Wetting. A properly wetted braze joint has a filler metal deposit which is smooth, adherent, and has no evidence of repulsion of the filler metal by the base metal surface.

Joint Dimensions. The joint length is the greater of the two dimensions of the joint parallel to the joint surfaces. The joint width is the lesser of these two dimensions of the joint. Clearance between the joint faces is the third dimension to be considered.

AWS Brazing and Soldering Documents

Designation	Title
BRM	Brazing Manual
SM	Soldering Manual
0 08	Soldering in Electronics—Second Edition by R. J. Klein-Wassink
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 (Available July 1990)
C3.8	Recommended Practices for Ultrasonic Inspection

For additional information contact the Order Department, The American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135, Phone (305) 443-9353.