

AWS C3.5:1999
An American National Standard



Specification for Induction Brazing



American Welding Society



Key Words— Induction brazing, quality control inspection of brazed joints, brazing materials, brazing equipment, classification of brazed joints, brazed joint defects, nondestructive testing, induction brazing procedure

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Specification for Induction Brazing

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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 inspection requirements for the induction brazing of steels, copper, copper alloys, and heat and corrosion resistant alloys and other materials that can be adequately induction brazed. For the brazing of aluminum alloys refer to AWS C3.7, *Specification for Aluminum Brazing*. This specification provides criteria for classifying induction 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 induction brazing equipment, materials, and procedures, as well as the required inspection for each class of joint.



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Foreword

(This Foreword is not a part of AWS C3.5:1999, *Specification for Induction Brazing*, but is included for information purposes only).

This specification is one of a series prepared at the request of the Aerospace Industries 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 in the same format. They are AWS C3.4, *Specification for Torch Brazing*, AWS C3.5, *Specification for Induction Brazing*, and AWS C3.6, *Specification for Furnace Brazing*. Torch, induction and furnace brazing of aluminum alloys are covered in AWS C3.7, *Specification for 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 committee is currently working to complete a specification on resistance brazing.

The survey showed that these categories would cover the vast majority of brazing done in the United States today. An additional document is ANSI/AWS C3.8, *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, Committee on Brazing and Soldering, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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, 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 Induction Brazing

1. Scope

This specification presents minimum fabrication and quality requirements for induction brazing material such as steels, stainless steels, copper, copper alloys, and heat or corrosion-resistant materials and other materials that can be adequately induction brazed. For the brazing of aluminum alloys refer to AWS C3.7, *Specification for Aluminum Brazing*. The purpose of this specification is to standardize induction 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 a 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. Units are rationalized conversions from U.S. Customary Units to SI Units and may be used interchangeably.

2. Applicable Documents

The following documents form 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) ANSI/AWS A2.4, *Symbols for Welding, Brazing, and Nondestructive Examination*
- (2) ANSI/AWS A3.0, *Standard Welding Terms and Definitions*
- (3) ANSI/AWS A5.8, *Specification for Filler Metals for Brazing and Braze Welding*

- (4) ANSI/AWS A5.31, *Specification for Fluxes for Brazing and Braze Welding*
- (5) ANSI/AWS B2.2, *Brazing Procedure and Performance Qualification*
- (6) ANSI/AWS C3.8, *Recommended Practices for Ultrasonic Inspection of Brazed Joints*
- (7) AWS *Brazing Handbook*
- (8) ANSI/ASQC Z1.4, *Sampling Procedures and Tables for Inspection by Attributes*
- (9) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (10) AMS 2403, *Plating, General Purpose*
- (11) AMS 2404, *Plating, Electroless Nickel*
- (12) AMS 2424, *Plating, Nickel, Low Stressed Deposit*
- (13) ASTM E 1742, *Standard Practice for Radiographic Examination*
- (14) ASTM E 1417, *Standard Practice for Liquid Penetrant Examination*
- (15) ANSI/NCSS Z540-1, *General Requirements for Calibration Laboratories and Measuring and Test Equipment*

Document Sources:

American Welding Society (AWS), 550 N.W. LeJeune Road, Miami, FL 33126

American Society for Quality (ASQ), 611 East Wisconsin Avenue, Milwaukee, WI 53201

American Society for Testing and Materials (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959

National Conference of Standards Laboratories, 1800 30th Street; Suite 305B, Boulder, CO 80301

Society of Automotive Engineers (SAE), 400 Commonwealth Drive, Warrendale, PA 15096-0001

3. Classification of Brazed Joints

3.1 Method of Classification. Induction brazed joints are classified in this specification based on two criteria: the design requirements and the consequences of their failure. It is the responsibility of the Organization Having Quality Responsibility to evaluate these or other factors and assign the proper classification. This classification controls which inspection methods and limits are required.

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

3.3 Class B Joints. Class B joints are those joints subjected to low or moderate stresses, cyclic stresses or both, the failure of which could result in significant risk to persons or property, or could result in a significant operational failure.

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

3.5 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 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 ANSI/AWS A2.4, *Symbols for Welding, Brazing, and Nondestructive Examination*.

4. Process Requirements

4.1 Process Description. In induction brazing, the joint area is heated directly or indirectly (using susceptors) by the electromagnetic field set up around a copper conductor through which an alternating electric current is passed. Induction brazing is capable of rapidly heating localized joint areas to the brazing temperature.

4.2 Equipment

4.2.1 Coils. Coils shall be so designed and constructed as to be suitable for the particular part configurations to be joined and to be compatible with the induction generator and output transformer used. Their design shall be such as to concentrate the heat at the joint area without unnecessary heating of adjacent areas. Coil design shall take into account any important configuration considerations such as corners or irregular shapes so the heating of the entire joint area shall be in accordance with the Brazing Procedure Specification.

4.2.2 Induction Generators. Induction generators and associated equipment shall be in good operating condition and suitable for the particular application in both output frequency and capacity. They shall have suitable controls to produce repeatable, controlled heating of the components being brazed.

4.2.3 Temperature Sensing and Control Devices. Temperature sensing and control devices shall be in good working order and suitable for the particular application. Automatic systems used for the brazing of Class A and Class B joints shall be calibrated by the use of a simulated part with suitable optical instrumentation or thermocouples properly attached so as to accurately read the temperature of the base metal at the joint area to verify control standard settings. (Improperly attached thermocouples may be heated independently by the induction heating field or may not accurately read the temperature of the base metal.) Instruments used for calibration shall be calibrated in a manner traceable to the standards of the National Institute of Standards and Technology.¹ All instruments shall be calibrated in accordance with AMS 2750 and ANSI/NCSL Z540-1. Instruments shall be calibrated on a regular schedule or whenever repairs or modifications are made to them.

For joints in which overheating of the base metals could adversely affect base-metal properties, sensors shall be used which shut down the system if overheating occurs and shall be calibrated as above. This sensor shall be set at a temperature below the temperature where reduction in properties can take place. It shall be located and aligned so that it reads the area of highest temperature. Automatic systems used to manufacture Class A and Class B joints shall be equipped with calibrated control devices which produce a repeatable brazing cycle.

4.2.4 Atmosphere Induction Brazing Equipment. If induction brazing is to be conducted in a protective atmosphere (including vacuum), the equipment and enclosures shall be in good working condition and shall be as specified in the qualified Brazing Procedure Specification (see 4.4 and 4.5). The atmosphere controls shall meet the requirements of AWS C3.6, *Specification for Furnace Brazing*.

4.2.5 Induction Brazing Work Stations. Induction brazing work stations shall be suitable for the intended purpose and in good condition and working order. They shall be constructed to ensure that the dimensional relationships between the coil, the temperature sensing equipment, and the parts are maintained during brazing

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

and are not changed by the normal use of the work station such as the bumping that may occur during loading and unloading of parts.

Work stations shall meet all relevant federal, state, and local government health and safety requirements.

4.3 Materials

4.3.1 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 and Braze Welding*, 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-based alloys brazed with silver bearing filler metals and iron-based alloys brazed with silver or copper-based filler metals containing high phosphorous. Care shall be taken to assure that the filler metal selected is metallurgically compatible with the base metals.

4.3.2 Fluxes. Fluxes shall be compatible with the base and filler metals specified by the engineering drawing. Fluxes shall remove oxides and prevent their reformation during the brazing operation. They shall promote the flow and wetting of the filler metal onto the surfaces of the brazed joint. Fluxes are specified in ANSI/AWS A5.31, *Specification for Filler Metals and Fluxes for Brazing and Braze Welding*.

4.3.3 Cleaning Materials. Materials used in cleaning operations shall not leave any residues which could interfere with the wetting or flow of the brazing filler metal. For example, aluminum oxide, silica, or zirconia blast cleaning media may leave undesirable residue which could inhibit the braze wetability. Chemical cleaning solutions which are detrimental to the base metals shall not be used (see 4.4.10 for Safety Precautions).

4.3.4 Braze Stopoff. Braze stopoff, if used, shall be suitable for the intended purpose and compatible with the base metal, filler metal, and any protective atmospheres used. In certain specialized applications, residues from stopoff materials can produce unacceptable contamination of the product. If contamination is suspected, approval by the Organization Having Quality Responsibility should be obtained prior to use.

4.4 Procedure Requirements. Approved procedures that contain the control of the following items shall be maintained, and changes to such procedures must be re-approved.

4.4.1 Surface Preparation. The mating surfaces and adjacent areas of components to be brazed shall be free of oil, grease, dirt, oxides, paint, scale, or other foreign substances which 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 Nickel Plating. Nickel plating is recommended on the brazed joint areas of stainless, corrosion, or heat-resistant steels having equal or greater percentage by weight of the following alloying elements:

- (1) Titanium—0.40%
- (2) Aluminum—0.40%
- (3) Titanium plus aluminum—0.70%

Electrolytic Nickel plate 0.01 to 0.02 mm (0.0004 to 0.0008 in.) thick shall be applied in accordance with AMS 2424, *Plating, Nickel, Low Stressed Deposit* or AMS 2403, *Plating, General Purpose*. When the braze temperature is below 815°C (1500°F) AMS 2404, *Plating, Electroless Nickel*, may be used. It shall extend 2.5 mm (0.10 in.) minimum beyond the brazed joint area indicated by the brazing symbol on the engineering drawing unless part configuration does not permit this allowance. In addition, nickel plate may be specified by the Organization Having Quality Responsibility to cover any area, or the entire surface, of details or assemblies at its discretion. When the drawing or purchase documents do not specify localized plating, the parts may be completely plated.

4.4.3 Joint Clearance. Joint clearance between mating surfaces to be torch brazed shall be controlled by the assembly procedures so that proper joint clearance at the brazing temperature is provided. Suggested joint clearances for typical materials may be found in the AWS *Brazing Handbook*, Table 2.1.

4.4.4 Application of Filler Metal. Filler metal shall be introduced as defined in the approved Brazing Procedure Specification. It shall be so placed or applied as to be drawn onto the joint surfaces by capillary action during brazing. Preplacement of the filler metal between the surfaces of the joint proper of Class A or Class B joints shall only be permitted if ultrasonic inspection is specified to assure bonding of the filler to the base metal. Filler metal quantity and placement shall be such as to produce a satisfactory joint without excessive build up on adjacent surfaces which could interfere with part function.

4.4.5 Application of Flux. Flux, if used, shall be applied in the form and quantity and by the method specified in the approved brazing procedure. Flux quantity and placement shall be such as to produce a satisfactory brazed assembly and adequately protect adjacent surfaces from detrimental oxidation.

4.4.6 Application of Stopoff. Braze stopoff, if used, shall be applied in the quantity and locations necessary to control filler metal flow to meet the requirements of the engineering drawing. It shall be applied so as to avoid

contamination of either the braze joint surfaces or the preplaced filler metal.

4.4.7 Brazing Cycle. The approved brazing procedure shall be defined so that the braze joints be heated uniformly to the brazing temperature. For example: cylindrical assemblies 25 mm (1 in.) or more in diameter may need to be rotated within the coil during brazing to assure uniform heating and temperature monitoring of the joint. The assembly shall be held at the brazing temperature for the minimum time needed to produce a satisfactory joint without causing adverse metallurgical effects. Assemblies shall be cooled after brazing in such a manner that cracking of the filler metal or base metal is avoided, and residual stresses are minimized.

4.4.8 Postbrazing Operations. Postbrazing heat treatments shall be performed as required by the engineering drawing. Residual flux and stopoff shall be removed by suitable methods. Postbrazing 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 filler or base metals shall not be used.

4.4.9 Accessibility. Joints to be brazed shall be accessible for proper preparation, assembly, heating, cooling, brazing, 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.

4.4.10 Safety and Health. Brazing fluxes and filler metals, particularly those containing cadmium, emit hazardous fumes during the brazing cycle. It is mandatory that all induction brazing operations be properly and adequately ventilated or that the operator be provided with adequate breathing apparatus, or both, as required to assure that all relevant federal, state, and local health and safety requirements are met. In addition, there are hazards involved in induction brazing such as those relating to the use of corrosive fluxes and electrical equipment. Refer to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, for information on these and other safety and health hazards that should be controlled in induction brazing.

4.5 Qualification. Induction brazing procedures, equipment, and operators shall be qualified in accordance with the latest revision 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 of 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 all inspection of the brazed joints. This requirement includes a system of quality control and documentation which assures and can attest that all required operations and procedures were performed. Suppliers may use their own facilities or any other facility acceptable to the Organization Having Quality Responsibility for the inspection of 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 Requirements 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 braze 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. Induction 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. Inspection should be done after postbrazing cleaning.

5.4 Required Inspections of Brazed Joints. All brazed joints shall meet the acceptance criteria given in 5.5.

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. Radiographic inspection shall be performed in accordance with ASTM E 1742, *Standard Practice for Radiographic Examination*. Braze joints shall be radiographically inspected only when specified in the engineering drawing, or when the following configuration and process requirements are met:

(1) The clearance between the joint surfaces at assembly should be two percent or more of the total thickness of the base metals at the joint. In cases where the joint clearance is less than 2 percent of the thickness of the base metals, the radiographic technique shall be demonstrated to have adequate sensitivity and be approved by the Organization Having Quality Responsibility.

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

(3) 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 within the joint area.

Ultrasonic inspection shall be required if one or more of these requirements are not met, except as specified in 5.4.1.4.

5.4.1.2 Ultrasonic Inspection. Ultrasonic inspection shall be performed in accordance with ANSI/AWS C3.8, *Recommended Practice for Ultrasonic Inspection of Braze Joints*. Ultrasonic inspection shall only be performed when all of the following configuration and process criteria are met. Radiographic inspection shall be required when one or more of these criteria are not met, except as specified in 5.4.1.4.

(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.

5.4.1.3 Leak and Pressure Testing of Class A and Class B Joints. If specified on the engineering drawing or approved in writing by the Organization Having Quality Responsibility, pressure and leak testing to the following requirements may be substituted for radiographic and ultrasonic inspection of Class A and Class B joints:

(1) Class A joints shall be pressure tested at an internal pressure and by procedures specified in writing by the Organization Having Quality Responsibility. No measurable leakage shall be allowed. They shall then be helium leak tested in accordance with a procedure outlined by the Organization Having Quality Responsibility, and leakage of not more than 3.0×10^{-5} cc/second shall be detected with a suitable detector in good working condition calibrated as specified by its manufacturer.

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

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

5.4.1.4 Alternate Inspection Techniques. Certain specialized braze 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, 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 for service of the final product and of the selected inspection techniques to verify the suitability of the braze joints.

5.4.2 Sample Inspection Plans

5.4.2.1 Class C joints may be inspected using sample plans in accordance with ANSI/ASQC Z1.4, *Sampling Procedure and Tables for Inspection by Attributes*, 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 ANSI/ASQC Z1.4, 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. 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 percent 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 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. 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 ANSI/ASQC Z1.4, *Sampling Procedures and Tables for Inspection by Attributes*, AQL 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 ASTM E 1417, *Standard Practice for Liquid Penetrant Examination*, 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 results.

5.4.3.2 Additional Tests. Additional nondestructive examination may be specified by the Organization Having Quality Responsibility.

5.4.3.3 Destructive Test of Assemblies or Samples. 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 examination 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 External Discontinuities

5.5.1.1 Pinholes and Voids. Pinholes, voids, or filler metal skips are allowed provided they shall not

exceed the following limits. Imperfections of less than 0.38 mm (0.015 in.) are uninterpretable and are not considered as defects.

(1) Class A—Maximum size 2.3 mm (0.090 in.) with a total accumulated length less than 10 percent of fillet length.

(2) Class B—Maximum size 2.3 mm (0.090 in.) with a total accumulated length less than 25 percent of fillet length.

(3) Class C—Maximum size 3.1 mm (0.120 in.) with a total accumulated length less than 50 percent of fillet length.

5.5.1.2 Cracks. Cracks are unacceptable.

5.5.1.3 Erosion. Any evidence of braze filler erosion of the exposed base metal surfaces is unacceptable, if the erosion of either member exceeds 5 percent of the thickness for Class A and 15 percent for Class B or Class C of the thinnest component of the brazed joint.

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

5.5.1.5 Edge Voids. Voids which are continuous across the joint between any two opposite joint edges are unacceptable for Class A and Class B. Through voids are acceptable for Class C.

5.5.1.6 Braze Filler Penetration. If the edge of the joint opposite that to which the filler metal is applied is visible after brazing, filler metal shall be present at that edge of the joint. 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 Flux or Flux Residue. Evidence of flux or flux residue is unacceptable.

5.5.1.8 Quality of Workmanship. 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 Discontinuities

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 percent of the total joint area. The size of the largest void or unbonded area as measured parallel to the joint width shall not exceed 60 percent of the total joint width. Any such area which is wider than 40 percent of the width of the joint, shall extend no closer to either edge of the joint than 20 percent 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 percent of the total joint area. The width of the largest void, as measured parallel to the joint width shall not exceed 70 percent of the total joint width. Any such area which is wider than 60 percent of the width of the joint, shall extend no closer to either joint edge than 15 percent of the joint width.

5.5.2.3 Class C Joints. No internal inspection requirements.

5.6 Process Completion. Brazed joints may be reworked by brazing to the original, qualified brazing procedure specification without the specific, written approval of the Organization Having Quality Responsibility, unless otherwise specified by that organization. Additional brazing filler metal, of the same type used in the original procedure, may be used. 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 4.5.

6. Definitions

Terminology related to this specification is included in this section. Additional terms may be found in ANSI/AWS A3.0, *Standard Welding Terms and Definitions, Including Terms for Brazing, Soldering, Thermal Spraying, and Thermal Cutting*.

brazed 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.

brazed 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.

brazed 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*.

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

brazing procedure specification (BPS). A document specifying the required brazing variables for a specific application.

defect. A discontinuity or discontinuities that by nature or accumulated effect (for example total crack length) render a part or product unable to meet minimum applicable acceptance standards or specifications. The term designates rejectability. See also **discontinuity** and **flaw**.

discontinuity. An interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical, metallurgical, or physical characteristics. A discontinuity is not necessarily a defect. See also **defect** and **flaw**.

flaw. An undesirable discontinuity. See also **defect**.

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.

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.

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 to those or any other operations.

surface porosity. A roughened or spongy appearance 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.

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

Annex A

Guidelines for Preparation of Technical Inquiries for AWS Technical Committees

(This Annex is not a part of AWS C3.5:1999, *Specification for Induction Brazing*, but is included for information purposes only.)

A1. Introduction

The AWS Board of Directors has adopted a policy whereby all official interpretations of AWS standards will be handled in a formal manner. Under that policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

A2. Procedure

All inquiries must be directed to:

Managing Director, Technical Services
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries must contain the name, address, and affiliation of the inquirer, and they must provide enough information for the committee to fully understand the point of concern in the inquiry. Where that point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and should also be in the format used here.

A2.1 Scope. Each inquiry must address one single provision of the Standard, unless the point of the inquiry

involves two or more interrelated provisions. That provision must be identified in the Scope of the inquiry, along with the edition of the standard that contains the provisions or that the Inquirer is addressing.

A2.2 Purpose of the Inquiry. The purpose of the inquiry must be stated in this portion of the inquiry. The purpose can be either to obtain an interpretation of a Standard requirement, or to request the revision of a particular provision in the Standard.

A2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to quickly and fully understand the point of the inquiry. Sketches should be used when appropriate and all paragraphs, figures, and tables (or the Annex), which bear on the inquiry must be cited. If the point of the inquiry is to obtain a revision of the Standard, the inquiry must provide technical justification for that revision.

A2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry, or the wording for a proposed revision, if that is what inquirer seeks.

A3. Interpretation of Provisions of the Standard

Interpretations of provisions of the Standard are made by the relevant AWS Technical Committee. The secretary of the committee refers all inquiries to the chairman of the particular subcommittee that has jurisdiction over the portion of the Standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply

to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation will be an official interpretation of the Society, and the secretary will transmit the response to the inquirer and to the *Welding Journal* for publication.

A4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal*.

A5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS Standards should be limited to questions of a general nature or to matters directly related to the use of the Standard. The Board of Directors' Policy requires that all AWS Staff members respond to a telephone request for

an official interpretation of any AWS Standard with the information that such an interpretation can be obtained only through a written request. The Headquarters Staff can not provide consulting services. The staff can, however, refer a caller to any of those consultants whose names are on file at AWS Headquarters.

A6. The AWS Technical Committee

The activities of AWS Technical Committees in regard to interpretations, are limited strictly to the Interpretation of provisions of Standards prepared by the Committee or to consideration of revisions to existing provisions on the basis of new data or technology. Neither the committee nor the Staff is in a position to offer interpretive or consulting services on: (1) specific engineering problems, or (2) requirements of Standards applied to fabrications outside the scope of the document or points not specifically covered by the Standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

AWS Brazing and Soldering Documents

AWS Designation	Title
ANSI/AWS A2.4	Standard Symbols for Welding, Brazing, and Nondestructive Examination
ANSI/AWS A3.0	Standard Welding Terms and Definitions, Including Terms for Brazing, Soldering, Thermal Spraying, and Thermal Cutting
ANSI/AWS A5.8	Specification for Filler Metals for Brazing and Braze Welding
ANSI/AWS A5.31	Specification for Fluxes for Brazing and Braze Welding
BRH	Brazing Handbook, 4th Edition
SH	Soldering Handbook
ANSI/AWS B2.2	Specification of Brazing Procedure and Performance Qualification
ANSI/AWS C3.2	Standard Method for Evaluating the Strength of Brazed Joints in Shear, Butt Tension, and 4-Point Bending (Short Time Shear and Tensile, Creep Strength, and Stress Rupture)
ANSI/AWS C3.3	Recommended Practices for the Design, Manufacture, and Inspection of Critical Brazed Components
AWS C3.4	Specification for Torch Brazing
AWS C3.5	Specification for Induction Brazing
AWS C3.6	Specification for Furnace Brazing
AWS C3.7	Specification for Aluminum Brazing
ANSI/AWS C3.8	Recommended Practices for Ultrasonic Inspection of Brazed Joints

For ordering information, contact the AWS Order Department, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126. Telephones: (800) 334-9353, (305) 443-9353, ext. 280; FAX (305) 443-7559.