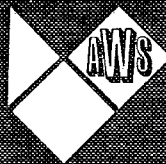


**Recommended Practices
for
Design, Manufacture, and Inspection
of
Critical Brazed Components**



AMERICAN WELDING SOCIETY

AWS C3.3-80

Recommended Practices for Design, Manufacture, and Inspection of Critical Brazed Components

Prepared by
AWS Committee on Brazing and Soldering

Under the direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors, August 11, 1980

AMERICAN WELDING SOCIETY, INC.
2501 N.W. 7th Street, Miami, FL 33125

International Standard Book Number: 0-87171-211-3

American Welding Society, 2501 N.W. 7th Street, Miami, FL 33125

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Printed in the United States of America

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Foreword

These recommended practices were written to provide a basic guide to what should be done to assure the suitability of a brazed component for a critical application. Although such applications vary widely, there are certain common considerations in materials, design, manufacture, and inspection that should not be overlooked. It is the intent of this document to list and explain these common considerations and the best techniques for dealing with them. It is not within the scope of this document to give specific details of each of these techniques, which the user must adapt to fit his own application.

The AWS C3 Committee on Brazing and Soldering prepared these recommended practices and invites comments and suggestions for revisions. Such correspondence should be addressed to:

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Recommended Practices for Design, Manufacture, and Inspection of Critical Brazed Components

1. Introduction

1.1 Scope. These recommended practices deal with those procedures that should be followed in the design, manufacture, and inspection of brazed joints for critical components in order to assure their reliability in service.

The procedures recommended represent the best current practice in the opinion of the American Welding Society and are necessary to the control of brazed joint quality. At the present state of the art, all practices may not be applicable to all products or all brazing processes. However, when some of these practices are omitted on critical components, it should be the result of a rational decision, not the result of a lack of knowledge of the best practice.

1.2 Definition of Critical Component. A critical component is one, the primary failure of which would cause significant danger to persons or property, or would result in a significant operational penalty.

1.3 Application. Each user of this document has the responsibility to decide which products and which brazed joints in those products are critical.

These recommended practices are neither a general brazing nor an inspection specification. Because of the great diversity of brazed joints, one universal set of criteria cannot apply to all specific cases. The basic premise of these recommended practices is that each component having critical brazed joints should be completely defined by an engineering drawing and pertinent specifications.

1.4 Format. This document is divided into sections on materials, design, manufacturing, and inspection. These sections are followed by an appendix of sample specifications that are intended as guides in the preparation of the user's own documents.

1.5 Documentation. Critical components should be controlled by documents specifying:

(1) The materials required and their minimum acceptable properties.

(2) The complete design configuration and dimensions of the product.

(3) All required controls of the manufacturing process, including facilities, equipment, and detailed work instructions so that no important factors are left to the discretion of persons involved in fabrication; for example, specific detail dimensions and tolerances or techniques that control braze joint clearances, or the locations and resulting accessibility for inspection of pipe joints in complex plumbing systems.

(4) The inspection procedures required and minimum acceptance limits.

(5) A procedure for disposition of materials or products not meeting the minimum acceptance limits.

All requirements should be specified as limits for acceptance of the product and never as goals, the attainment of which, while desirable, is not absolutely necessary.

1.6 Note on Qualifications of Brazers and Processes.

While destructive qualification tests of sample joints or specimens are useful to demonstrate the ability of processes and operators to produce the required joints, they do not, in themselves, assure the quality of the components produced. Qualification procedures should not be used as a substitute for inspection and nondestructive testing procedures that directly indicate the quality of the actual hardware to be used in service.

1.7 Note on Safety and Health Procedures. Procedures for the protection of the safety and health of those performing brazing and related operations are of great importance. There are a number of potential hazards that must be considered. Among them are:

- (1) Exposure to fumes and gases
- (2) Radiation
- (3) Toxic materials

Read and understand the manufacturer's instructions for

the material and equipment used. Detailed information on this subject is included in these AWS publications: ANSI Z49.1, Safety in Welding and Cutting, and Chapter 29 of *Brazing Manual*.

2. Brazing Materials

2.1 Composition. The composition of the filler materials from each incoming lot, batch, or heat of brazing filler metal should be specified and verified. Identification and traceability should be provided. The acceptable composition ranges of the major alloying elements should be specified. Detrimental trace elements should be identified and allowable levels defined. If necessary, the analytical procedures should be defined.

2.2 Form. Brazing filler metals may be obtained in several different physical shapes and sizes that should be specified by the user as follows:

- (1) Wire: diameter, length, and dimensions of formed shapes; temper, if for use in automatic feeding equipment.
- (2) Foil: thickness, width, and length; temper, if for use in automatic feeding equipment.
- (3) Powder: particle size distribution.
- (4) Paste: binder type and content, powder particle size.
- (5) Plasticized tape: thickness, width, percent density, and binder type.
- (6) Brazing sheet: cladding thickness and composition.

2.3 Fluxes. Fluxes should be controlled to AWS flux specifications or equivalent.

2.4 Packaging and Storage. Methods of packaging to prevent contamination or loss of identification should be specified. Storage conditions and shelf-life, where appropriate, should be specified.

2.5 Identification. Procedures should be established to maintain identification of materials during use.

3. Design

3.1 Basic Considerations. Reliability requires deliberate steps during the design phase to assure effective control of quality. Quality control procedures must not be an afterthought, to be specified once the design is finalized. Procedures should be developed along with the design and verified as appropriate. Consideration should be given to the practical aspects of brazing, the characteristics of the filler and base materials involved, and the limitations of the inspection procedures. The requirements of the brazing and inspection operations should be given equal weight. For example, the completed assembly may not provide accessibility for inspection of each joint; therefore, step brazing of various subassemblies may be neces-

sary to permit inspection at intermediate stages and should be considered during the design of the component. Designs for critical brazed components should be conservative and should assure that the joints are inspected in the condition in which they will enter service. The designer should consider the following items to assure that the final brazed component is suitable for the critical service intended.

3.2 Materials. Materials include the base metals as well as the brazing filler metals. Each should be suitable and its suitability proved, if necessary, by preparation of appropriate sample specimens and performance of mechanical, corrosion, and service tests. Besides the usual factors considered in any materials selection, the following are particularly important in designing brazed joints: the effects of filler metal interaction during brazing (dissolution, diffusion, or embrittlement of the base metal); the hardness changes and gradient of ductility in the heat-affected zone; and degradation of the brazed joint in service by formation of embrittling phases or by galvanic corrosion. Equally important is the effect of materials on the ease and reliability of both brazing and inspection. Materials factors that affect inspection processes are relative x-ray density and the suitability of the materials for ultrasonic or penetrant inspections. For further information on the properties of brazed materials and joints and their importance in design, see Chapters 2, 3, and 6 of the Third Edition of the *AWS Brazing Manual*.

3.3 Configuration. Component configuration should be suitable for inspection of the finished joints as well as for manufacturing and service requirements. It is essential to assure that misalignment or unacceptable changes in clearances do not occur during heating. Excessive residual stresses or cracking should not be introduced during cooling. The clearance between the prepared joint faces should be that which gives the best flow and strength with the filler material selected. Where applicable, AWS recommended configurations (Chapter 6, Third Edition of the *AWS Brazing Manual*) should be incorporated in the design, and prototype life-cycle tests should be run to assure serviceability. Special care should be taken when designing a brazed structure for a critical application to assure that joints are not placed in areas of high stress concentration or at locations that make inspection of the joints impossible. The sequence of assembly, brazing, and inspection should be carefully considered and specified during the design of multi-joint structures to assure that a part with the required dependability can be built.

3.4 Brazing Process Selection. It is important to select the appropriate brazing process for the design. Considerations influencing this selection are discussed in the *AWS Brazing Manual*. Beyond these considerations, particular attention should be directed to the reproducibility of the brazing process in the manufacturing facility and to the availability of adequate process controls.

3.5 Post-Brazing Operations. It should be assured that

specified post-brazing operations do not induce cracks that can initiate a fatigue or other type of failure. The integration of brazing and heat-treating operations should be considered. Care should be exercised in handling, forming, and machining. Forming operations should be performed only in special instances, because differences in the mechanical properties of brazing filler metals and base metals may cause cracking. The integration of brazing and heat-treating operations should be considered.

3.6 Acceptance Criteria. Minimum acceptance criteria for brazed joints are an essential part of a design. Limits should be realistic and conservative for critical brazed joints. They should be established with due consideration for the sensitivity of inspection techniques and the actual requirements of the most severe conditions that can be reasonably expected in service. Decisions should be based on an understanding of the nature of the stresses developed in service and the behavior of the materials in the presence of imperfections and other stress concentrations that can occur in brazed joints. Service testing is often required to develop this understanding.

4. Manufacture

This section on manufacture discusses recommended practices for facilities, equipment, and manufacturing procedures. All of these areas should be considered when defining adequate process controls to assure braze quality. Development of process controls frequently involves fabrication of sample assemblies to identify the critical variables. Process controls are not a substitute for product inspection, but they are a valuable and often necessary adjunct to inspection. In addition to the benefits of process controls to brazing quality, they also reduce costs by minimizing rework and rejection rates.

4.1 Facilities and Equipment

4.1.1 Work Area and Cleaning Facilities. A specific work area should be established for cleaning and assembly of subcomponents and fixtures prior to brazing, in order to maintain adequate cleanliness. Air conditioning or air filtering often is necessary to prevent contamination from other manufacturing operations; e.g., grinding dust, machining coolant mist, or corrosive chemical fumes. Such a controlled area also affords contamination-free storage of cleaned materials, subcomponents, assemblies, and fixtures. Adequate cleaning is imperative for all brazing.

4.1.2 Control of Heating Equipment. The adequacy of control systems depends upon the accuracy and response time of temperature measurement, the durability of temperature measurement device (usually a thermocouple), and the response characteristics of the control system (control of overshoot and cycling, changes in work load, etc.) The system should include a means of recording the time-temperature profile. A thorough survey should be made to determine temperature gradients and heating rates

of the equipment and proposed braze cycle with a dummy load before beginning production. The heating equipment, thermocouples or other temperature measuring devices, controllers, and recorders should be periodically inspected and recalibrated to assure that they are functioning properly. Frequency of calibration, calibration procedure, and accuracy requirements should be specified, as should documentation requirements.

4.1.3 Control of Protective Atmosphere. The composition requirements for the protective gases should be established and the gas composition monitored at the brazing location. It is important to note that a significant source of problems is the contamination of protective gases between the source and the brazing equipment. The system should be leak-free.

A vacuum pumping system should have adequate capacity both to evacuate the chamber to the proper level and to handle the outgassing from the assembly during heating to the braze temperature. Appropriate vacuum gauges are required, and they should be located as near to the work area as possible in order to provide relevant vacuum readings. The performance of the vacuum system during operation should be monitored to identify problems requiring maintenance.

4.1.4 Fixtures. Fixtures to align and support the subcomponents during brazing may contribute as much to the success of the operation as the design of the assembly itself. Fixtures are specifically designed for a particular assembly and heating method, but good designs reflect common considerations. These are explained in the AWS *Brazing Manual*.

Care should be taken to maintain the cleanliness of tooling between operations.

Dimensional inspection should be made as required to assure that unacceptable distortions have not occurred.

4.2 Procedures

4.2.1 Subcomponent and Filler Metal Preform Fabrication. Subcomponents and filler metal preforms, where used, should be defined by the engineering or process drawings. Dimensional tolerances should be established, recognizing their effect on joint clearances. Surface finish and edge condition should be specified. The details should be inspected to assure conformance with requirements.

4.2.2 Cleaning and Handling. Detailed cleaning and surface preparation procedures should be established for each application. Solution composition ranges should be defined and provisions made for periodic checks to assure that they are not degraded. Where possible, parts should be inspected to assure that the procedures have been performed correctly.

Handling and storage after cleaning and surface preparation should prevent contamination of the parts. The shelf-life of a cleaned part should be determined and adequate controls established to provide recleaning when it is exceeded.

4.2.3 Plating Process Controls. Plating of joint surfaces may be required for some applications. Process controls similar to those used for cleaning should be provided

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to control plating composition, adherence, and thickness. Often, an atmosphere furnace cycle test may be used to assure plating quality.

4.2.4 Assembly for Brazing. Cleaned parts should not be contaminated during assembly and application of filler metal. This may require a controlled atmosphere or "whiteglove" handling. Filler metals, whether in the form of wire, rings, washers, shims, powder, or paste, should be preplaced by an established procedure. Where preplaced filler metal is not visible after assembly, verification of placement before closure should be made. The amount and location of filler metal applied as powder or paste should be defined and controlled, as should the location of stop-off materials if used. Handling and storage after assembly should maintain cleanliness and not disrupt filler metal placement or assembly alignment.

4.2.5 Brazing Procedures and Process Controls. A brazing procedure should be written that specifies the essential process variables, such as heating rate, brazing temperature range and time, visual observations to verify filler metal melting and flow, etc. It should specify time limits between preparation and brazing operations if applicable. Post-brazing procedures, such as cooling rates and protective atmosphere requirements to minimize distortion and contamination, should also be included in this written procedure. Placement of the assembly in the heating equipment should be done in a manner that maintains cleanliness, filler metal placement, and assembly and fixture alignment.

A final reinspection is valuable. Where thermocouples are used, they should be located on or in the assembly so as to suitably monitor the temperature of the joint area being brazed.

A procedure should be established when using a protective atmosphere to assure adequate purging of the system and to verify the dew point of gases. In vacuum brazing, pumpdown procedures should incorporate a check of leak rate and allowances for out-gassing.

Heat practices differ with brazing method, but a procedure should be established for the specific application. Heating procedures should reflect such considerations as out-gassing or temperature stabilization to reduce thermal gradients.

After brazing, care should be taken in removing the assembly from the fixtures and in subsequent handling to avoid damage. Cleanliness should be maintained to facilitate repair and heat treatment as required.

4.2.6 Post-Brazing Precautions. Certain post-brazing operations should be carefully controlled to assure that they do not adversely affect the brazed joints; this includes passivating and chemical cleaning solutions that attack certain brazing filler metals, and heat treatments in air, which may oxidize them.

for critical applications should have an adequate general quality control system. As well as the documentation normally required by such, the system should document all inspections of critical brazements. The system should assure that all required inspections are performed on every joint.

Nondestructive inspection methods are applicable to brazements made by all of the brazing processes and should be used to control the quality of brazements for critical application. The size, complexity, and degree of critical application will dictate the particular inspection method or methods most suitable. If no accurate and dependable method of inspecting a critical brazed joint can be found, either the part should be redesigned to permit inspection, or another more readily inspected joining technique should be used. Neither periodic destructive inspection nor process qualification requirements are completely acceptable substitutes for nondestructive inspection of actual hardware entering critical service.

When defining the acceptance limit for any type of brazing defect, the following should be considered: shape, orientation, and location in the brazement, including whether surface or subsurface, and the relationship to other imperfections.

Judgments for disposition of discrepant components should be made by persons competent in the fields of brazing metallurgy and quality assurance who fully understand the function of the component. Such dispositions should be documented.

5.2 Common Imperfections in Brazed Joints. Nondestructive inspection is used to identify the following types of common imperfections. The limits of acceptability should be specifically defined.

5.2.1 Lack of Fill (Voids, Porosity). Lack of fill can be the result of improper cleaning, excessive clearances, insufficient filler metal, entrapped gas, and movement of the mating parts caused by improper fixturing while the filler metal is in the liquid or partially liquid state. This imperfection reduces the strength of the joint by reducing the load-carrying area, and it may provide a path for leakage.

5.2.2 Flux Entrapment. Entrapped flux may be found in any brazing operation where a flux is added to prevent and remove oxidation during the heating cycle. The entrapped flux prevents flow of the filler metal into that particular area, thus reducing the joint strength. It may also cause false leak or proof test acceptance. The entrapped flux, if corrosive, may reduce service life.

5.2.3 Noncontinuous Fillets. These are usually found by visual inspection and may or may not be acceptable depending upon the specified requirements of the brazed joint.

5.2.4 Base Metal Erosion. This condition is caused by the filler metal alloying with the base metal during brazing. It may cause undercuts or the disappearance of the mating surface and may reduce the strength of the joint by changing the composition of the materials and by reducing the base metal cross-sectional area.

5.2.5 Unsatisfactory Surface Appearance. Excessive

5. Inspection

5.1 Introduction. An organization making components

brazing filler metal spread, roughness, and excessive filler metal may be detrimental for several reasons. In addition to aesthetic considerations, these may act as stress concentrations, corrosion sites, or may interfere with inspection of the brazement.

5.2.6 Cracks. Cracks reduce both the strength and service life expectancy. They may act as stress raisers, causing premature fatigue failure as well as lowering the mechanical strength of the brazement.

5.3 Inspection Methods for Brazed Joints

5.3.1 Visual Inspection. Visual inspection is probably the most widely used of the nondestructive methods for inspection of brazed joints. It is done with and without magnification. It is effective in evaluating the external evidence of voids and porosity, noncontinuous fillets, base metal erosion, surface cracks, fillet size and shape, and general braze appearance. If a brazement can be inspected on one side only, there is no guarantee of a satisfactory joint even though there is a good fillet. Visual inspection cannot reveal internal imperfections in a brazed joint, such as trapped flux, porosity, lack of fill, and internal cracks. If there is any chance for misinterpretation, the inspector should be provided with samples, photos, or sketches to assure that he knows precisely what conditions he is to recognize and reject.

5.3.2 Leak Testing. This inspection method is recommended when gas or liquid tightness is required of the brazed joints. Assemblies subjected to low pressure, and not coming under the ASME Pressure Vessel Code requirements, may be tested with air. Assemblies subjected to high pressure and those coming under Code requirements should be tested hydrostatically after initial testing with air. Test pressure and duration should be specified to provide a realistic measure of joint quality. It should be emphasized that leak tightness of a joint when originally tested does not necessarily assure continued integrity in service after subjection to various and repeated loadings.

Pressure testing with air may be done by one of several methods:

- (1) Closing all openings, pressurizing the assembly, submerging in water, and noting any signs of leakage indicated by rising air bubbles.

- (2) Closing all openings, pressurizing the assembly, brushing a soap solution or commercially available indicator over the joint area, and noting the location where bubbles are formed.

- (3) Closing all openings, pressurizing the assembly, locking the air under pressure within the assembly by closing the air inlet source, and noting any change in trapped gas pressure over a period of time (corrections for temperature and barometric pressure may be necessary).

Pressure testing with helium is frequently preferred because of the relative ease of finding very minute leaks. A mass spectrometer is used to detect leakage of helium. In testing for very small leaks, it is usually important to remove thoroughly all liquid or vapors from the assembly by a suitable drying operation. Purging with dry gas while heating the assembly above the boiling point of the liquid

is one method.

Pressure testing with freon is used frequently in the refrigeration industry to determine very small volume leakage. Special freon equipment is available, the simplest being either an air acetylene or air and petroleum-gas halide leak detector. The detector samples the atmosphere from the area being checked, and any leak is indicated by a color change of the detector flame. The more elaborate equipment is of the electronic type and will detect very minute leaks.

5.3.3 Vacuum Testing. This method of testing is generally employed in checking assemblies used in refrigeration equipment and small assemblies where it is imperative that the most minute leak be detected. The mass spectrometer is used in this method with helium as the sensing medium. Either the assembly being tested is placed in a container having a helium atmosphere, or helium is flushed over the surface. The mass spectrometer is connected to the vacuum side of the assembly, preferably between the auxiliary diffusion pump and the mechanical backing pump. If mass spectrometer helium leak testing is to be used, care should be taken to prevent the use of liquid on the joint prior to the helium leak testing, because of the potential for masking leaks. It should again be emphasized that leak tightness of a joint when originally tested does not necessarily assure continued integrity in service.

5.3.4 Proof Testing. Proof testing subjects the completed joint to loads in excess of the loads to be applied during its subsequent service life. These loads can be applied by hydrostatic methods, by tensile loading, by spin testing, or by other methods. Occasionally, it is not possible to assure a serviceable part by any of the other nondestructive methods of inspection, and proof testing then becomes the most satisfactory method. Great caution should be used when specifying proof testing as the primary method of inspection of brazed joints for critical applications. Because it does not inspect braze quality but applies a one time loading that may not closely simulate all the conditions encountered in service, it may not accurately predict service life, especially if cyclic loadings are encountered in service.

5.3.5 Radiography. The radiographic method of inspection is used extensively for examination of brazed joints; however, many brazed joints cannot be radiographically inspected. Sensitivities of better than 2 percent are difficult to achieve, and joints may be radiographed satisfactorily only if thickness and x-ray adsorption ratios permit differentiation of the joint. Possible differences in adsorption characteristics of base metals and filler metals should always be considered in interpreting the radiographs. A joint that may be inspectable when brazed with silver filler may not be inspectable if brazed with nickel because of the differences in x-ray characteristics of the two elements.

Special techniques are required to reliably inspect joints of varying thickness. Views that show two sides of a cylindrical joint, such as taken through a pipe fitting, should be interpreted with particular care.

Radiography is used to find internal flaws, cracks, and braze voids that are not discernible by those techniques limited to surface observation. It is also useful in determining the depth of surface cracks and voids, if within the limits of the x-ray process.

Radiographic inspection shows the presence of filler material in a joint. It does not necessarily indicate the presence of a metallurgical bond between the base metal and filler metal. (These must be assured by process controls.) It should be noted that a radiograph showing no voids may indicate either 100 percent or 0 percent joint coverage, or merely poor x-ray technique. Careful steps should be taken to assure that film readers are aware of this and are particularly suspicious of joints appearing to show 100 percent coverage.

5.3.6 Ultrasonic Inspection. Ultrasonic inspection of brazed joints generally depends upon the reflection of sound waves by surfaces. A transducer emits a pulse and then receives back echoes. In the standard brazed lap joint, these echoes will come from the front surface and the rear surface of the part detail at areas of completely bonded joint. At defective areas, a third echo located between the first two will be caused by the unbrazed faying surfaces of the joint. These echos may be displayed on an oscilloscope. The defect signal may be used to trigger the pen of a recording device to produce a facsimile of the joint showing bonded and unbonded areas.

This inspection method is sensitive to setup variables, part configuration, and materials. It should therefore be considered a comparative method of inspection, requiring a reference standard identical to the part being inspected containing defects of known configuration. This standard is used to set up and calibrate the equipment at specified intervals. The applicability of this method of inspection depends largely upon the design of the joint and the configuration of the adjacent areas of the brazed assembly. Ultrasonic techniques have been developed and used for a wide range of brazing applications and often provide one

of the best methods of evaluating joint quality.

5.3.7 Dye and Fluorescent Penetrant Inspections. Dye and fluorescent penetrant inspections are used for the detection of imperfections open to the surface of brazed joints in both magnetic and nonmagnetic materials.

Cracks and surface porosity in the fillet may be detected, but interpretation is sometimes difficult because of small irregularities. Incomplete flow and partial fillets may also be observed. These inspection methods should not be used if subsequent repairs are to be made, since the penetrants are often difficult or impossible to remove completely.

5.3.8 Thermal Transfer Inspection. Thermal transfer inspection may be used in certain specific cases. For example, brazed aircraft propeller blades may be photographed while still hot, a few minutes after leaving the furnace. The covering skins appear to be bright red in areas where they are brazed to the reinforcing rib, but are a much darker red, or black, in areas where improper brazing has occurred.

A method of inspecting brazed honeycomb panels utilizes powdered or liquid materials with low melting points to indicate the differences in heat transfer characteristics when the honeycomb assembly is placed under infrared heat lamps. Temperature variations cause the liquid to be repelled from warm areas and to accumulate in cool spots. The core partitions act as heat sinks, causing the fluid to flow to each area of good braze.

More sophisticated techniques use thermally sensitive phosphors, liquid crystals, and other temperature-sensitive materials. Infrared-sensitive electronic imaging devices with television readout are now commercially available to monitor temperature differences produced by heat transfer differences characteristic of variations in braze quality. Careful verification of the specific inspection technique should be done prior to use of the technique for acceptance of critical components.

Appendix: Sample Specifications for Specific Critical Components

These sample specifications are based on those in use by various manufacturers. They are not intended to be directly applicable to the user's product, but rather to serve as a guide in the preparation of a specification for his product.

Sample Specification A

Manufacture and Inspection of an Induction Brazed Shaft

1. Scope

This specification covers the processing requirements for the fabrication of ...

2. Applicable Documents

The latest issue in effect of the following documents forms a part of this specification to the extent specified herein. (Identify by number and title.)

3. Requirements

3.1 Approvals. The brazing facility shall be approved and the operator qualified in accordance with ... Approvals shall be subject to renewal every ...

3.2 Equipment. The brazing facility shall include the following: (Identify and specify in each case.)

- 3.2.1 Power supply.
- 3.2.2 Induction coil.
- 3.2.3 Holding fixture.
- 3.2.4 Temperature pickup.
- 3.2.5 Temperature recorder and controller.
- 3.2.6 Reference standards.
- 3.2.7 Potentiometer.
- 3.2.8 Work area.

3.3 Material (Identify and specify in each case.)

- 3.3.1 Cleaning solvents.
- 3.3.2 Chemical cleaners.
- 3.3.3 Abrasive cloth and brushes.
- 3.3.4 Braze stripping solution.
- 3.3.5 Brazing filler metal.
- 3.3.6 Flux.
- 3.3.7 Lint free wipers.

3.4 Procedure

3.4.1 Final machining (details)

3.4.1.1 Machine the braze preform groove to the dimensions specified on the engineering drawing.

3.4.1.2 Mate the machined detail so the braze joint has a radial clearance of ...

3.4.2 Cleaning details. The detail parts shall be thoroughly cleaned as follows:

- (1) Vapor degrease ...
- (2) Rinse in ...
- (3) Abrade all joint surfaces to be brazed ...
- (4) Clean brazing filler metal preforms ...

Note: Cleaning operations in preparation for brazing shall be followed exactly, paying particular attention to braze surfaces. All cleaning solutions, abrasives, etc., shall be rigorously controlled as to chemical composition and condition.

3.4.3 Brazing. Application of braze filler metal and flux shall be as follows:

3.4.3.1 Install the brazing filler metal preforms as shown by ...

3.4.3.2 Assure that the temperatures of areas shown by ... do not exceed ... during the brazing and cool down cycles.

3.4.3.3 Rotate the details while brazing area is brought to specified temperatures at ... rpm.

3.4.3.4 When the joint to be brazed reaches the brazing temperature of ..., hold at temperature for ... seconds.

3.4.3.5 Cool the brazed joint to at least ...

3.4.4 Cleaning of assemblies. The completely brazed assemblies shall be cleaned as follows: ...

4. Quality Assurance Provisions

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the vendor may utilize his own facilities or any other facility acceptable to ... The right to perform or witness any of the necessary tests to demonstrate that supplies and services conform to the prescribed requirements is reserved.

4.2 Monitoring of Brazing Equipment

4.2.1 Calibration. The brazing unit shall be calibrated at ... intervals by the following procedure ...

4.3 Inspection of brazed assemblies. Visual, ultrasonic, and magnetic particle inspection shall be performed as stated herein.

4.3.1 Visual. Visual inspection shall be performed on the brazed joint areas to detect the presence of the following unacceptable conditions:

- (1) Interior of shaft ...
- (2) Exterior of shaft ...

4.3.2 Ultrasonic. Ultrasonic inspection shall be performed on brazed joints as follows:

4.3.2.1 Equipment

- (1) Facsimile recorder ...
- (2) Fixtures ...
- (3) A reference standard shaft with known defects as defined by ...

Note: All assemblies shall be serial numbered prior to ultrasonic inspection.

4.3.2.2 Calibration Procedure. Instrument calibration shall be performed at ... intervals as follows ...

4.3.2.3 Inspection Procedure. ...

4.3.2.4 Acceptance Limits. Acceptance limits shall be as follows: ...

4.3.3 Magnetic Particle. Magnetic particle inspection shall be performed on finish machined assemblies before surface treatment. Inspection shall be performed in accordance with ... (*Note:* This inspection is for the ferromagnetic shaft component and not for the brazed joint.)

4.3.3.1 Rejection criteria. ...

4.4 Rejection of Assemblies. Assemblies not conforming to the requirements of this specification shall be rejected.

4.5 Rework. All rework of rejected braze joints shall be performed in accordance with ...

4.5.1 Procedure. ...

4.5.2 Disassembly. ...

Notes

5.1 Acknowledgement. A vendor shall mention this specification number and revision letter in all quotations and when acknowledging purchase orders.

5.2 Definitions. For the purpose of this specification, the following definitions shall apply: ...

Sample Specification B

Inspection Standard Braze Joint Quality of Heat Exchangers

Note: Documents of this type are used when required process controls are specified separately.

1. Purpose

The purpose of this specification is to establish an inspection standard for the determination of ...

2. General

2.1 It shall be the responsibility of ... to determine that the procedures and requirements outlined in this specification are met.

2.2 This specification is applicable to ...

2.3 The term "imperfection" as used throughout this specification shall mean ...

2.4 All brazed joints that do not meet the requirements of this specification shall be referred to ... for disposition except when repair is permitted in accordance with ...

2.5 No imperfections shall be allowed in the parent material. Significant excursions of braze filler metal from the brazed joint fillet shall be removed when objectionable in the final part due to appearance or function. Removal of parent material is not permitted.

2.6 All exposed brazed joints shall show the presence of filler material completely around the periphery of the joint.

2.7 "Bridging" or bonding of braze material between ... and ... is not permissible. The joining of a group of internal tubes into a cluster due to brazing material runoff shall not exceed an accumulative total of ...

2.8 Minimum brazed bond in any joint shall be ... percent of the joint area. However, an individual unbrazed area shall not exceed ... percent of the total joint area or ..., whichever is the greater.

3. Visual Inspection

3.1 Scope. Each brazed joint shall be inspected by visual methods, at both the internal and external edges, as follows: ...

3.2 Brazing filler metal shall be evident along ... percent of the periphery of each side of the joints.

3.3 Surface imperfections in brazing material shall not exceed ... in length or diameter. Individual indications ... or smaller shall not be considered as imperfections.

3.4 Cumulative length of imperfections in any inch of joint length shall not exceed ...

3.5 A rough or irregular surface on brazing material shall be ...

4. Pressure and Leakage Testing

4.1 Scope. Units shall be evaluated by a cycling proof pressure and leakage test. Each unit shall be cycled ... times at proof pressure specified by ... On the last cycle, proof pressure shall be maintained for at least ... minutes. The unit must meet all leakage test requirements after this test.

NOTE: General visual inspection for defects such as ... shall not be affected by these requirements.

4.2 Testing Method

4.2.1 The water bath temperature shall be maintained at a temperature of ... to ...

4.2.2 A wetting agent shall be added to the water bath to aid in wetting the item by reducing the surface tension. A concentration of ... is required.

4.2.3 Plug off the item to be tested with adequate plugs. One plug shall have a suitable connection to a source of clean air or inert gas with an adequate pressure regulator.

4.2.3.1 Immerse unit under water and put safety shield in place.

4.2.3.2 Slowly apply gas pressure to the item being tested as required by ...

4.2.3.3 Hold pressure for ... minutes after the entrained bubbles have disappeared.

5. Quality Assurance Provisions

The Quality Control Department shall establish a quality plan to assure conformance with this specification and drawing requirements. Parts not meeting these requirements shall be rejected, and referred to ... for disposition.

Sample Specification C

Manufacture and Inspection of a Manual Torch Brazed Component for a Nuclear Application

1. Joint Design

(Sketch of the joint showing insertion requirements, fillers metal placement, etc.)

2. Brazing Equipment

2.1 Torch. ...

2.2 Tip size and type. ...

2.3 Gases. ...

2.3.1 Flow rate. ...

2.3.2 Type of flame. ...

3. Brazing Materials

3.1 Filler material

3.1.1 Filler metal specification and grade. ...

3.1.2 Form. ...

3.2 Flux specification and grade. ...

4. Procedure for Pipe Joints

4.1 Abrade joint surfaces with ... Wipe all joint surfaces with a cloth wet with ... Bottom pipe and lightly scribe a line ... from the joint interface, then back the pipe out of the joint.

Note: Lines may be scribed on adjacent tee or flange in lieu of pipe if insufficient pipe length exists.

4.2 Measure components to ensure proper joint diametrical cold clearance of ... is obtained. Pipe and tee/flange may be expanded or rolled to meet joint clearance requirements. The I.D. of the tee bores will be measured using a three (3) point intra-micrometer at three different elevations (top, bottom, center) to ensure the required diametrical clearance is met. The pipe O.D. is measured using a hand micrometer to ensure pipe is round prior to fit-up.

4.3 Preform two (2) alloy rings to fit loading groove on pipe. Clean components with ... and place filler metal rings around loading groove of pipe.

4.4 Visually inspect per ... Verify dimension from end of tee/flange to scribe line.

4.5 Clean all joint surfaces with ...

4.6 Clamp vibrator assembly to pipe being brazed, approximately ... from tee being brazed. Set up vibrator to obtain ...

4.7 Mix flux per ...

4.8 Flux the joint surface (I.D. of tee, O.D. of pipe). Apply flux with ...

4.9 Assemble pipe to tee/flange to scribe line on pipe. Apply flux to outside of joint (tee/flange-pipe).

4.10 Heat pipe adjacent to joint for approximately ... or until ... Heat tee/flange quickly, angling torch towards interface with pipe.

NOTE: Heat uniformly around tee/flange.

When filler metal is visible around total joint (360°), remove heat from tee/flange to adjacent pipe by feathering out on pipe.

NOTE: Do not overheat (red hot).

4.11 Once brazing is completed, remove vibrator set-up from header.

4.12 Air cool to room temperature. Clean to remove flux, using a wire brush and hot water.

5. Inspection

5.1 Visually inspect for:

5.1.1 Complete ring of sound fillet

5.1.2 Correct joint insertion

5.2 Ultrasonic Inspection

5.2.1 Scope. This procedure provides the requirements for UT inspection and disposition of braze joints using ... technique.

5.2.2 References. ...

5.2.3 Definitions.

inner band. The portion of the land equal to 1/2 the land and farthest from the face of the fitting.

outer band. The portion of the land equal to 1/2 the land nearest to the face of the fitting.

land. The total width by design of the joint to be brazed that must be inspected.

increment. A major division of the circumference of the land used as a reference point for inspection.

division. A portion of an increment. There are four equispaced divisions per increment.

5.2.4 General.

5.2.4.1 Only qualified inspectors shall perform the inspections required by this document. An inspector requires requalification when he has not performed inspections for a period of ... months or when disqualified by the examiner. Also the inspector must be requalified every ... per ...

5.2.4.2 The ultrasonic inspection equipment shall consist of:

5.2.4.3 Ultrasonic unit model ...

5.2.4.4 Transducers ...

5.2.4.5 Couplant shall be ...

5.2.4.6 Calibration standards shall be per ...

5.3 The ultrasonic instrument shall have been qualified and calibrated within the past ... months.

5.4 The outer surface of the fitting shall have been prepared sufficiently to obtain satisfactory sound transmission and shall not be rounded in the longitudinal direction.

5.5 The static scan technique shall be used.

5.6 The land dimension, i.e. the minimum brazed length, is ...

6. Procedure

6.1 Layout of Joint

6.1.1 Place the header in a horizontal position (serial number facing downward). Scribe the first increment line on the inner edge of the fitting at 12 o'clock.

6.1.2 Using a template per ..., place one mark over the first increment line and scribe six more lines on the inner edge of the fitting in line with the outer marks on the template.

6.2 Equipment Setup

6.2.1 Apply couplant to the applicable calibration standard. Place the transducer on the standard and adjust the display to obtain proper resolution and a signal amplitude between ...

6.3 Testing

6.3.1 Apply couplant to the surface of the fitting. The increments run clockwise when facing the pipe end of the fitting. The centerline of the transducer is aligned with ... (see Fig. ...).

6.3.2 Observe the amplitudes of bond and unbond signals to the nearest ... and refer to Table ... to obtain percent bond. Record results on form number ...

7. Acceptance Criteria

7.1 A joint is considered acceptable when the average bond is ... Parts not meeting this requirement shall be rejected.

8. Rework

8.1 Parts may be reworked by the following procedure ... times.

8.1.1 Procedure for rework by reheating ...

8.2 Parts still not acceptable after rework by 8.1.1 ... times shall be completely disassembled and the details inspected and referred to ... for disposition.