

Specification for Brazing Procedure and Performance Qualification



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Specification for Brazing Procedure and Performance Qualification

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Prepared by the
American Welding Society (AWS) B2 Committee on Procedure and Performance Qualification

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification provides the requirements for qualification of brazing procedure specifications, brazers, and brazing operators for manual, mechanized, and automatic brazing. The brazing processes included are torch brazing, furnace brazing, diffusion brazing, resistance brazing, dip brazing, infrared brazing, and induction brazing. Base metals, brazing filler metals, brazing fluxes, brazing atmospheres, and brazing joint clearances are also included.



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This standard is subject to revision at any time by the AWS B2 Committee on Procedure and Performance Qualification. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS B2 Committee on Procedure and Performance Qualification and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS B2 Committee on Procedure and Performance Qualification to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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Foreword

This foreword is not part of this standard but is included for informational purposes only.

This specification originated in the B2A Subcommittee on Brazing Qualification. The B2A Subcommittee was formed in the early 1980s in order to explicitly address the unique requirements of brazing procedure and brazing performance qualification outside the spectrum of [B2.1/B2.1M](#), *Specification for Welding Procedure and Performance Qualification*.

This is the fourth edition of [AWS B2.2/B2.2M](#), *Specification for Brazing Procedure and Performance Qualification*. [AWS B2.2/B2.2M](#) was first published in 1985. AWS B2.2-85, *Standard for Brazing Procedure and Performance Qualification*, was revised in 1991 and 2010.

The welding terms used in this specification shall be interpreted in accordance with the definitions given in the latest edition of [AWS A3.0M/A3.0](#), *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*. The application of brazing symbols shall conform to the requirements of [AWS A2.4](#), *Standard Symbols for Welding, Brazing, and Nondestructive Examination*.

A vertical line in the margin or underlined text in clauses, tables, or figures indicates an editorial or technical change from the 2010 edition.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS B2 Committee on Procedure and Performance Qualification, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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Specification for Brazing Procedure and Performance Qualification

1. General Requirements

1.1 Scope. This specification provides the requirements for qualification of Brazing Procedure Specifications (BPSs). This specification also provides requirements for the performance qualification of brazers and brazing operators. This specification is intended for use where referenced by a product standard or contract document.

Employers shall be responsible for the brazing done by their organization, including the use of qualified brazing procedures, qualified brazers, and qualified brazing operators. It is the Employer's responsibility to assure that BPSs meet any additional requirements of the Referencing Document. Each Employer shall maintain the applicable BPSs, Brazing Procedure Qualification Records (BPQRs), and Brazing Performance Qualification (BPQ)s during the period of their use.

When not otherwise specified by the Referencing Document, the edition of this specification to be used shall be established in accordance with the following: (1) editions may be used at any time after the effective date of issue; (2) the latest edition of this document should be used for new contracts; (3) editions established by contract date may be used during the entire term of the contract, or the provisions of later editions may be used when agreed upon by the contracting parties.

This document is intended for use with the following brazing processes:

- (1) Torch Brazing (TB)
- (2) Furnace Brazing (FB)
- (3) Induction Brazing (IB)
- (4) Resistance Brazing (RB)
- (5) Dip Brazing (DB)
- (6) Infrared Brazing (IRB)
- (7) Diffusion Brazing (DFB)

1.1.1 Base Metals. The grouping of base metals by Base Metal Number (BM No.) in Table B.1 has been made on the basis of metallurgical compatibility, chemical composition, and brazeability to decrease the number of required brazing qualifications. The grouping does not imply that base metals may be indiscriminately substituted within the same BM No. without consideration of their applicability. For some materials or combinations of materials, additional tests may be required by the procuring activity, the Referencing Document, or the design engineer.

Base metals are identified by their American Society for Testing and Materials (ASTM), American Bureau of Shipping (ABS), or Unified Numbering System (UNS) designations. Cross reference specifications, listed in the UNS for Metals and Alloys opposite a given UNS No., are included in the same BM No. group as the given UNS No. An American Society of Mechanical Engineers (ASME) designation, is included in the same BM No. group.

Eight categories are included as follows:

- (1) Ferrous metals (BM Nos. 100 through 180)
- (2) Aluminum and aluminum alloys (BM Nos. 200 through 220)
- (3) Copper and copper alloys (BM Nos. 300 through 360)

- (4) Nickel and nickel alloys (BM Nos. 400 through 420)
- (5) Titanium and titanium alloys (BM No. 500)
- (6) Zirconium and zirconium alloys (BM No. 600)
- (7) Magnesium alloys (BM No. 700)
- (8) Cobalt alloys (BM No. 800)

1.1.2 Filler Metals. The grouping of filler metals by Filler Metal Number (FM No.) in Table C.1 has been made on the basis of chemical composition to decrease the number of required brazing qualifications. The grouping does not imply that filler metals may be indiscriminately substituted within the same FM No. without consideration of their applicability. [AWS A5.8M/A5.8](#), *Specification for Filler Metals for Brazing and Braze Welding*, provides detailed requirements and general applicability of filler metals.

Filler metals other than those listed in [AWS A5.8M/5.8](#) may be used provided such filler metal meets the qualification requirements of this specification. For such filler metals, the term “special” shall be listed on the BPS and BPQR in lieu of an FM No.

1.2 Units of Measure. This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets ([]) or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently.

1.3 Safety. Safety and health issues and concerns are beyond the scope of this standard and therefore are not fully addressed herein. Safety and health information is available from the following sources:

American Welding Society:

- (1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (2) AWS Safety and Health Fact Sheets
- (3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

- (1) Safety Data Sheets supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The following standards contain provisions which, through reference in this text, constitute mandatory provisions of this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

AWS Documents¹:

- (1) [AWS A2.4](#), *Standard Symbols For Welding, Brazing, And Nondestructive Examination*;
- (2) [AWS A3.0M/A3.0](#), *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*;

¹ AWS standards are published by the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

- (3) [AWS A5.8M/A5.8](#), *Specification for Filler Metals for Brazing and Braze Welding*;
- (4) [AWS A5.31M/A5.31](#), *Specification for Fluxes for Brazing and Braze Welding*;
- (5) [AWS B4.0](#), *Standard Methods for Mechanical Testing of Welds*; and
- (6) [AWS B4.0M](#), *Standard Methods for Mechanical Testing of Welds*.

Other Documents²:

- (1) ANSI Z49. 1, *Safety in Welding, Cutting, and Allied Processes*.

3. Terms and Definitions

The brazing terms used in this standard shall be interpreted in accordance with the definitions given in the latest edition of [AWS A3.0M/A3.0](#), *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, and additional terms as used in this standard as defined below.

Brazing Performance Qualification (BPQ). A record of brazing conditions used to produce an acceptable test brazement and the results of tests conducted on the brazement to qualify a brazer or brazing operator.

brazing variable. Any controllable detail of a brazing procedure which is required to be addressed on the BPS.

Employer. The contractor or manufacturer of the production brazement for which brazing procedure and performance qualifications are required. Whenever approval, signature, or certification by the Employer is required by this specification, it shall mean the Employer or a designated employee within the Employer's organization. Closely related companies, including those with different names for which effective control of brazing is as one organization, shall be considered as one Employer.

plate. Used generally to refer to plate and sheet.

qualification variable. A brazing variable which, if changed beyond the limitations specified, requires requalification of the procedure, brazer, or brazing operator.

qualified brazer. One who is qualified to the requirements of this specification to perform manual brazing.

qualified brazing operator. One who is qualified to the requirements of this specification to operate furnace, mechanized, or automatic brazing equipment.

Qualifier. The Employer, organization, or individual specified by the Referencing Document as responsible for conducting and supervising qualification testing.

rabbit joint. Typical design is indicated in Figures 4.2 and 5.1.

Referencing Document. The product standard or contract document that invokes this specification.

specimen. The test pieces taken from a portion of a test coupon that are evaluated for qualification purposes. In some cases, the test brazement is also the specimen.

specimen blank. That portion of a test brazement that is removed for the production of a portion of the test coupon. In some cases, the specimen blank is also the specimen.

T. A symbol for base metal thickness.

TS. A symbol for test specimen thickness.

² ANSI Z49.1 is published by the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

4. Brazing Procedure Qualification

4.1 General. A brazing procedure qualification provides test data for assessing the properties of a brazed joint. It is the obligation of manufacturers to produce brazements that have properties suitable for the application. The proof of production braze soundness is determined by the type and extent of testing and examination applied, which is the responsibility of the Referencing Document.

4.1.1 The Employer shall determine the appropriate test assembly to be used to make a test brazement.

4.1.1.1 To qualify a brazing procedure, the following steps are necessary.

(1) Any format may be used for the BPS, provided all qualification variables and other applicable information are included.

(2) The actual conditions used in making the test brazement and the results of the required examination and specimen testing shall be recorded on a BPQR. Any format may be used, provided all qualification variables are addressed.

(3) The qualifying company shall certify that the information on the BPQR is an accurate record of the tests performed and the test results are in compliance with the qualification variables and testing requirements of [AWS B2.2/B2.2M, Specification for Brazing Procedure and Performance Qualification](#).

(4) If the results do not meet acceptance requirements, a new test brazement shall be prepared. Test brazements shall not be repaired.

(5) Procedures qualified by one Employer are not transferable to another Employer.

4.1.2 During the making of procedure test brazements for qualification, the brazer or brazing operator shall be under the full supervision and control of the Qualifier. The Qualifier is responsible for assuring proper:

- (1) Preparation of workpieces for brazing
- (2) Documentation of the test brazing variables
- (3) Preparation of specimens from the completed brazement
- (4) Performance of examination and mechanical tests
- (5) Documentation of results

4.1.3 A change in any brazing variable beyond the limits of 4.3 Qualification Variables shall require preparation of a new or revised BPS supported by one or more BPQRs. Changes in variables within the limits of 4.3 do not require requalification provided the BPS is revised to address the new brazing variables or conditions.

4.1.4 BPQRs shall not be revised except to correct errors or add omitted information. All revised changes shall be identified, dated and the revision number listed on the BPQR.

4.1.5 The identification of the BPQR(s) that support the BPS shall be recorded on the BPS.

4.1.6 A BPS may require the support of more than one BPQR, while alternatively, one BPQR may support a number of BPSs.

4.2 Test Brazements and Acceptance Criteria. Each brazing procedure shall be qualified by making one or more test brazements. These may be either standard test brazements, or when permitted by the Referencing Document, workmanship test brazements. Standard test brazements are illustrated in Figures 4.1 through 4.4 and summarized in Table 4.1. Typical workmanship test brazements are shown in Figure 4.5.

4.2.1 Visual Examination. Specimens shall be inspected with at least a four-power magnifying glass.

4.2.2 Acceptance Criteria for Visual Examination. The results of the visual examination shall meet the following requirements.

4.2.2.1 Braze metal shall be present at all edges of a joint.

4.2.2.2 No unmelted filler metal shall be visible.

4.2.2.3 Undercutting shall have a maximum depth of 5% of the base metal thickness, or 0.010 in [0.25 mm], whichever is the lesser.

4.2.2.4 No cracks shall be visible in the brazed joint.

4.2.2.5 No evidence of base metal melting shall be present, except that corners of aluminum and aluminum alloys, copper alloys, and magnesium alloys may be rounded by melting. Base metal melting resulting from tack welds used to assemble a test brazement and located in portions to be discarded are acceptable.

4.2.3 Tension Test. The cutting plan for the blanks for the tension specimens from standard test brazements is shown in Figures 4.1 through 4.4, except that the specimen for pipe and tube with an outside diameter of 3 in [75 mm] or less shall be in accordance with 4.2.3.4.

4.2.3.1 For butt or scarf joints, tension specimens shall be prepared as shown in Figure A.2A for plate and Figure A.2B for pipe greater than 3 in [75 mm] OD.

4.2.3.2 For lap joints, spliced butt joints, and rabbet joints in plate or pipe greater than 3 in [75 mm] OD, tension specimens shall be prepared as shown in Figure A.2C. Specimens shall be tested with no restraining device to prevent distortion. Where a peel test with a flanged member is substituted for the macroetch test, as described in 4.2.6, the tension specimen shall be tested without removal of the flanges.

4.2.3.3 For pipe and tubes with an outside diameter greater than 3 in [75 mm], tension specimens as shown in Figure A.2A or A.2B, except for the curvature of the specimen transverse axis, shall be tested with no restraining device to prevent distortion during testing. Where a peel test with a flanged member is substituted for the macroetch test, as described in 4.2.6, the tension specimen shall be tested without removal of the flanges.

4.2.3.4 For pipe and tubes with an outside diameter of 3 in [75 mm] or less, a tension specimen consisting of a length of the entire joint shall be tested as shown in Figure A.2D.

4.2.3.5 Acceptance Criteria for Butt Joints. The specimen shall have a minimum tensile strength in accordance with Table B.1 or as established by the Referencing Document.

4.2.3.6 Acceptance Criteria for Lap Joints, Spliced Butt Joints, and Rabbet Joints. The specimen shall have a tensile strength not less than 95% of the minimum tensile strength of the base metal. If this base metal minimum tensile strength is not given in Table B.1, it shall be established in the Referencing Document. The tensile strength of the specimen shall be computed by dividing the ultimate load by the cross-sectional area of the base metal. For dissimilar metal joints the divisor shall be the cross-sectional area of the joint member where the failure occurred.

4.2.4 Bend Test. The cutting plan for the blanks for the bend specimens from standard test brazements is shown in Figures 4.1 and 4.4. Figure 4.4 applies to pipe and tubes of all diameters.

4.2.4.1 Bend specimens as shown in Figures A.1A and A.1D shall be tested for butt joints in plate, pipe, or tube.

4.2.4.2 Bend test specimen shall be prepared as shown in Figures A.3A and A.3B. The bend specimens shall be bent in accordance with [AWS B4.0, Standard Methods for Mechanical Testing of Welds](#), or [AWS B4.0M, Standard Methods for Mechanical Testing of Welds](#).

4.2.4.3 Acceptance Criteria for Bend Tests. The specimen shall meet one of the following criteria:

- (1) The specimen does not separate.
- (2) The specimen separates in the base metal.
- (3) If the specimen separates at the braze joint it is acceptable providing:

(a) The total area of discontinuities such as pores, voids, unbrazed areas, and inclusions, does not exceed 15% of the area of either fracture surface and

(b) No discontinuity dimension, or combination of discontinuity dimensions, extends more than 25% along any line that would provide a leak path from one plate or pipe and tube surface to the opposing surface.

4.2.5 Macroetch Test. The cutting plan for the blanks for the macroetch specimens from the standard test brazements is shown in Figures 4.2 and 4.4. The blanks shall be 1-1/2 in [38 mm] in width; except that for pipe and tube with an outside diameter of 3 in [75 mm] or less, the blanks shall be two opposing quadrants.

4.2.5.1 Both sides of each blank shall be smoothed and, if necessary, etched with a suitable reagent to give a clear definition of the braze metal. Each surface shall be examined with at least a four-power magnifying glass.

4.2.5.2 Acceptance Criteria for Macroetch Tests. None of the cross sections, when considered individually, shall have a total length of discontinuities, such as pores, voids, unbrazed areas, and inclusions, greater than 20% of any single lap length. No cracks shall be present in the brazed joint or in the base metal.

4.2.6 Peel Test. Peel tests of standard test brazements with lap or spliced butt joints in plate or pipe and tube with an outside diameter greater than 3 in [75 mm] may be substituted for the macroetch test, provided that the peel specimen separates entirely at the braze joint.

4.2.6.1 The cutting plan for the blanks for the peel specimens from standard test brazements is shown in Figures 4.3 and 4.4. The blanks shall be approximately 1-1/2 in [38 mm] in width.

4.2.6.2 The inclusion of a flange on one member of a lap joint, or the splice member of a spliced butt joint as illustrated in Figure 4.3, to facilitate peel testing, is optional.

4.2.6.3 No preparation of the specimen blank is necessary. Using any peeling technique, the specimen shall be separated through the braze metal, at either braze interface, or a combination thereof.

4.2.6.4 Acceptance Criteria for Peel Tests. None of the exposed surfaces, when considered individually, shall have a total area of discontinuities, such as pores, voids, unbrazed areas, and inclusions greater than 25% of the faying surface. No discontinuity dimension, or combination of discontinuity dimensions, shall extend more than 25% along any line that would provide a leak path from one plate or pipe and tube surface to the opposing surface.

4.2.7 Workmanship Test Brazements. For joints other than those identified in Table 4.1 as standard test brazements, one workmanship test brazement representative of the design details of the joint to be qualified is required. Typical workmanship test brazements are shown in Figure 4.5.

This test in itself does not constitute procedure qualification but must be validated by conductance of tests of butt or lap joints as appropriate. For joints connecting tension members, the validation data may be based upon butt joints; for joints connecting members in shear, the validation data may be based on lap joints.

4.2.7.1 Test brazements of linear joints shall be 10 in [250 mm] in length or the entire joint to be qualified, whichever is less. The brazement shall be cut perpendicular to the braze joint into five equal parts. The two parts adjacent to the center part shall be selected as macroetch specimen blanks.

4.2.7.2 Test brazements of circular joints shall be cut into quadrants. Two opposing quadrants shall be selected as macroetch specimen blanks.

4.2.7.3 The four cut sides of the two macroetch specimen blanks shall be smoothed and etched with a reagent to give a clear definition of the braze, and examined with at least a four-power magnifying glass.

4.2.7.4 Acceptance Criteria for Workmanship Tests. None of the cross sections, when considered individually, shall have a total length of discontinuities, such as pores, voids, unbrazed areas, and inclusions greater than 20% of any single braze length of each joint member. No cracks shall be present in the joint or in the base metal.

4.3 Qualification Variables

4.3.1 Brazing Process. A BPS shall be requalified when there is any change in the variables as described below:

4.3.1.1 A change from one brazing process to any other.

4.3.1.2 The addition or deletion of any other brazing process to that already qualified. For example, the use of an oxyacetylene torch to finish joints brazed by the resistance brazing process.

4.3.2 Base Metal. A BPS shall be requalified when there is any change in the variables as described below:

4.3.2.1 A change from a base metal given under one BM No. in Table B.1 to a base metal given under another BM No. or to a base metal not included in the table.

4.3.2.2 A change from a base metal not included in Table B.1 to any other base metal.

4.3.2.3 The brazing of dissimilar metals need not be requalified if each base metal is qualified individually for the same brazing filler metal, flux, atmosphere, and process. Similarly, the brazing of dissimilar metals qualifies for the individual base metal brazed to itself and for the same brazing filler metal, flux, atmosphere, and process, provided the tensile strength recorded on the qualification record equals or exceeds that required in 4.2.3.6 for the metals brazed.

4.3.3 Base Metal Thickness. A change made in base metal thickness to a value outside the range qualified in accordance with Table 4.2 requires requalification of the BPS.

4.3.4 Base Metal Preparation. A change made in methods of preparing the base metal, such as mechanical cleaning, coating, plating, or surface treatment by chemical means, requires requalification of the BPS.

4.3.5 Brazing Filler Metal. A BPS shall be requalified when there is any change in the variables as described below:

4.3.5.1 A change from a filler metal given in Table C.1 under one FM No. to a filler metal given under another FM No. or to a filler metal not included in the table.

4.3.5.2 A change from a filler metal not included in Table C.1 to any other filler metal.

4.3.5.3 A change from any form of filler metal to another form.

4.3.5.4 A change from preplaced filler metal to mechanically or manually fed filler metal, and vice versa.

4.3.6 Brazing Flux. A BPS shall be requalified when there is any change in the variables as described below:

4.3.6.1 The addition or deletion of brazing flux.

4.3.6.2 A change in the AWS classification in accordance with AWS A5.31, *Specification for Fluxes for Brazing and Braze Welding*. In lieu of an AWS classification, a change in chemical composition or the flux trade name.

4.3.6.3 A change from a flux not listed in AWS A5.31 to another flux.

4.3.7 Brazing Bath Composition. A BPS for dip brazing shall be requalified when a change is made to the chemical composition or trade name of the brazing medium.

4.3.8 Brazing Atmosphere. A BPS shall be requalified when there is any change in the variables as described below:

4.3.8.1 A change in the brazing atmosphere from one AWS type given in Table D.1 to any other AWS type or to any other atmosphere.

4.3.8.2 A change from a brazing atmosphere not included in Table D.1 to any other atmosphere.

4.3.9 Brazing Temperature. Except for torch brazing, the test coupon shall be brazed within the temperature range specified in Table C.1, and the BPS shall limit the brazing temperature to that range. For test coupons brazed outside the ranges specified in Table C.1, the brazing temperature shall be limited to the temperature qualified $\pm 20^\circ\text{F}$ [$\pm 10^\circ\text{C}$].

4.3.10 Brazing Time. A change in the brazing time at temperature of more than 10% requires requalification. This variable is not applicable to torch brazing.

4.3.11 Joint Design. A BPS shall be requalified when there is any change in the variables as described below:

4.3.11.1 A change from a butt or scarf to a lap, to socket, or rabbet from that qualified. The addition or deletion of a flange for the joint types of Figure 4.3 is not considered a change in joint type.

The required overlap shown on the BPS may be expressed as a minimum dimension or as a ratio of part thickness.

For lap or socket joints, a decrease from the overlap length used on the test coupon (overlap may be increased without requalification).

4.3.12 Joint Clearance. A BPS shall be requalified when there is any change in the variables as described below:

4.3.12.1 A change to a joint clearance outside of the given range in Annex E1.

4.3.12.2 For filler metals not included in Table E.1:

(1) For a qualified joint clearance of 0.001 in to 0.002 in [0.02 mm to 0.05 mm], a change in joint clearance greater than 0.001 in [0.02 mm].

(2) For a qualified joint clearance of 0.003 in to 0.005 in [0.08 mm to 0.1 mm], a change in joint clearance of 0.002 in [0.05 mm].

(3) For a qualified joint clearance of 0.006 in to 0.010 in [0.2 mm to 0.25 mm], a change in joint clearance of 0.003 in [0.08 mm].

4.3.13 Brazing Flow Position. When the filler metal is face-fed, preplaced outside a joint or preplaced inside a joint such that flow occurs, a change in the brazing work position qualified beyond those permitted in Table 5.2 shall be requalified. If the brazing filler metal is preplaced in a joint such that there is no major flow, the joint may be brazed in any position without requalification. When production brazing is performed in a position that does not conform to a standard test position, qualifications are valid only for the position tested, except that an angular deviation of 15° is allowed.

4.3.14 Post Braze Heat Treatment (PBHT). The BPS shall be requalified when there is a change in the variables as described below:

4.3.14.1 The addition or deletion of a PBHT.

4.3.14.2 A change in the postbrazing heat treatment temperature more than $\pm 25^{\circ}\text{F}$ [$\pm 10^{\circ}\text{C}$] from that qualified or a change in postbrazing heat treatment time of the greater of 15 minutes or 10% of the postbrazing heat treatment time recorded on the BPQR.

Table 4.1
Procedure Qualification Test Brazement

Test Brazement	Joint Type	Specimens ^a
Standard	Butt (including scarf)	Tension and bend
	Lap	Tension and macroetch or tension and peel
	Single spliced butt	Tension and macroetch or tension and peel
	Double spliced butt	Tension and macroetch or tension and peel
	Rabbit	Tension and macroetch
Workmanship	Other (see 4.2.7)	Macroetch

^a Two specimens are required for each test.

Table 4.2
Thickness Range Qualified for Butt, Scarf, and Lap Joints

Thickness T of Test Coupon Brazed, in [mm]	Range of Base Metal Thickness Qualified, Plate or Pipe, in [mm] ^a	
	Minimum	Maximum
Less than 1/8 [3]	0.5t	2T
1/8 to 3/8 [3 to 10]	1/8 [3]	2T
Over 3/8 [10]	3/16 [5]	2T

^a When the test coupon thicknesses are dissimilar and the base metals are dissimilar, the range qualified shall be determined separately for each material.

Note: t = Braze metal thickness.

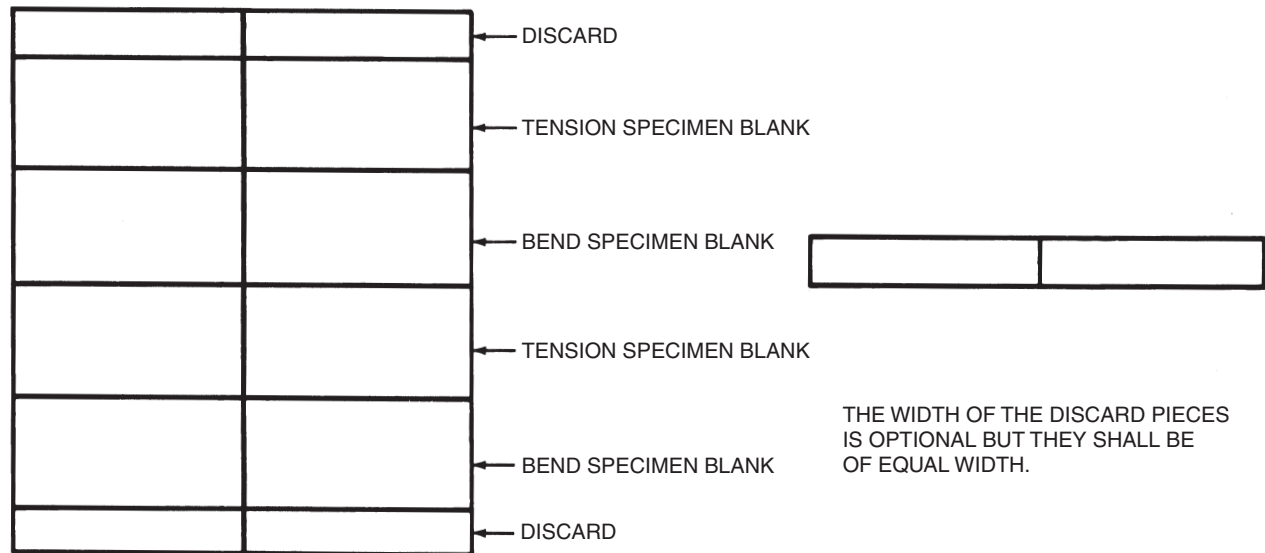


Figure 4.1—Cutting Plan of Test Brazement for Butt Joints in Plate

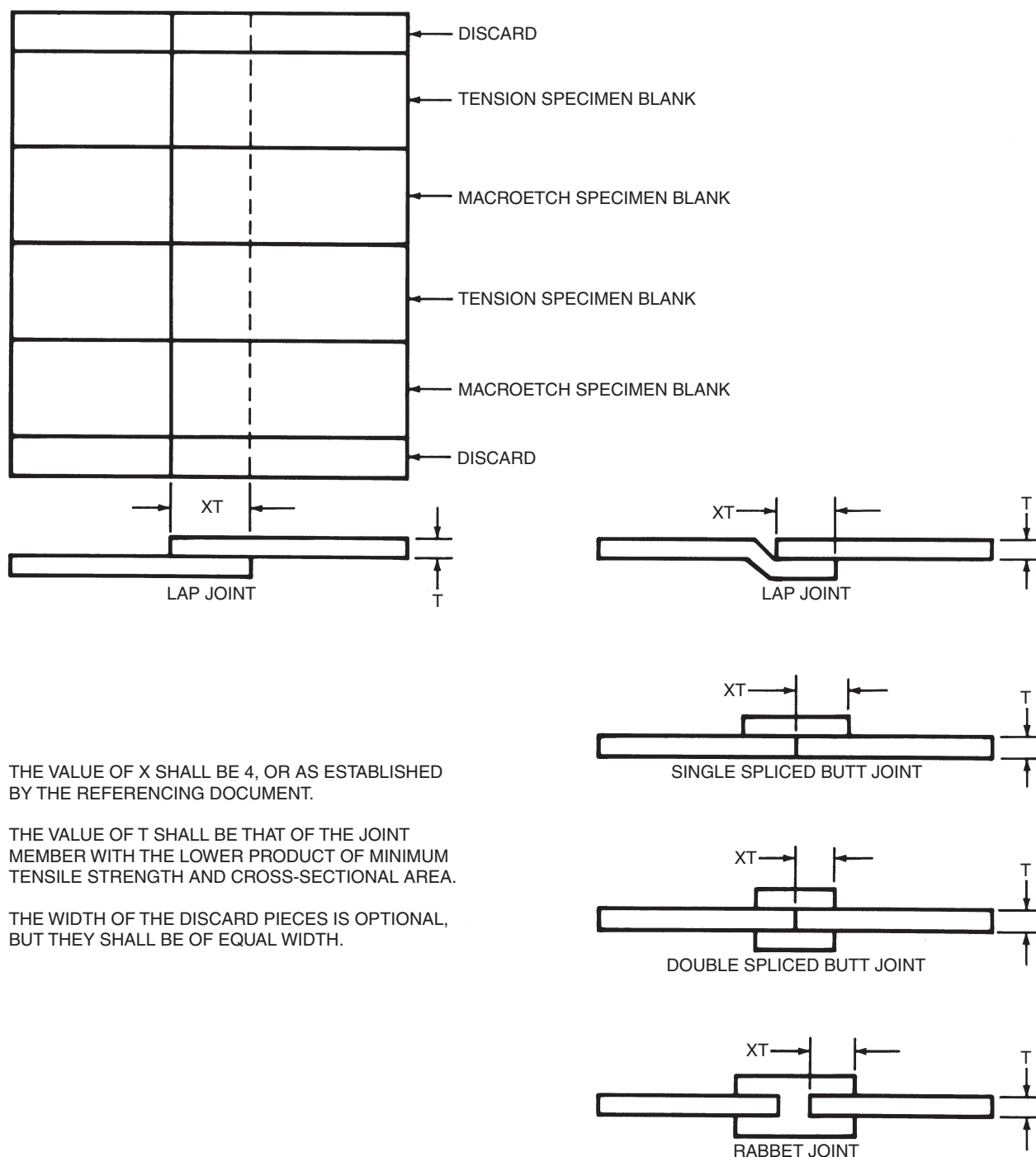
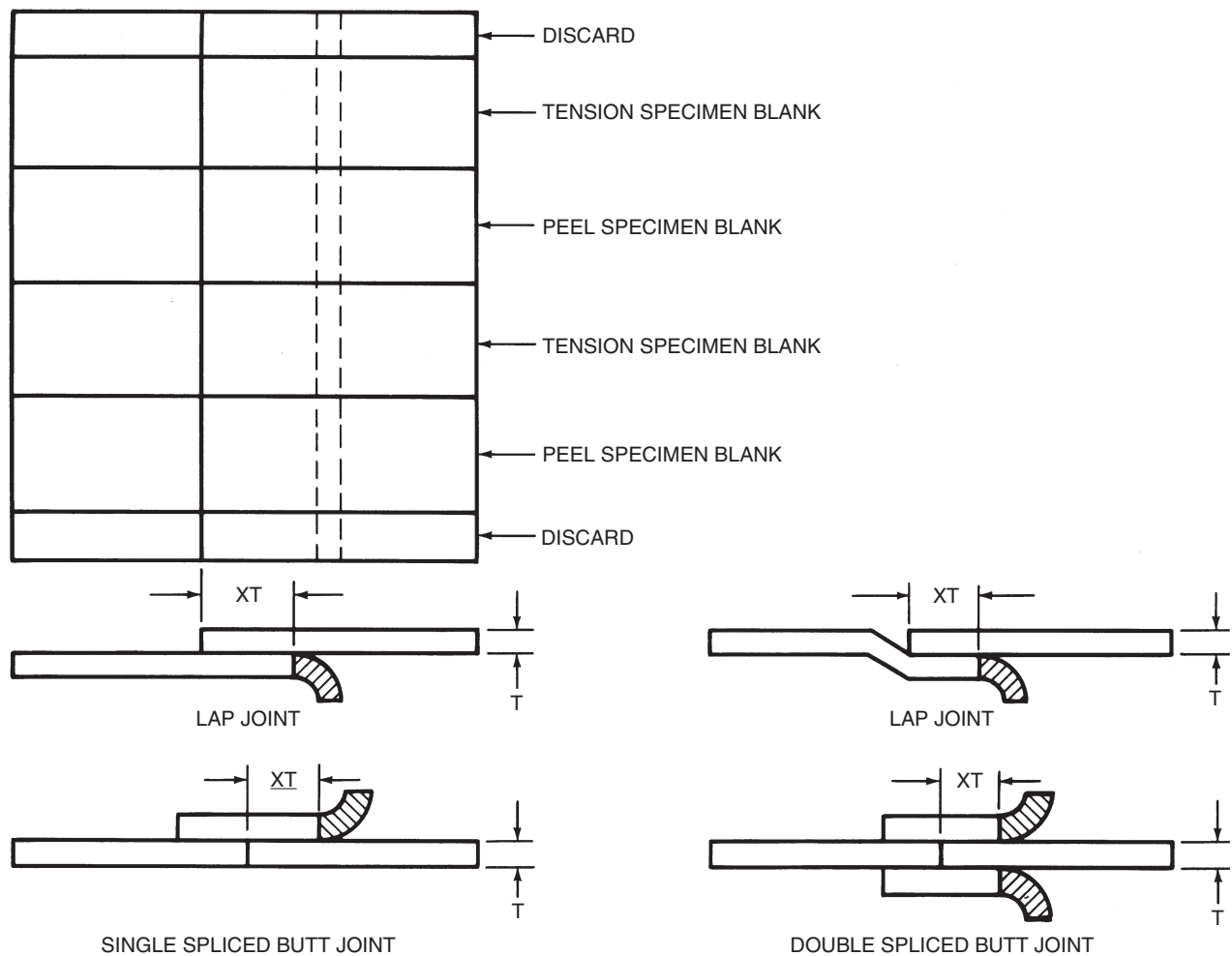


Figure 4.2—Cutting Plan of Test Brazement for Lap Joints, Single and Double Spliced Butt Joints, and Rabbet Joints in Plate



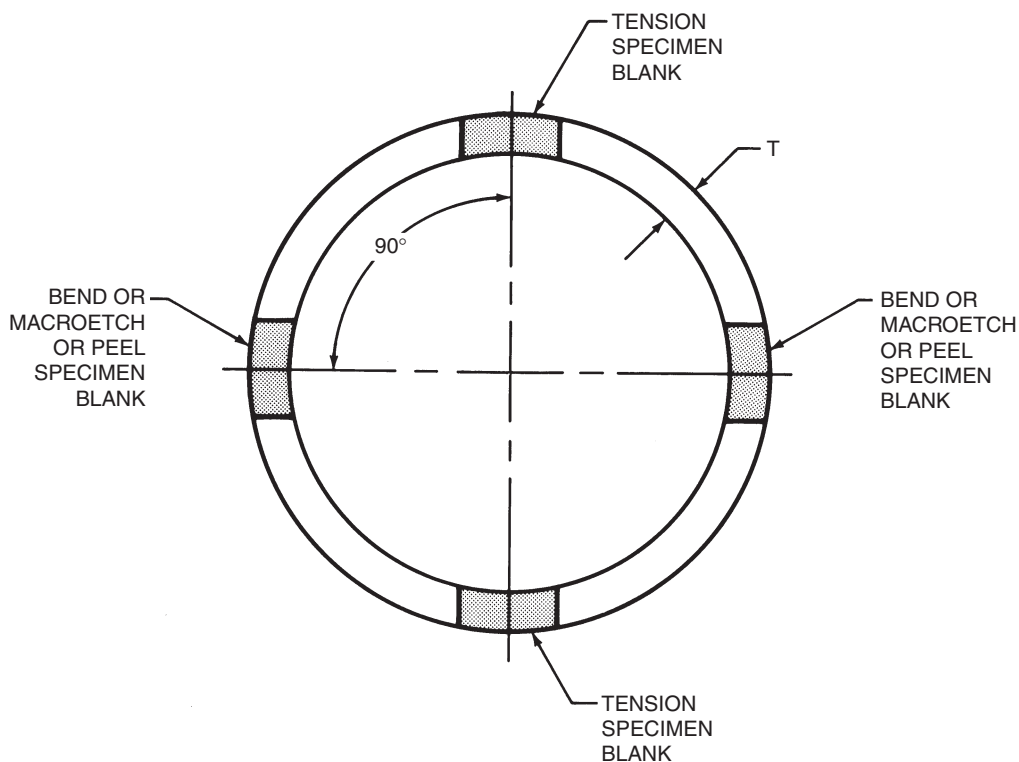
THE VALUE OF X SHALL BE 4, OR AS ESTABLISHED BY THE REFERENCING DOCUMENT.

THE VALUE OF T SHALL BE THAT OF THE JOINT MEMBER WITH THE LOWER PRODUCT OF MINIMUM TENSILE STRENGTH AND CROSS-SECTIONAL AREA.

THE WIDTH OF THE DISCARD PIECES IS NOT SPECIFIED, BUT THEIR WIDTH SHALL BE SIMILAR TO THE TEST SPECIMEN(S).

SHADED AREA SHOWS OPTIONAL FLANGE.

Figure 4.3—Cutting Plan of Test Brazement for Lap Joints and Single and Double Spliced Butt Joints in Plate



THE SPECIMENS AT THE HORIZONTAL DIAMETER ARE BEND SPECIMENS FOR BUTT JOINTS, MACROETCH SPECIMENS FOR RABBIT JOINTS, AND EITHER MACROETCH OR PEEL SPECIMENS FOR LAP JOINTS AND SPLICED BUTT JOINTS.

THIS SKETCH IS INTENDED TO REPRESENT ALL OF THE JOINT TYPES IN FIGURES 4.1 THROUGH 4.3

Figure 4.4—Cutting Plan of Test Brazement for Procedure Qualification Joints in Pipe and Tube of Greater Than 3 in [75 mm] Outside Diameter

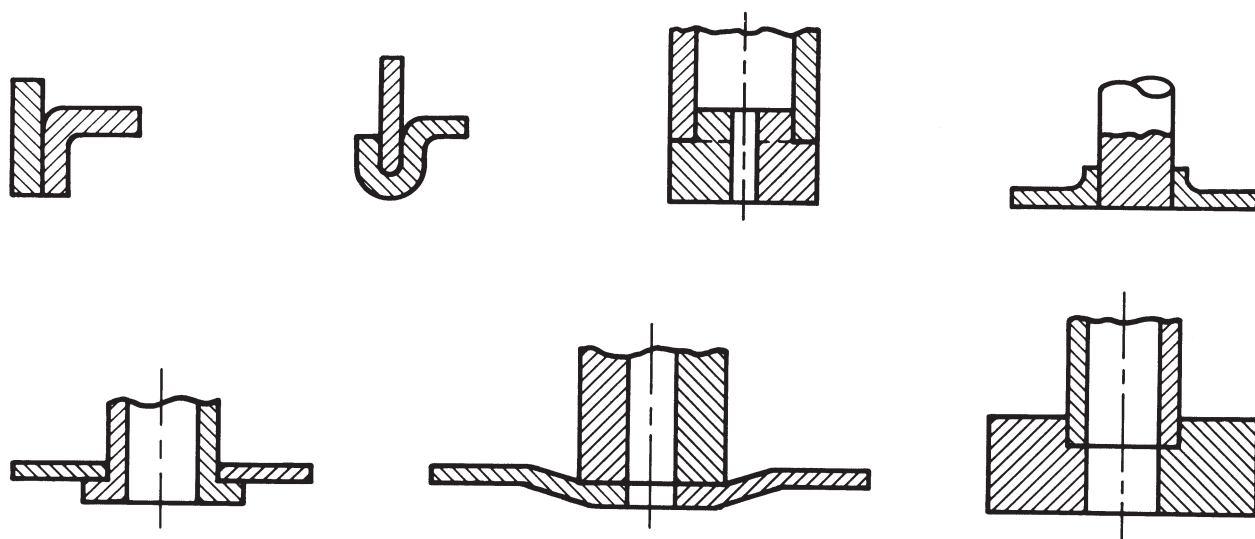


Figure 4.5—Typical Workmanship Test Brazements

5. Brazing Performance Qualification

5.1 General. Brazer performance qualification tests determine the ability of brazers to make sound brazed joints following a Brazing Procedure Specification (BPS) and under conditions that will be encountered in production applications.

Brazing operator performance qualification tests determine the ability of brazing operators to operate furnace, mechanized, or automatic brazing equipment in accordance with a BPS.

5.1.1 Qualification under this section requires completion of test brazements in accordance with a qualified BPS and acceptance by the Qualifier. The results of the specimen tests shall be recorded on the Brazer or Brazing Operator qualification record.

5.1.2 Acceptance of performance test brazements may be allowed by either of two methods:

5.1.2.1 Qualification by visual examination (see 5.2), when allowed by the Referencing Document.

5.1.2.2 Qualification by specimen testing (see 5.3).

5.1.3 Performance qualification by specimen testing shall qualify the individual to perform production brazing, where qualification by either specimen testing or visual examination is specified. Performance qualification by visual examination shall qualify the production work only where qualification by visual examination is permitted by the Referencing Document.

5.1.4 A brazer or brazing operator who completes an acceptable procedure or performance qualification test brazement shall be qualified for production work within the limits of variables specified in 5.4 and 5.5.

5.1.5 Qualification as a brazer does not qualify the individual as a brazing operator or vice versa.

5.1.6 Qualification is permitted on production brazements, provided such qualification is not prohibited by the Referencing Document.

5.1.7 Test brazements shall not be repaired.

5.1.8 The brazer or brazing operator undertaking performance qualification tests shall be under the full supervision and control of the Qualifier during the making of test brazements. Acceptance or rejection and documentation of test results are the responsibility of the Qualifier. Performance qualification documentation shall be dated and signed by the Qualifier. Any format may be used, provided all qualification variables, test results, and other applicable information are included.

5.1.9 The performance qualification shall remain in effect indefinitely unless the brazer or brazing operator does not braze with the qualified process for a period exceeding six months, or there is some specific reason to question the ability of a brazer or brazing operator.

5.1.10 A brazer or brazing operator who fails the performance test required by this clause may be retested at the option of the Qualifier.

5.2 Qualification by Visual Examination

5.2.1 Qualification by visual examination is permitted when allowed by the Referencing Document.

5.2.2 Qualification by visual examination requires completion of a workmanship test brazement representative of the design details of the joint qualified, which shall be accepted or rejected by visual examination. Typical workmanship test brazements are shown in Figure 4.5.

5.2.3 Unless otherwise specified in the Referencing Document, the workmanship test brazement shall be visually examined and shall meet the following requirements:

5.2.3.1 Braze metal shall be present at all edges of a joint.

5.2.3.2 No unmelted brazing filler metal shall be present.

5.2.3.3 Undercutting shall have a maximum depth of 5% of the base metal thickness, or 0.010 in [0.25 mm], whichever is the lesser.

5.2.3.4 No cracks shall be present in the braze metal.

5.3 Qualification by Specimen Testing

5.3.1 Performance qualification by specimen testing shall be conducted where acceptance is based on both macroetch tests and visual examination of the test brazement. Qualification by specimen testing requires completion and acceptance of either a standard test brazement or a workmanship test brazement.

5.3.2 Visual Examination. All test brazements shall be inspected by visual means prior to cutting. The results of the visual examination shall meet the requirements of 5.2.3.

5.3.3 Macroetch Test of Standard Test Brazement. The test brazement shall be one of the joint types shown in Figures 4.1, 4.2, or in 4.4 in either plate, or in pipe of any diameter, with a minimum test coupon length of 3 in [75 mm]. Multiple specimens and coupons may be used.

5.3.3.1 Plate joints shall be cut perpendicular to the braze axis into three 3/4 in [19 mm] wide specimens as shown in Figure 5.1. Pipe and tube specimens shall be removed as shown in Figure 5.3.

5.3.3.2 Both sides of each specimen blank shall be smoothed to give a clear definition of the braze, and examined with at least a four-power magnifying glass. If the braze filler metal is not evident after polishing, the specimen shall be etched with the proper reagent.

5.3.3.3 None of the cross sections, when considered individually, shall have a total length of discontinuities, such as pores, voids, unbrazed areas, and inclusions, greater than 20% of any single joint length. No cracks shall be present in the joint or in the base metal.

5.3.4 Peel Test of Standard Test Brazement. Peel tests of test brazements with lap or spliced butt joints in plate, pipe, or tube with an outside diameter greater than 3 in [75 mm] may be substituted for the macroetch test, provided that, the peel specimen separates entirely at the braze joint.

5.3.4.1 The test brazement shall be selected from those shown in Figure 4.2, 4.3, or 4.4. The inclusion of a flange on one member of the lap joint, to facilitate peel testing, is optional. The inclusion of flanges on the splice members of the spliced butt joints, similar to the flange of the lap joint, is also optional.

5.3.4.2 Plate joints shall be cut perpendicular to the braze axis into five equal parts, and the two parts adjacent to the center part shall be selected as peel specimen blanks as shown in Figure 5.2. For pipe and tube joints, two peel specimen blanks, each 3/4 in [19 mm] in width, shall be cut at locations 180° apart.

5.3.4.3 No preparation of the specimen blank is necessary. Using any peeling technique, the specimen shall be separated through the braze metal, at either braze interface, or a combination thereof.

5.3.4.4 None of the exposed surfaces, when considered individually, shall have a total area of discontinuities, such as pores, voids, unbrazed areas, and inclusions, greater than 25% of the faying surface. No discontinuity dimension, or combination of discontinuity dimensions, shall extend more than 25% along any line that would provide a leak path from one plate or pipe surface to the opposing surface.

5.3.5 Workmanship Test Brazements. The test brazement shall be representative of a production joint, with a minimum length of 3 in [75 mm] for linear joints, or the entire joint for circular joints. Typical workmanship test brazements are shown in Figure 4.5.

5.3.5.1 Linear joints shall be cut perpendicular to the braze joint into five equal parts. The two parts adjacent to the center part shall be selected as macroetch specimen blanks. Circular joints shall be cut into quadrants. Two opposing quadrants shall be selected as macroetch specimen blanks.

5.3.5.2 The four cut sides of the two macroetch specimen blanks shall be smoothed and etched with a suitable reagent to give a clear definition of the braze, and examined with at least a four-power magnifying glass.

5.3.5.3 None of the cross sections, when considered individually, shall have a total length of discontinuities; such as pores, voids, unbrazed areas, and inclusions, greater than 20% of any single joint length. No cracks shall be present in the joint or in the base metal.

5.4 Qualification Variables for Brazers. Brazers must be requalified when there is any change in the variables as described below:

5.4.1 Brazing Process

5.4.1.1 A change from one brazing process to any other.

5.4.1.2 The addition or deletion of any other brazing process to that or those already qualified (for example, the use of an oxyacetylene torch to finish joints brazed by the resistance brazing process).

5.4.2 Base Metal

5.4.2.1 A change from a base metal given under one BM No. in Table B.1 to a base metal given under another BM No., with the exceptions as given in Table 5.1.

5.4.2.2 A change from a base metal not included in Table B.1 to any other base metal.

5.4.2.3 The brazing of dissimilar metals need not be requalified if each base metal involved is qualified individually for the same brazing filler metal, flux, atmosphere, and process. Similarly, the brazing of dissimilar metals qualifies for the individual base metal brazed to itself and for the same brazing filler metal, flux, atmosphere, and process, provided the tensile strength recorded on the qualification record equals or exceeds that required in 4.2.3.6 for the metals to be brazed.

5.4.3 Base Metal Thickness. A change in base metal thickness to a value outside the range qualified in accordance with Table 4.2.

5.4.4 Brazing Filler Metal

5.4.4.1 A change from a filler metal given in Table C.1 under one FM No. to a filler metal given under another FM No. or to a filler metal not included in the table.

5.4.4.2 A change from a filler metal not included in Table C.1 to any other filler metal.

5.4.4.3 A change from preplaced filler metal to mechanically-fed filler metal or manually-fed filler metal.

5.4.5 Brazing Position. When the filler metal is face-fed, preplaced outside a joint or preplaced inside a joint such that major flow occurs, a change in the brazing work position qualified beyond those permitted in Table 5.2 shall be requalified. If the brazing filler metal is preplaced in a joint such that there is no major flow, the joint may be brazed in any position without requalification. When production brazing is performed in a position that does not conform to a standard test position, qualifications are valid only for the position tested, except that an angular deviation of 15° is allowed.

5.4.6 Joint Design

5.4.6.1 A change from a butt joint to any joint with overlapping members or vice versa.

5.4.6.2 For lap and socket joints, an increase in lap length of 1/16 in [1.5 mm] or 25%, whichever is greater from that used on the performance qualification test coupon. A decrease in overlap is permitted without requalification.

5.5 Qualification Variables for Brazing Operators. Brazing operators must be requalified when there is any change in the variables described below: