

**Standard for
Brazeing Procedure and
Performance Qualification**



American Welding Society

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brazing performance qualification,
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Standard for Brazing Procedure and Performance Qualification

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Prepared by
AWS Committee on Welding Qualification

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This standard 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, induction brazing, resistance brazing, dip brazing, and infrared brazing. Base metals, brazing filler metals, brazing fluxes, brazing atmospheres, and brazing joint clearances are also included.



American Welding Society

550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135

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*Advisor

Foreword

(This Foreword is not a part of ANSI/AWS B2.2-91, *Standard for Brazing Procedure and Performance Qualification*, but is included for information purposes only.)

This standard provides requirements for brazing procedure and brazing performance qualification. It is intended that this standard be referenced by other documents, such as standards or contracts.

This standard defines and establishes qualification variables. The criterion for determining if a brazing condition is a qualification variable is whether or not a change in that condition beyond the allowable tolerance will affect the properties of a sound brazement to the extent that the properties will not meet the specified minimum.

Qualification requirements are based on the premise that the referencing document will specify fabrication, design, base metal, filler metal, heat treatment, examination, and test requirements applicable to the production brazement. Brazing procedure and performance qualifications that meet the requirements of other documents are acceptable provided they also meet the requirements of this standard.

Brazing Procedure Qualification

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.

Brazing Performance Qualification

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.

Materials

Base metals and filler metals have been grouped, which will reduce the number of qualifications required. Substitution of one base metal or filler metal for another, even when within the allowable limits, should only be made after an evaluation of the factors involved. For some materials or combinations of materials, additional tests may be required.

Comments and suggestions for improvement are welcome. They should be sent to the Secretary, AWS Committee on Welding Qualification, American Welding Society, 550 N.W. LeJeune Rd., P.O. Box 351040, Miami, FL 33135.

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Standard for Brazing Procedure and Performance Qualification

1. General Provisions

1.1 Scope

1.1.1 This standard provides the requirements for qualification of Brazing Procedure Specifications.

1.1.2 This standard also provides requirements for the performance qualification of brazers and brazing operators.

1.1.3 This standard is intended for use where referenced by a product standard or contract document.

1.2 Terms and Definitions

1.2.1 The welding and brazing terms used in this standard shall be interpreted in accordance with the definitions given in the latest edition of ANSI/AWS A3.0, *Standard Welding Terms and Definitions*.

1.2.2 Two A3.0 terms, as identified, and other terms are defined below.

brazing performance qualification record. 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 a brazing operator.

brazing procedure qualification record. (BPQR) A record of brazing variables used to produce an acceptable test brazement and the results of tests conducted on the brazement to qualify a brazing procedure specification. (As defined in ANSI/AWS A3.0.)

brazing procedure specification (BPS). A document specifying the required brazing variables for a specific application. (As defined in ANSI/AWS A3.0.)

brazing variable. Brazing data that are recorded on the BPQR and 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 standard, 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.

pipe. Used generally to refer to pipe and tube.

plate. Used generally to refer to plate and sheet.

procedure qualification record. See brazing procedure qualification record.

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

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

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

qualified brazing procedure. A brazing procedure meeting the qualification requirements of this standard based on qualification tests of brazements made in accordance with the BPS and recorded on a BPQR.

qualifier. The employer, organization, or individual specified by the referencing document as responsible for conducting and supervising qualification testing.

referencing document. The product standard or contract document that invokes this standard.

specimen. The article made from a specimen blank that is 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 specimen. In some cases, the specimen blank is also the specimen.

T. A symbol for base metal thickness.

t. A symbol for bend specimen thickness.

test brazement. Workpieces joined by brazing for the purpose of qualifying brazing procedures, brazers, or brazing operators.

1.2.3 When required by context in this standard, the singular shall be interpreted as the plural, and vice versa; and the masculine gender shall be considered as both genders.

1.3 Responsibilities

1.3.1 Employers shall be responsible for the brazing done by their organization, including the use of qualified brazing procedures, qualified brazers, and qualified brazing operators.

1.3.2 It is the employer's responsibility to assure that Brazing Procedure Specifications meet any additional requirements of the referencing document.

1.3.3 Each employer shall maintain the applicable Brazing Procedure Specifications, Brazing Procedure Qualification Records, and Brazing Performance Qualification Records during the period of their use.

1.4 Effective Date. When not otherwise specified by the referencing document, the edition of this standard to be used shall be established in accordance with the following:

1.4.1 Editions may be used at any time after the effective date of issue.

1.4.2 Editions become mandatory for new contracts six months after the effective date of issue.

1.4.3 In cases where there is no specific contract date, the edition to be used shall be established by the contracting parties.

1.4.4 Editions established by contract date may be used during the entire term of the contract, or the provisions of later editions shall be established by the contracting parties.

1.5 Brazing Processes. This document is intended primarily for use with the following brazing processes:

- (1) TB Torch brazing
- (2) FB Furnace brazing
- (3) IB Induction brazing

(4) RB Resistance brazing

(5) DB Dip brazing

(6) IRB Infrared brazing

1.6 Base Metals

1.6.1 The grouping of base metals by Base Metal Number (BM No.) in Table B1 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.

1.6.2 Base metals are identified by their American Society for Testing and Materials (ASTM)¹ or American Bureau of Shipping (ABS)² designations for ferrous metals, except for stainless steels; and by Unified Numbering System (UNS)³ numbers for stainless steels, aluminum and aluminum alloys, copper and copper alloys, nickel and nickel alloys, titanium and titanium alloys, zirconium and zirconium alloys, magnesium alloys, and cobalt alloys.

1.6.2.1 Cross reference specifications, listed in the Unified Numbering System for Metals and Alloys opposite a given UNS No., are included in the same BM No. group as the given UNS No.

1.6.2.2 An American Society of Mechanical Engineers (ASME) designation, which is the same as an ASTM designation preceded by the letter S, is included in the same BM No. group.

1.6.3 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. ASTM standards can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia PA 19103.

2. ABS standards can be obtained from the American Bureau of Shipping, 45 Eisenhower Drive, Paramus NJ 07662.

3. SAE standards can be obtained from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale PA 15096; or American Society for Testing and Materials.

1.7 Filler Metals

1.7.1 The grouping of filler metals by Filler Metal Number (FM No.) in Table C1 has been made on the basis of chemical composition to decrease the number of required brazing qualifications.

1.7.2 The grouping does not imply that filler metals may be indiscriminately substituted within the same FM No. without consideration of their applicability.

1.7.3 ANSI/AWS A5.8, *Specification for Brazing Filler Metal*,⁴ provides the detailed requirements and general applicability of filler metals.

1.7.4 Filler metals other than listed in AWS A5.8 may be used provided such filler metal meets the qualification requirements of this standard.

1.8 Safety Precautions. All brazing, whether for qualification purposes or production work poses safety and health concerns. The requirements of ANSI/AWS Z49.1, *Safety in Welding and Cutting* should be part of each employer's safety program.

2. Brazing Procedure Qualification

2.1 General

2.1.1 Each brazing procedure shall be qualified to establish the properties that are expected to result from its application to production brazements. To qualify a brazing procedure, the following steps are necessary.

(1) The employer shall prepare a preliminary Brazing Procedure Specification (BPS) to be used in making a test brazement. A suggested form for this BPS is given in Appendix A, Form A1. Other forms may be used, provided all qualification variables and other applicable information are included.

(2) The conditions used in making the test brazement and the results of required examination and specimen testing shall be recorded on a Brazing Procedure Qualification Record (BPQR). A suggested BPQR form is given in Appendix A, Form A2. Other forms may be used, provided all qualification variables and other applicable information are included.

(3) If the results meet acceptance requirements, the BPQR shall be signed and dated by the Qualifier as an accurate record of the brazing and testing of the procedure test brazement.

(4) If the results do not meet acceptance requirements, the test brazement shall be discarded, and a new test

brazement prepared in accordance with a revised BPS. Test brazements shall not be repaired.

(5) The employer shall signify acceptance of responsibility for the brazing, testing, and production application of the procedure by signing and dating the final BPS. Procedures qualified by one employer are not transferable to another employer.

2.1.2 During the making of procedure test brazements, 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 procedure test brazing
- (3) Preparation of specimens from the completed brazement
- (4) Performance of examination and mechanical tests
- (5) Documentation of results

2.1.3 A change in qualification variable beyond the allowed limits shall require requalification of the BPS and preparation of a new BPS. Changes in other variables shall not require requalification, provided such change is documented in a revised BPS.

2.1.4 BPQR's shall not be revised, except to correct errors or add omitted information. However, all such changes shall be identified and dated on the BPQR.

2.1.5 BPS's and BPQR's shall be identified according to a system that allows permanent traceability between the BPS and BPQR.

2.1.6 A BPS may require the support of more than one BPQR, while alternatively, one BPQR may support a number of BPS's.

2.2 Test Brazements and Acceptance Criteria. Each brazing procedure shall be qualified by making one test brazement for each supporting BPQR; except where the required specimens cannot be obtained from one test brazement. These may be either standard test brazements or workmanship test brazements, when permitted by the referencing document, as indicated in Table 1, together with the required type of specimens to be made from the test brazements. Standard test brazements are illustrated in Figures 1A through D. Typical workmanship test brazements are shown in Figure 2.

2.2.1 Visual Examination. All test brazements shall be inspected by visual means prior to cutting for mechanical and macroetch specimens. The results of the visual examination shall meet the following requirements:

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

4. ANSI/AWS standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, P. O. Box 351040, Miami FL 33135.

Table 1
Procedure Qualification Test Brazement

Test Brazement	Joint Type	Specimens*
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 2.2.6)	Macroetch

*Two specimens are required for each test.

2.2.1.2 No unfused filler metal shall be present.

2.2.1.3 Undercutting shall have a maximum depth of five percent of the base metal thickness, or 0.010 in., whichever is the lesser.

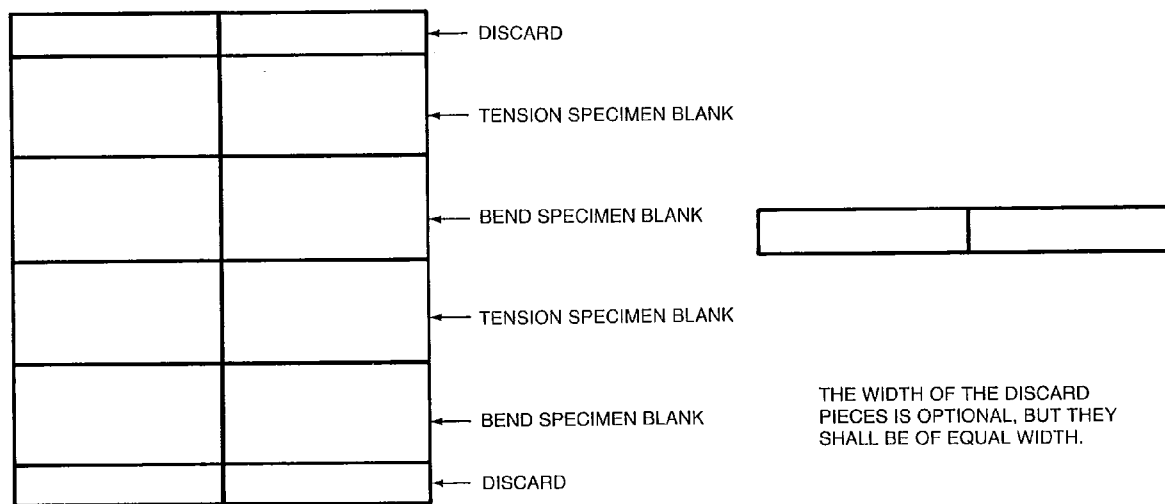
2.2.1.4 No cracks shall be visible in the joint perimeter.

2.2.1.5 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. This requirement does not apply to fusion resulting from tack welds, located in portions to be discarded, used to assemble a test brazement.

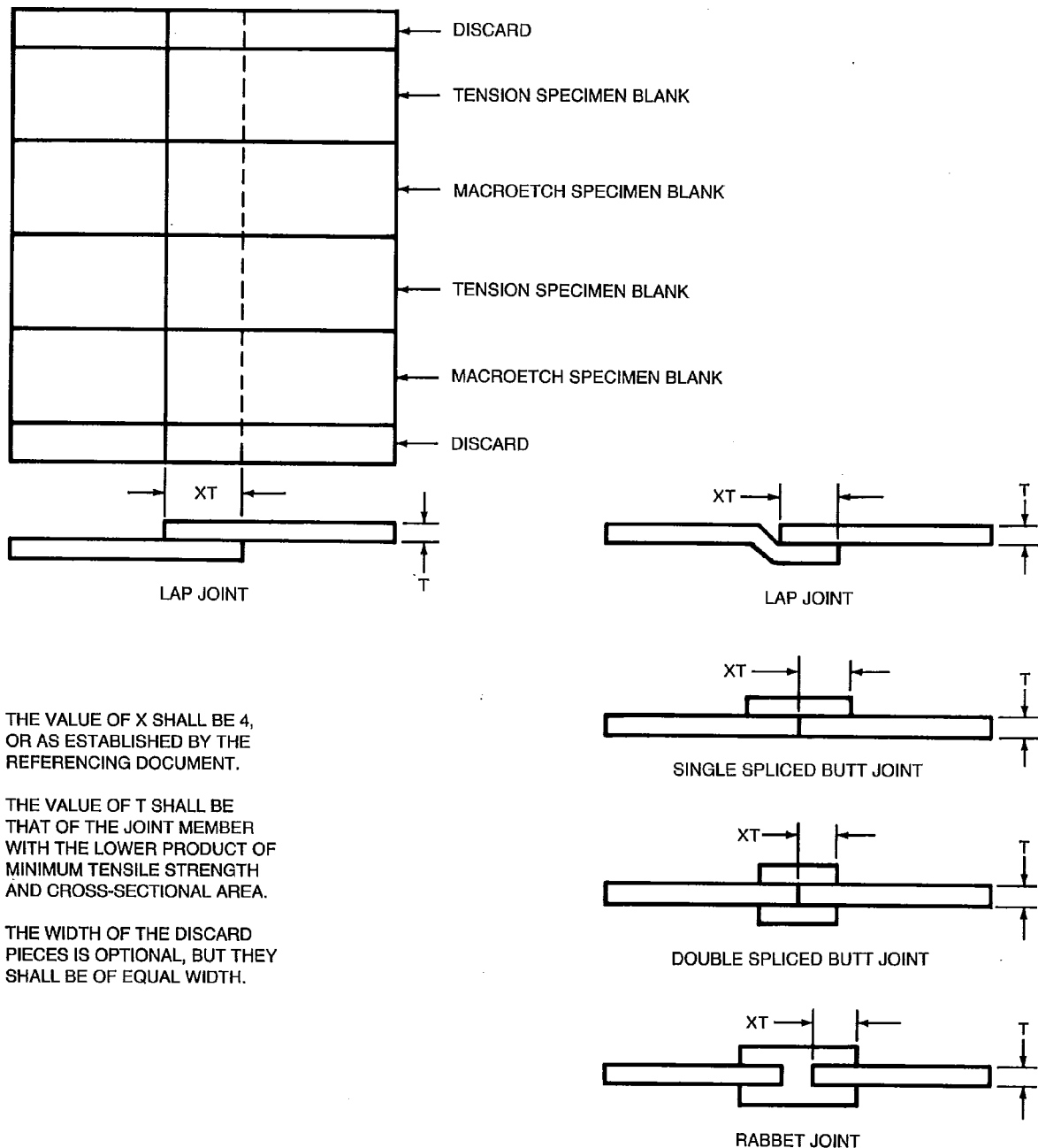
2.2.2 Tension Test. The cutting plan for the blanks for the tension specimens from standard test brazements is shown in Figures 1A through D, except that the specimen for pipes with an outside diameter of 3 in. or less shall be in accordance with 2.2.2.4.

2.2.2.1 Tension specimens as shown in Figure A2A shall be tested for butt joints in plate.

2.2.2.2 Tension specimens as shown in Figure A2B for lap joints, spliced butt joints, and rabbit joints in plate 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 2.2.5, the tension specimen shall be tested without removal of the flanges.



**Figure 1A—Cutting Plan of Test
Brazement for Butt Joints in Plate**

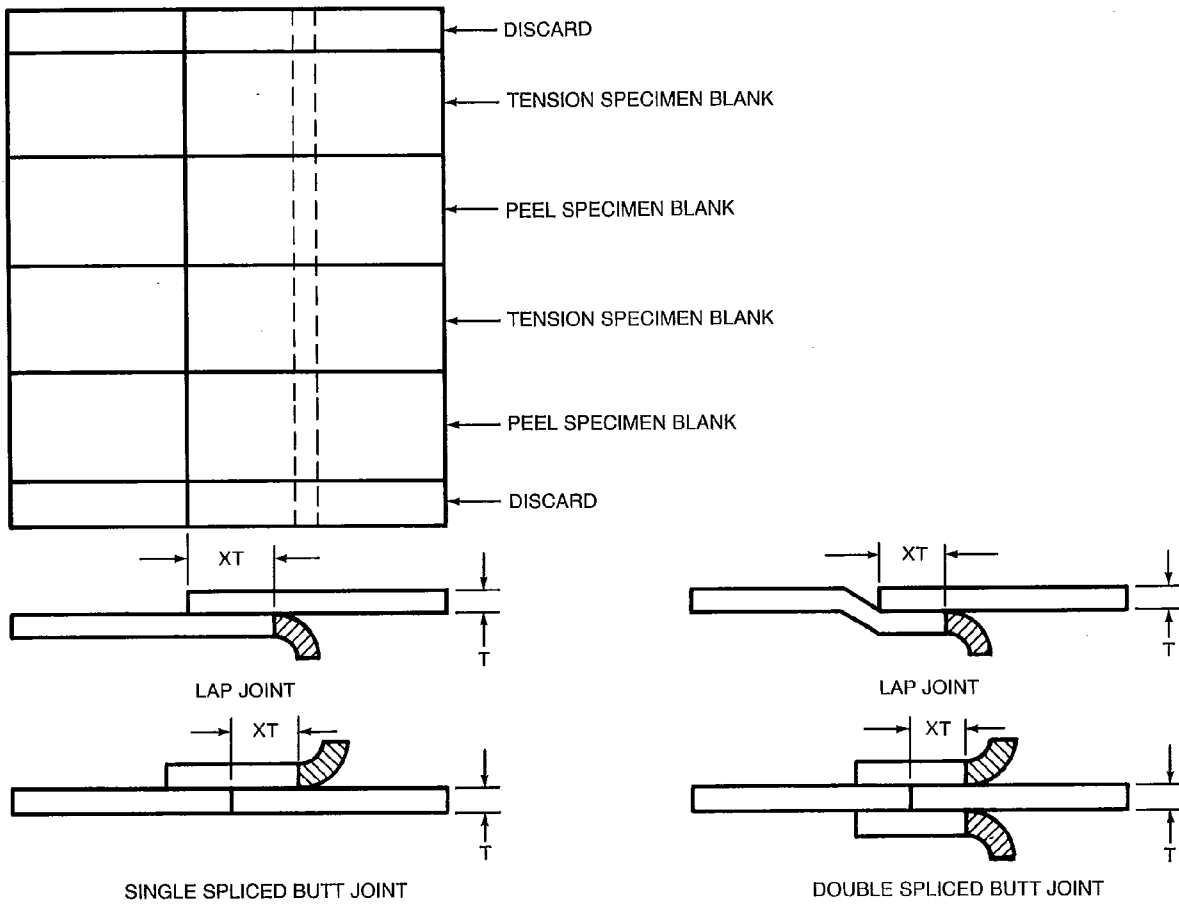


THE VALUE OF X SHALL BE 4,
OR AS ESTABLISHED BY THE
REFERENCING DOCUMENT.

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 OPTIONAL, BUT THEY
SHALL BE OF EQUAL WIDTH.

**Figure 1B—Cutting Plan of Test
Braze 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 OPTIONAL, BUT THEY SHALL BE OF EQUAL WIDTH.

SHADED AREA SHOWS OPTIONAL FLANGE.

**Figure 1C—Cutting Plan of Test
Brazement for Lap Joints and Single and Double
Spliced Butt Joints in Plate**

2.2.2.3 For pipes with an outside diameter greater than 3 in., tension specimens as shown in Figure A2A or A2B, 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 2.2.5, the tension specimen shall be tested without removal of the flanges.

2.2.2.4 For pipes with an outside diameter of 3 in. or less, a tension specimen consisting of a length of the entire joint shall be tested as shown in Figure A2C.

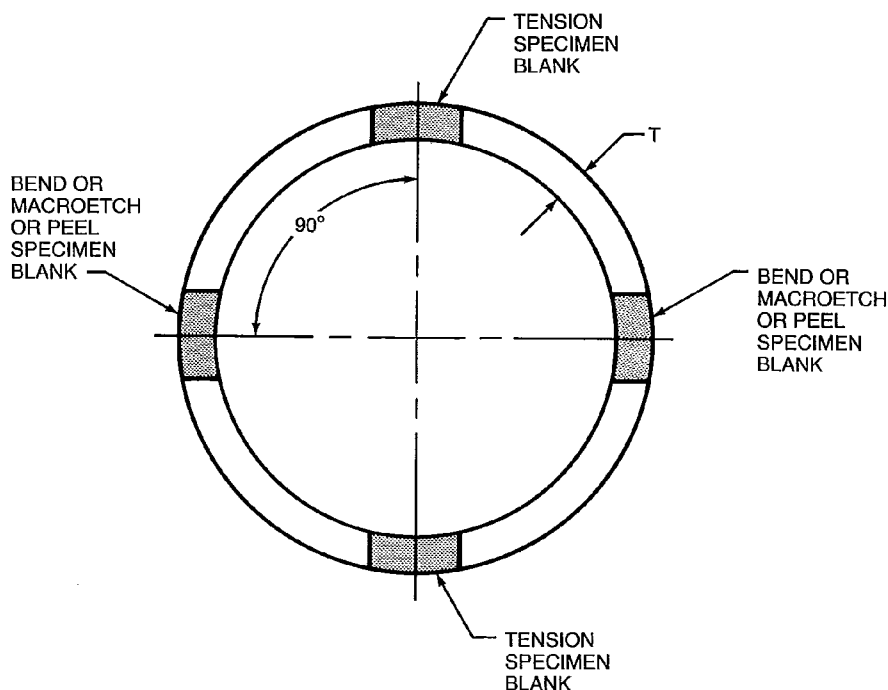
2.2.2.5 Acceptance criteria for Butt Joints. The specimen shall have a tensile strength not less than that established by the referencing document.

2.2.2.6 Acceptance Criteria for Lap Joints, Spliced Butt Joints, and Rabbet Joints. The specimen shall have a tensile strength not less than 95 percent

of the minimum tensile strength of the base metal. If this minimum tensile strength is not given in Table B1, 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 a dissimilar metal joint, either in thickness or chemical composition of the base metal or both, the divisor shall be the cross-sectional area of the joint member with the lower product of minimum tensile strength and cross-sectional area.

2.2.3 Bend Test. The cutting plan for the blanks for the bend specimens from standard test brazements is shown in Figures 1A and D. Figure 1D applies to pipes of all diameters.

2.2.3.1 Bend specimens as shown in Figure A3A shall be tested for butt joints in plate and pipe.



THE SPECIMENS AT THE HORIZONTAL DIAMETER ARE BEND SPECIMENS FOR BUTT JOINTS, MACROETCH SPECIMENS FOR RABBET 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 1A THROUGH C.

Figure 1D—Cutting Plan of Test Brazement for All Joints in Pipe of Greater Than 3 in. (76 mm) Outside Diameter

2.2.3.2 The bend specimens shall be bent to a 90 degree angle by hammer blows or other suitable means, in a jig as shown in Figure A3B.

2.2.3.3 The specimen shall meet one of the following criteria:

- (1) The specimen does not separate.
- (2) The specimen separates in the base metal.
- (3) The specimen separates at the braze joint, and the total area of discontinuities; such as pores, voids, unbrazed areas, and inclusions, does not exceed 15 percent of the area of either fracture surface. No discontinuity dimension, or combination of discontinuity dimensions, extends more than 25 percent along any line that would provide a leak path from one plate or pipe surface to the opposing surface.

2.2.4 Macroetch Test. The cutting plan for the blanks for the macroetch specimens from the standard test brazements is shown in Figures 1B and D. The blanks shall be 1-1/2 in. in width; except that for pipe with an outside diameter of 3 in. or less, the blanks shall be two opposing quadrants.

2.2.4.1 Both sides of each blank shall be smoothed and etched with a reagent to give a clear definition of the braze and examined with a 3-power magnifying glass.

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

2.2.5 Peel Test. Peel tests of standard test brazements with lap or spliced butt joints in plate or pipe with an outside diameter greater than 3 in. may be substituted for the macroetch test; provided that the peel specimen separates entirely at the braze joint.

2.2.5.1 The cutting plan for the blanks for the peel specimens from standard test brazements is shown in Figures 1C and D. The blanks shall be approximately 1-1/2 in. in width.

2.2.5.2 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 1C, to facilitate peel testing, is optional.

2.2.5.3 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.

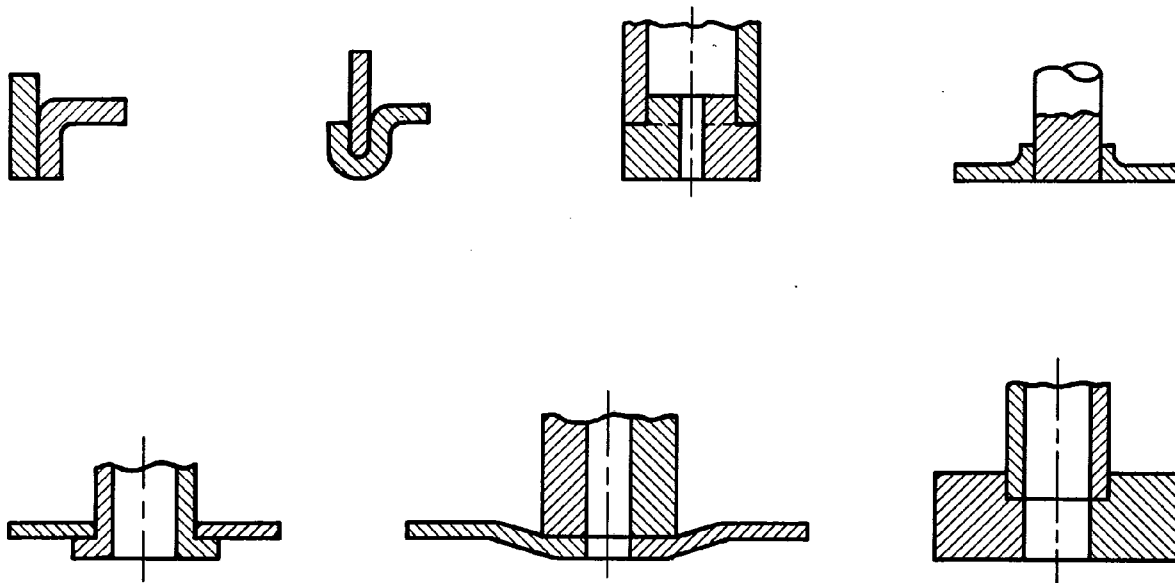


Figure 2—Typical Workmanship Test Brazements

2.2.5.4 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 30 percent of the faying surface. No discontinuity dimension, or combination of discontinuity dimensions, shall extend more than 25 percent along any line that would provide a leak path from one plate or pipe surface to the opposing surface.

2.2.6 Workmanship Test Brazements. For joints other than those identified in Table 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 2.

2.2.6.1 Test brazements of linear joints shall be 10 in. 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.

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

2.2.6.3 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 a 3-power magnifying glass.

2.2.6.4 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 percent of any single braze length of each joint member. No cracks shall be present in the joint or in the base metal.

2.3 Qualification Variables

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

- (1) A change from one brazing process to any other.
- (2) The addition 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.

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

- (1) A change from a base metal given under one BM No. in Table B1 to a base metal given under another BM No. or to a base metal not included in the table.
- (2) A change from a base metal not included in Table B1 to any other base metal.

(3) When a joint in a given base metal is qualified, qualification in another base metal of the same BM No. is limited to a joint strength equal to the lesser of the following.

(a) Ninety-five percent of the minimum tensile strength of the base metal used for the test brazement. If this minimum tensile strength is not given in Table B1, the joint tensile strength shall be established in the referencing document.

(b) Ninety-five percent of the minimum tensile strength of the other base metal under consideration. If this minimum tensile strength is not given in Table B1, the joint tensile strength shall be established in the referencing document.

(4) The brazing procedure for dissimilar metal joints need not be requalified if the base metals involved are included in only one of the eight categories given in 1.6.3, and if the brazing conditions for the dissimilar metal joint are the same as for each of the base metals involved, within the limitations of the qualification variables.

2.3.3 Base Metal Thickness. A change made in base metal thickness to a value outside the range qualified in accordance with Table 2, requires requalification of the BPS.

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

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

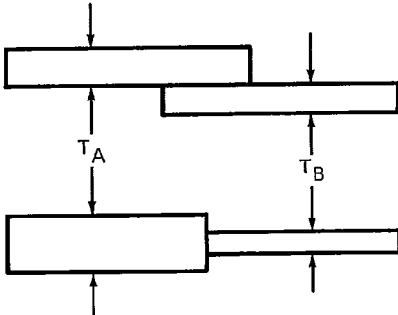
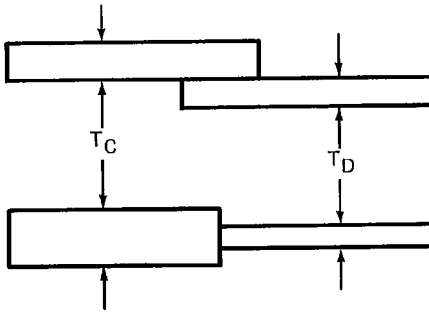
- (1) A change from a filler metal given in Table C1 under one FM No. to a filler metal given under another FM No. or to a filler metal not included in the table.
- (2) A change from a filler metal not included in Table C1 to any other filler metal.
- (3) A change from any form of filler metal to another form.
- (4) A change from preplaced filler metal or mechanically-fed filler metal to manually-fed filler metal.

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

- (1) A change in the brazing flux from one AWS type given in Table D1 to any other AWS type or to a flux not included in the table.
- (2) A change from a brazing flux not included in Table D1 to any other flux.
- (3) A change from fluxless brazing to flux brazing or vice versa.

Table 2
Range of Thickness Qualified

Test Brazement Base Metal Thickness $T_A \geq T_B$		Qualified Base Metal Thickness $T_C \geq T_D$			
Member A	Member B	Member C		Member D	
		max.	min.	max.	min.
T_A	T_B	$1.2(T_A/T_B)T_D$	T_D	T_B	$1/4 T_B$

Note: T_A is the thickness of thicker member of the test brazement with a minimum thickness equal to T_B .
 T_B is the thickness of thinner member of the test brazement with a maximum thickness equal to T_A .
 T_C is the thickness of thicker member of the qualified brazement with a maximum thickness equal to $1.2 (T_A/T_B)T_D$ and the minimum thickness equal to T_D .
 T_D is the thickness of thinner member of the qualified brazement with a maximum thickness equal to T_B and a minimum thickness equal to $1/4 T_B$.

2.3.7 Bath Composition. A change made in the nominal composition of the brazing medium requires requalification of the BPS.

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

- (1) A change in the brazing atmosphere from one AWS type given in Table E1 to any other AWS type or to any other atmosphere.
- (2) A change from a brazing atmosphere not included in Table E1 to any other atmosphere.

2.3.9 Brazing Temperature. A BPS shall be requalified when there is a change in brazing temperature as described in any of the following subparagraphs,

- (1) A change of more than 20 percent of the A to D range.
- (2) A change from a temperature within the B to C range to a temperature within either the A to B range or the C to D range.
- (3) A change from a temperature within the A to B range to a lower temperature.
- (4) A change from a temperature from within the C to D range to a higher temperature.
- (5) For filler metals not included in Table C1, any change in brazing temperature.

where, for the applicable filler metal classification:

A is the lower limit of the brazing temperature range given in Table C1,

B is 20 percent of the brazing temperature range given in Table C1 above the lower limit,

C is 20 percent of the brazing temperature range given in Table C1 below the upper limit, and,

D is the upper limit of the brazing temperature range given in Table C1.

2.3.10 Brazing Time. A change in the brazing time of more than 10 percent requires requalification.

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

(1) A change from a joint type included in Figures 1A through D to another joint type included in Figures 1A through D or to any other joint type.

(2) A change from a joint type not included in Figures 1A through D to any other joint type.

(3) The addition or deletion of a flange for the joint types of Figure 1C is not considered a change in joint type.

(4) An increase in lap length of $1/4$ in. or $2T$, whichever is the lesser. For joints of dissimilar base

metal thickness, the applicable T is that of the thinner joint member.

(5) A decrease in the ratio of lap length to base metal thickness.

(6) A decrease in the bevel angle.

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

(1) For a qualified joint clearance within the range given in Table F1, a change to a joint clearance outside the given range.

(2) For a qualified joint clearance outside the range given in Table F1, and for filler metals not included in Table F1:

(a) A change in joint clearance of 1 mil⁵ for a qualified joint clearance of 1 to 2 mils

(b) 2 mils for 3–5 mils

(c) 3 mils for 6–10 mils

2.3.13 Brazing Position. A change from one of the seven brazing positions included in Appendix A1 to another of those positions requires requalification, with the exceptions given below.

(1) Qualification in the horizontal flow position for pipe shall also qualify in plate for both flat flow position and horizontal flow position.

(2) Qualification in the vertical downflow position for pipe shall also qualify for same position in plate.

(3) Qualification in the vertical upflow position for pipe shall also qualify for same position in plate.

(4) When production brazing is performed in a position that does not conform to any of the seven brazing test positions included in Appendix A1, qualification test brazements shall be made in the production brazing position. Such qualifications are valid only for the position actually tested; except that an angular deviation, analogous to that permitted in the seven positions of Appendix A1, is permitted.

2.3.14 Postbrazing Heat Treatment. A change in the postbrazing heat treatment requires requalification of the BPS.

3. Brazing Performance Qualification

3.1 General

3.1.1 Qualification under this section requires completion of test brazements in accordance with a qualified BPS and acceptance by the Qualifier of the test brazements and the results of the specimen tests.

⁵ 1 mil = 0.001 in.

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

(1) Qualification by visual examination (see 3.2), when allowed by referencing document.

(2) Qualification by specimen testing (see 3.3).

3.1.3 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.

3.1.4 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 3.4 and 3.5.

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

3.1.6 Qualification is permitted on production brazements, provided such qualification is not prohibited by the referencing document.

3.1.7 Test brazements shall not be repaired.

3.1.8 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. A suggested form is Form A3. Other forms may be used, provided all qualification variables and other applicable information are included.

3.1.9 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.

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

3.2 Qualification by Visual Examination

3.2.1 Qualification by visual examination is permitted when allowed by the referencing document.

3.2.2 Qualification by visual examination requires completion of a workmanship test brazement representative of the design details of the joint to be qualified, which shall be accepted or rejected by visual examination. Typical workmanship test brazements are shown in Figure 2.

3.2.3 The workmanship test brazement shall be visually examined and shall meet the following requirements:

- (1) Braze metal shall be present at all edges of a joint.
- (2) No unfused brazing filler metal shall be present.
- (3) Undercutting shall have a maximum depth of five percent of the base metal thickness, or 0.010 in., whichever is the lesser.
- (4) No cracks shall be present at the joint perimeter.
- (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. This requirement does not apply to fusion resulting from tack welds, located in portions to be discarded, used to assemble a test brazement.

3.3 Qualification by Specimen Testing

3.3.1 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.

3.3.2 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 3.2.3.

3.3.3 Macroetch Test of Standard Test Brazement. The test brazement shall be one of the joint types shown in Figures 1A, 1B, or 1D in either plate with a minimum joint length of 3 in., or in pipe.

(1) 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 macroetch specimen blanks. Pipe joints shall be cut into quadrants, and two opposing quadrants shall be selected as macroetch specimen blanks.

(2) Both sides of each specimen blank shall be smoothed and etched with a reagent to give a clear definition of the braze, and examined with a 3-power magnifying glass.

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

3.3.4 Peel Test of Standard Test Brazement. Peel tests of test brazements with lap or spliced butt joints in plate or pipe with an outside diameter greater than 3 in. may be substituted for the macroetch test, provided

that, the peel specimen separates entirely at the braze joint.

(1) The test brazement shall be selected from those shown in Figures 1B, 1C, or 1D. 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.

(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. For pipe joints, two peel specimen blanks, each 3/4 in. in width, shall be cut at locations 180 degrees apart.

(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) 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 30 percent of the faying surface. No discontinuity dimension, or combination of discontinuity dimensions, shall extend more than 25 percent along any line that would provide a leak path from one plate or pipe surface to the opposing surface.

3.3.5 Workmanship Test Brazements. The test brazement shall be representative of a production joint, with a minimum length of 3 in. for linear joints, or the entire joint for circular joints. Typical workmanship test brazements are shown in Figure 2.

(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.

(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 a 3-power magnifying glass.

(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 percent of any single joint length. No cracks shall be present in the joint or in the base metal.

3.4 Qualification Variables for Brazers

3.4.1 Brazing Process. Brazers must be requalified when there is any change in qualification variables as described below:

- (1) A change from one brazing process to any other.

Table 3
Base Metals Qualified

Base Metal Number		Base Metal Number	
Test Brazement	Qualified	Test Brazement	Qualified
100	100	300	300-310
110	100, 110	310	300-310
120	100-120	320	300-320
130	100, 110, 130	330	300-330
140	100-140	340	300-340
150	100, 110, 130, 150	350	300-350
160	100-160	360	300-360
170	100-170	400	400-410
180	100-180	410	400-410
200	200, 210	420	400-420
210	200, 210	430	400-430
220	200-220	500	500
		600	600
		700	700
		800	800

(2) The addition of any other brazing process to that or those already qualified. (For example, the use of an oxy-acetylene torch to finish joints brazed by the resistance brazing process).

3.4.2 Base Metal. Brazers must be requalified when there is any change in qualification variables as described below:

(1) A change from a base metal given under one BM No. in Table B1 to a base metal given under another BM No., with the exceptions as given in Table 3.

(2) A change from a base metal not included in Table B1 to any other base metal.

(3) The brazing of dissimilar metal joints need not be requalified if the base metals involved are included in only one of the eight categories given in 1.6.3, and if the brazing conditions for the dissimilar metal joint are the same as for each of the base metals involved, within the limitations of the qualification variables.

3.4.3 Base Metal Thickness. A change in base metal thickness to a value outside the range qualified in accordance with Table 2 requires requalification.

3.4.4 Brazing Filler Metal. Brazers must be requalified when there is any change in qualification variables as described below:

(1) A change from a filler metal given in Table C1 under one FM No. to a filler metal given under another FM No. or to a filler metal not included in the table.

(2) A change from a filler metal not included in Table C1 to any other filler metal.

(3) A change from preplaced filler metal or mechanically-fed filler metal to manually-fed filler metal.

3.4.5 Brazing Position. A change from one of the seven brazing positions included in Appendix A1 to another of those positions is a qualification variable. Exceptions to this general requirement are given in Table 4, where brazing positions qualified by a test brazement are indicated by an X.

(1) Other Positions. When production brazing is performed in a position that does not conform to any of the seven brazing positions included in Appendix A1, qualification test brazements shall be made in the production brazing position. Such qualifications are valid only for the position actually tested; except that an angular deviation, analogous to that permitted in the seven positions of Appendix A1, is permitted.

(2) If the filler metal is preplaced in the joint so that there is no major flow, the joint may be brazed in any position without requalification.

3.4.6 Joint Design. Brazers must be requalified when there is any change in qualification variables as described below:

(1) A change from a butt joint to any joint with overlapping members or vice versa.

(2) An increase in lap length of 1/16 in. or 25 percent, whichever is greater.

Table 4
Brazing Position Qualified by Position of Test Brazement

Test Brazement		Qualified Brazing Position						
Form	Brazing position	Plate				Pipe		
		Flat flow	Vertical downflow	Vertical upflow	Horizontal flow	Horizontal flow	Vertical downflow	Vertical upflow
Plate	Flat flow	X	X					
	Vertical downflow		X					
	Vertical upflow		X	X				
	Horizontal flow		X		X			
Pipe	Horizontal flow	X	X		X	X	X	
	Vertical downflow		X				X	
	Vertical upflow		X	X			X	X

3.5 Qualification Variables for Brazing Operators

3.5.1 Brazing Process. Brazing operators must be requalified when there is any change in qualification variables as described below.

- (1) A change from one brazing process to any other.
- (2) The addition of any other brazing process to that or those already qualified. (For example, the use of an oxy-

acetylene torch to finish joints brazed by the resistance brazing process).

3.5.2 Base Metal. A change from a base metal included in one of the eight categories given in 1.6.3 to a base metal included in one of the other categories requires requalification.

Mandatory Appendixes

These Appendixes contain information and requirements that are part of ANSI/AWS B2.2-91, *Standard for Brazing Procedure and Performance Qualification*.

Appendix A—Brazing Positions, Specimens, Tension Test, Bend Test, and Suggested Forms

Appendix B—Base Metal Groups

Appendix C—Filler Metal Groups

Appendix D—Brazing Fluxes

Appendix E—Brazing Atmospheres

Appendix F—Brazing Joint Design

Appendix A

Brazing Position, Specimens, Tension Test, Bend Test, and Suggested Forms

A1. Brazing Position

The braze metal orientation with respect to planes of reference, for brazing positions, is shown in the first column of Figure A1.

A1.1 Plate Positions

A1.1.1 Flat Flow. Plates in a position for flat flow conditions are shown on line A in diagrams 1 through 5 of Figure A1. The maximum permitted deviation from the specified flow plane is plus or minus 15 degrees.

A1.1.2 Vertical Downflow. Plates in a position for vertical downflow conditions are shown on line B in diagrams 1 through 4 of Figure A1. Filler metal is fed from above the joint. The maximum permitted deviation from the specified flow plane is plus or minus 75 degrees.

A1.1.3 Vertical Upflow. Plates in a position for vertical upflow conditions are shown on line C in diagrams 1 through 4 of Figure A1. Filler metal is fed from below the joint. The maximum permitted deviation from the specified flow plane is plus or minus 75 degrees.

A1.1.4 Horizontal Flow. Plates in a position for horizontal flow conditions are shown on line D in diagram 1 of Figure A1. The maximum permitted deviation from the specified flow plane is plus or minus 75 degrees.

A1.2 Pipe Positions

A1.2.1 Horizontal Flow. Pipes in a position for horizontal flow conditions are shown on line E in diagram 1 of Figure A1. The maximum permitted deviation from the axis of the specified flow cylinder is plus or minus 15 degrees.

A1.2.2 Vertical Downflow. Conditions for vertical downflow are met when the longitudinal axes of the pipes are at an angle greater than 15 degrees from the horizontal position shown on line E in Figure A1, and the filler metal is fed from above the joint.

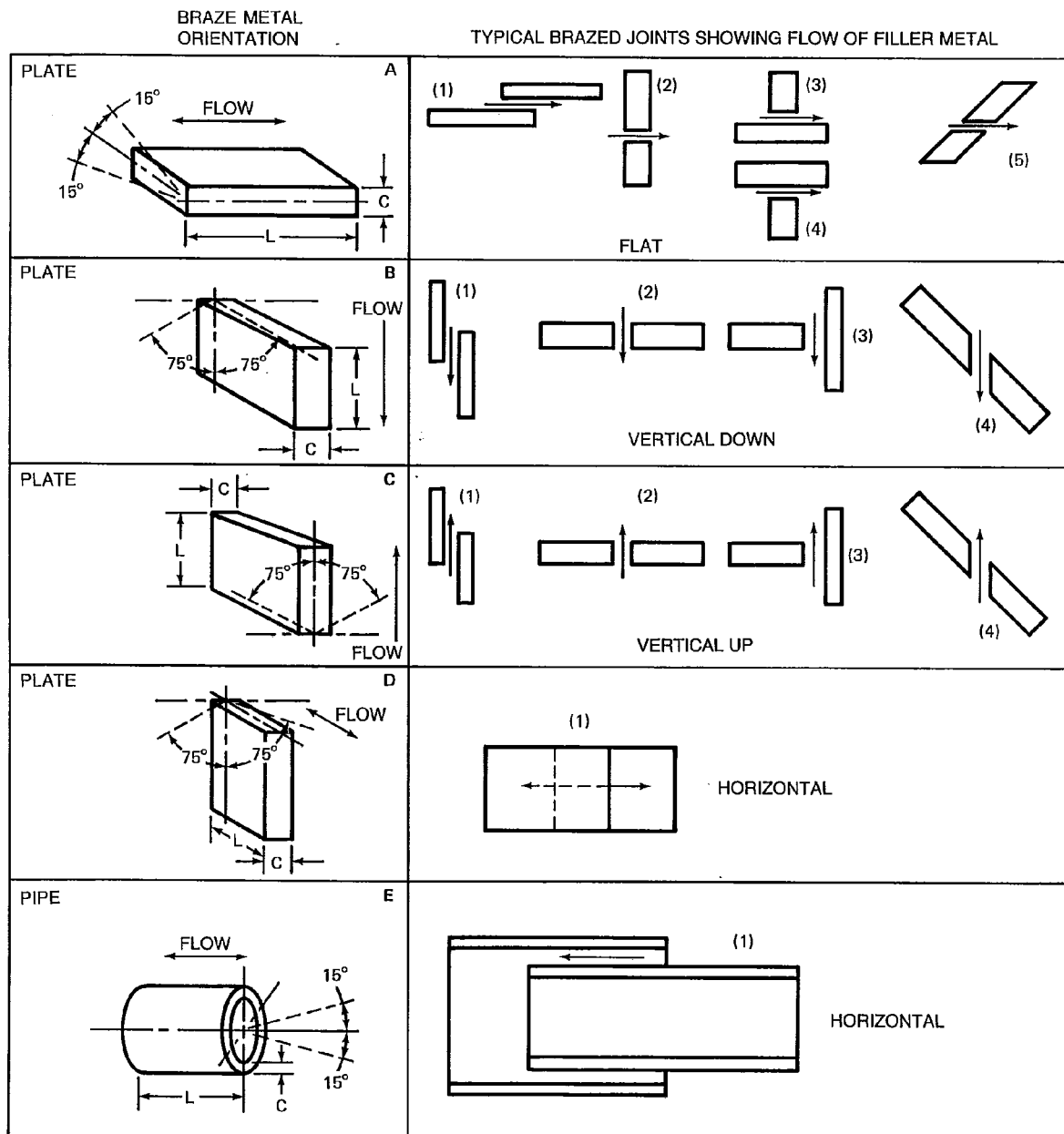
A1.2.3 Vertical Upflow. Conditions for vertical upflow are met when the longitudinal axes of the pipes are at an angle greater than 15 degrees from the horizontal position shown on line E in Figure A1, and the filler metal is fed from below the joint.

A2. Tension Specimens and Tension Test

A2.1 Tension specimens for butt joints are shown in Figure A2A.

A2.2 Tension specimens for lap joints, spliced butt joint, and rabbet joints are shown in Figure A2B.

A2.3 A tension test fixture for small diameter pipe is shown in Figure A2C.



NOTES: C = JOINT CLEARANCE
L = LENGTH OF BRAZE METAL

Figure A1—Brazing Positions

A3. Bend Specimens and Bend Test

A3.1 Bend test specimens for butt joints are shown in Figure A3A.

A3.2 Bend testing of butt joints is shown schematically in Figure A3B.

A4. Mechanical Testing

Further information on tensile testing and bend testing may be found in ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

A5. Suggested Brazing Forms

A5.1 Brazing Procedure Specification (BPS) Form. Form A1 is a suggested form for recording the essential information needed in preparing a BPS.

A5.2 Procedure Qualification Record (PQR) Form. Form A2 is a suggested form for recording the essential information and test results for a PQR.

A5.3 Performance Qualification Test Record Form. Form A3 is a suggested form for recording the essential information to document the performance qualification of a brazer or brazing operator.

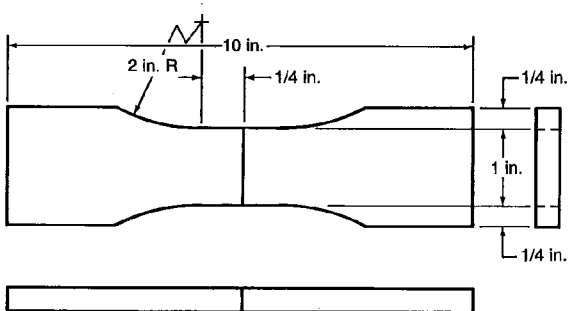


Figure A2A—Tension Specimen for Butt Joints

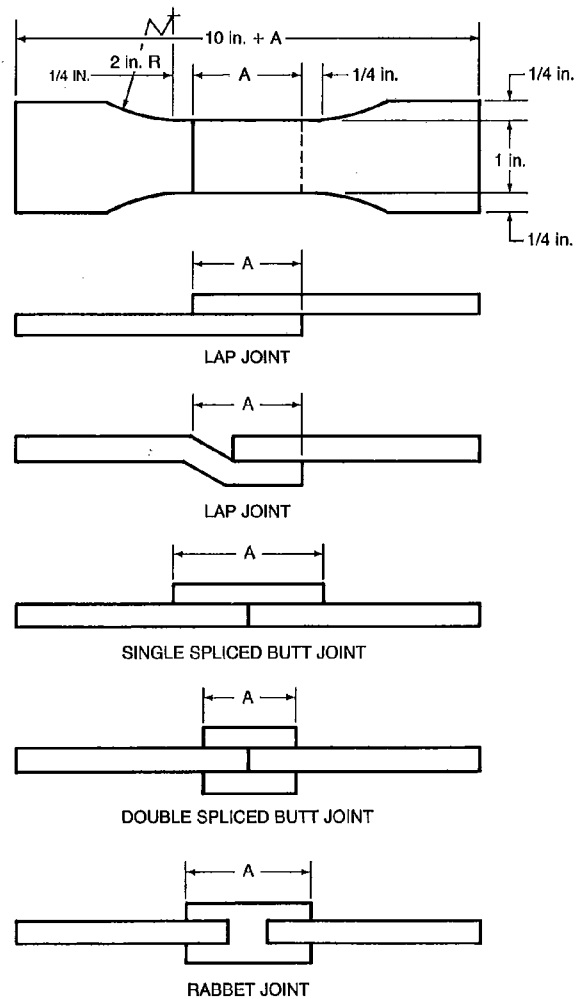


Figure A2B—Tension Specimens for Lap Joints, Spliced Butt Joints, and Rabbet Joints

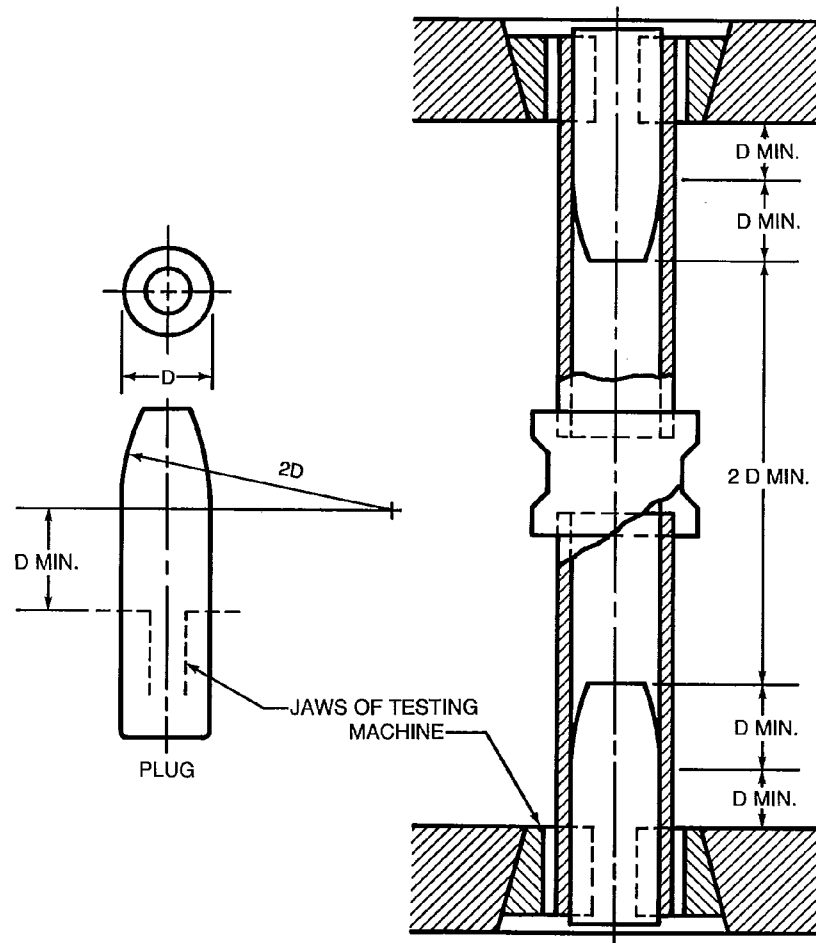
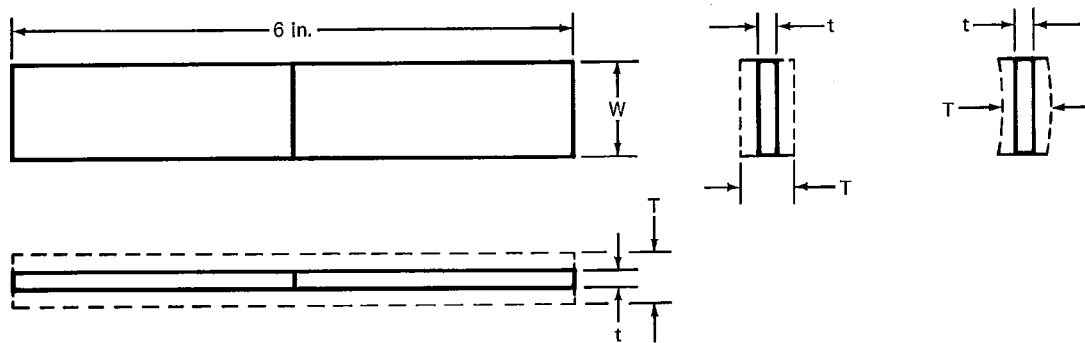


Figure A2C—Tension Test for Small Diameter Pipe



EQUAL THICKNESS OF METAL SHALL BE REMOVED FROM EACH SIDE, WHERE NECESSARY TO MEET THE BEND SPECIMEN THICKNESS REQUIREMENT SHOWN IN THE TABLE BELOW.

Test Brazement			Bend Specimen	
	Outside Diameter, D	Thickness, T	Thickness, t	Width, W
Form	in.	in.	in.	in.
Plate		3/8 and under	T	1 1/2
Plate		over 3/8	3/8	1 1/2
Pipe	under 4	1/4 (6.4) and under	T	D/8
Pipe	under 4	over 1/4	1/4	D/8
Pipe	4 and over	1/4 and under	T	1 1/2
Pipe	4 and over	over 1/4	1/4	1 1/2

Figure A3A—Bend Specimen for Butt Joints

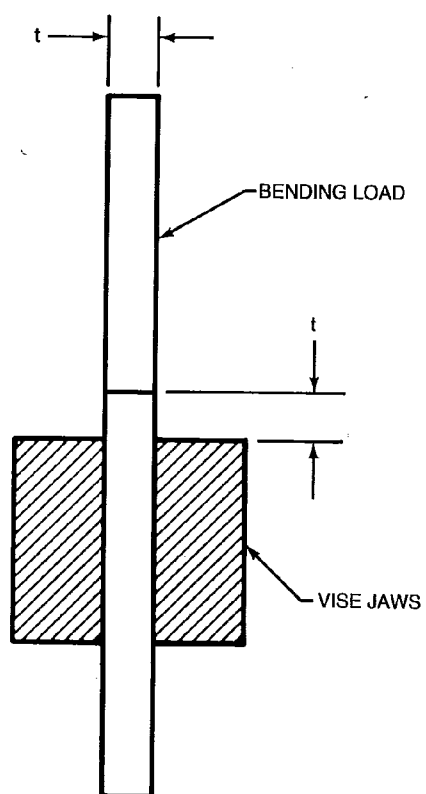


Figure A3B—Bend Test for Butt Joints

Form A1

BRAZING PROCEDURE SPECIFICATION (BPS)

BPS No. _____ Date _____ B PQR NO. _____

Company _____

Brazing Process _____ Manual ☐ Mechanized ☐ Automatic ☐

Brazing Equipment _____

BRAZING CONDITIONS

BASE METAL:

Identification _____ BM No. _____

Thickness _____ Preparation _____

Other _____

FILLER METAL:

FM No. _____ AWS Classification _____

Form _____ Method of Application _____

FLUX: AWS Type _____ Other _____

ATMOSPHERE: AWS Type _____ Other _____

TEMPERATURE: _____ TEST POSITION: _____

TIME: _____ CURRENT: _____

FUEL GAS: _____ TIP SIZE: _____

POSTBRAZE CLEANING: _____

POSTBRAZE HEAT TREATMENT: _____

OTHER: _____

JOINT:

Type _____

Clearance _____

UTS _____

Other _____

Approved for production by _____
Employer

JOINT SKETCH

Form A2

Sheet 1 of 2

PROCEDURE QUALIFICATION RECORD (PQR)

BPQR No. _____ Date _____ BPS NO. _____

Company _____

Brazers' Name and Id. _____

Brazing Process _____ Manual ☐ Mechanized ☐ Automatic ☐

Brazing Equipment _____

BRAZING CONDITIONS

BASE METAL:

Identification _____ BM No. _____

Thickness _____ Preparation _____

Other _____

FILLER METAL:

FM No. _____ AWS Classification _____

Form _____ Method of Application _____

FLUX: AWS Type _____ Other _____

ATMOSPHERE: AWS Type _____ Other _____

TEMPERATURE: _____ TEST POSITION: _____

TIME: _____ CURRENT: _____

FUEL GAS: _____ TIP SIZE: _____

POSTBRAZE CLEANING: _____

POSTBRAZE HEAT TREATMENT: _____

OTHER: _____

JOINT:

Type _____

Clearance _____

Other _____

JOINT SKETCH

Form A2

Sheet 2 of 2

TEST RESULTS

BPQR No. _____ Date _____

VISUAL

Pass

Fail

TENSION

Specimen
No.UTS
psi

Remarks

Pass

Fail

BEND

Specimen
No.

Remarks

Pass

Fail

MACROETCH

Specimen
No.

Remarks

Pass

Fail

PEEL

Specimen
No.

Remarks

Pass

Fail

We certify that the information in this record is correct and that the test brazements were prepared, brazed, and tested in accordance with the requirements of the American Welding Society *Standard for Brazing Procedure and Performance Qualification*, ANSI/AWS B2.2-91.

Approved by _____

Qualifier

Form A3

BRAZING PERFORMANCE QUALIFICATION RECORD

Name _____ Id. _____

Date _____ BPS No. _____

Brazing Process _____ Brazer ☐ Operator ☐

TEST BRAZEMENT

Base Metal Id. _____ BM No. _____ BM T _____

Filler Metal Id. _____ FM No. _____ FM Feed _____

Test Position _____ Joint Type _____

Other _____

TEST RESULTS

VISUAL

Pass

Fail

MACROETCH OR PEEL

Specimen
No.

Remarks

Pass

Fail

QUALIFIED FOR

Brazing Process _____ Position _____

BM No. _____ BM T _____

FM No. _____ FM Feed _____

Joint Type _____

Other _____

The above named individual is qualified in accordance with the American Welding Society *Standard for Brazing Procedure and Performance Qualification*, ANSI/AWS B2.2-91.

Date _____

Signed _____

Qualifier

Appendix B

Base Metal Groups

B1. Base Metal Numbers

Base metals have been grouped by Base Metal Number (BM No.) in Table B1 so that the required number of qualifications may be reduced. Substitution of one base metal for another, for any purpose other than for qualification, even when within the allowable rules, should be made only after an evaluation of all the factors involved.

B2. Basis for Classification of Base Metals for Brazing Qualification

B2.1 General

B2.1.1 Where classification is dependent on the amount of a given element, the controlling value is the maximum content given in the base metal specification.

B2.1.2 The tensile strength is for the annealed condition. Where the minimum tensile strength is not given in Table B1, that value shall be established by the referencing document.

B2.2 Ferrous Alloys. The base metal numbers for ferrous alloys are listed below:

BM No.

- 100 Steels containing 1 percent or less chromium
- 110 Steels containing more than 1 percent chromium. See (1) below.
- 120 Steels containing aluminum or titanium
- 130 Stainless steels, austenitic
- 140 Stainless steels, austenitic containing titanium of less than 1 percent
- 150 Stainless steels, martensitic and ferritic

160 Stainless steels, martensitic and ferritic containing less than 1 percent combined aluminum and titanium

170 Cast iron

180 Cast iron, austenitic

(1) Steels with 12 percent or greater chromium are included in stainless steels

(2) Where the tensile strength given in the specification is dependent on base metal thickness, the strength given in Table B1 is the value for the thickest base metal, up to a limit of 1 in.

B2.3 Aluminum and Aluminum Alloys. The base metal numbers for aluminum and aluminum alloys are listed below:

BM No.

- 200 Aluminum and aluminum alloys containing no magnesium
- 210 Aluminum alloys containing less than 1 percent magnesium
- 220 Aluminum alloys containing 1 percent or more magnesium

B2.4 Copper and Copper Alloys. The base metal numbers for copper and copper alloys are listed below:

BM No.

- 300 Copper and copper alloys
- 310 Copper alloys containing 0.5 to 1 percent lead
- 320 Copper alloys containing more than 1 percent and no more than 5 percent lead
- 330 Copper alloys containing more than 1 percent silicon
- 340 Copper alloys containing 0.5 to 1 percent aluminum or beryllium

350 Copper alloys containing more than 1 percent and no more than 5 percent aluminum or beryllium

360 Copper alloys containing more than 5 percent aluminum or beryllium

B2.5 Nickel and Nickel Alloys. The base metal numbers for nickel and nickel alloys are listed below:

BM No.

400 Nickel and nickel-copper alloys

410 Nickel-molybdenum alloys

420 Nickel-chromium-iron and nickel-chromium-molybdenum alloys

430 Nickel-chromium-iron and nickel-chromium-molybdenum alloys containing less than 1.5 percent combined aluminum and titanium

B2.6 Titanium and Titanium Alloys. The base metal number for titanium and titanium alloys is listed below:

BM No. 500

B2.7 Zirconium and Zirconium Alloys. The base metal number for zirconium and zirconium alloys is listed below:

BM No. 600

B2.8 Magnesium Alloys. The base metal number for magnesium alloys is listed below:

BM No. 700

B2.9 Cobalt Alloys. The base metal number for cobalt alloys is listed below:

BM No. 800

Table B1
Base Metal Groups

BM No.	Specification	Minimum Tensile Strength ksi	BM No.	Specification	Minimum Tensile Strength ksi
Steels					
100	ASTM A27	Grade N1 Grade N2 Grade U60-30 Grade 60-30 Grade 65-35 Grade 70-36 Grade 70-40	100	ASTM A192 ASTM A202 ASTM A203 ASTM A204 ASTM A209 ASTM 210 ASTM A213 ASTM A214 ASTM A216 ASTM A217 ASTM A225 ASTM A226 ASTM A236 ASTM A242 ASTM A250 ASTM 266 ASTM A283 ASTM A284 ASTM A285 ASTM A299 ASTM A302	47 <

Table B1
Base Metal Groups

BM No.	Specification	Minimum Tensile Strength ksi	BM No.	Specification	Minimum Tensile Strength ksi
Steels					
100	ASTM A333 Grade 1		100	ASTM A426 Grade CP1	65
	Grade 3			Grade CP2	60
	Grade 6			Grade CP15	60
	Grade 7		ASTM A441		67
	Grade 8		ASTM A442 Grade 55		55
	Grade 9			Grade 60	60
	ASTM A334 Grade 1		ASTM A455 Type I		70
	Grade 3			Type II	70
	Grade 6		ASTM A486 Class 70		70
	Grade 7			Class 90	
	Grade 8		ASTM A487 Class 1		
	Grade 9			Class 2	
ASTM A335 Grade P1		55		Class 4	
	Grade P2	55		Class 6	
	Grade P15	60		Class 7	
ASTM A336 Grade F1				Class 10	
	Class F30			Class 11	70
	Class F31			Class 12	70
ASTM A350 Grade LF1		60		Class 13	
	Grade LF2			Class 14	
	Grade LF3			Class A	60
	Grade LF5			Class B	70
	Grade LF9			Class C	70
ASTM A352 Grade LCA		60		Class D	80
	Grade LCB	65	ASTM A500 Grade A		45
	Grade LCC			Grade B	58
	Grade LC1			Grade C	62
	Grade LC2		ASTM A501		58
	Grade LC3		ASTM A517 Grade MT 1010		
	Grade LC4			Grade MT 1015	
ASTM A356 Grade 1		70		Grade MTX 1015	
	Grade 2	65		Grade MT 1020	
	Grade 5	70		Grade MTX 1020	
ASTM A366				Grade 1025	
ASTM A369 Grade FPA		48		Grade 1110	
	Grade FPB	60		Grade 1115	
	Grade FP1	55		Grade 1030	
	Grade FP2	55	ASTM A513 Grade 1008		
ASTM A381 Class Y35		60		Grade MT 1010	
	Class Y42	60		Grade MT 1015	
	Class Y46	63		Grade MTX 1015	
	Class Y48	62		Grade 1016	
	Class Y50	64		Grade 1017	
	Class Y52	66		Grade 1018	
	Class Y56			Grade 1019	
	Class Y60			Grade MT 1020	
	Class Y65			Grade MTX 1020	
ASTM A387 Grade 2		55		Grade 1021	
ASTM A414 Grade A		45		Grade 1022	
	Grade B	50		Grade 1023	
	Grade C	55		Grade 1024	
	Grade D	60		Grade 1025	
	Grade E	65		Grade 1026	
	Grade F	70		Grade 1027	
	Grade G	75		Grade 1030	
ASTM A423 Grade 2				Grade 1033	

(ASTM A513 continues next page)

**Table B1
Base Metal Groups**

BM No.	Specification	Minimum Tensile Strength ksi	BM No.	Specification	Minimum Tensile Strength ksi
Steels					
100	ASTM A513 Grade 1035		100	ASTM A519 Grade 4037	
	(continued) Grade 8630			(continued) Grade 4042	
	ASTM A515 Grade 55	55		Grade 4047	
	Grade 60	60		Grade 4063	
	Grade 65			Grade 4118	
	Grade 70			Grade 4337	
	ASTM A516 Grade 55	55		Grade E4337	
	Grade 60	60		Grade 4340	
	Grade 65			Grade E4340	
	Grade 70			Grade 4422	
	ASTM A519 Grade 1008			Grade 4427	
	Grade 1010			Grade 4520	
	Grade MT 1010			Grade 4615	
	Grade 1012			Grade 4617	
	Grade 1015			Grade 4620	
	Grade MT 1015			Grade 4621	
	Grade MTX 1015			Grade 4718	
	Grade 1016			Grade 4720	
	Grade 1017			Grade 4815	
	Grade 1018			Grade 4817	
	Grade 1019			Grade 4820	
	Grade 1020			Grade 5015	
	Grade MT 1020			Grade 5115	
	Grade MTX 1020			Grade 5120	
	Grade 1021			Grade 5132	
	Grade 1022			Grade 5140	
	Grade 1025			Grade 5145	
	Grade 1026			Grade 5150	
	Grade 1030			Grade 5155	
	Grade 1035			Grade 5160	
	Grade 1040			Grade E50100	
	Grade 1045			Grade 6118	
	Grade 1050			Grade 6120	
	Grade 1118			Grade 8115	
	Grade 11L18			Grade 8615	
	Grade 1132			Grade 8617	
	Grade 1137			Grade 8620	
	Grade 1141			Grade 8622	
	Grade 1144			Grade 8625	
	Grade 1213			Grade 8627	
	Grade 12L14			Grade 8630	
	Grade 1215			Grade 8637	
	Grade 1330			Grade 8640	
	Grade 1335			Grade 8642	
	Grade 1340			Grade 8645	
	Grade 1345			Grade 8650	
	Grade 1518			Grade 8655	
	Grade 1524			Grade 8660	
	Grade 1541			Grade 8720	
	Grade 3140			Grade 8735	
	Grade 4012			Grade 8740	
	Grade 4023			Grade 8742	
	Grade 4024			Grade 8822	
	Grade 4027			Grade 9255	
	Grade 4028			Grade 9260	
	(ASTM A519 continues next column)			(ASTM A519 continues next page)	

Table B1
Base Metal Groups

BM No.	Specification	Minimum Tensile Strength ksi	BM No.	Specification	Minimum Tensile Strength ksi
Steels					
100	ASTM A519 (continued)		100	ASTM A588 (continued)	
	Grade 9262			Grade E	
	Grade 9840			Grade F	
	Grade 9850			Grade G	
	Grade 50B40			Grade H	
	Grade 50B44			Grade J	
	Grade 50B46		ASTM A595	Grade A	55
	Grade 50B50			Grade B	60
	Grade 50B60		ASTM A611		
	Grade 51B60		ASTM A612		
	Grade 81B45		ASTM A618	Grade I	
	Grade 86B45			Grade II	
	Grade 94B15			Grade III	65
	Grade 94B17		ASTM A633	Grade A	63
	Grade 94B30			Grade B	63
	Grade 94B40			Grade C	
	ASTM A523			Grade D	
	Grade A	48		Grade E	
	Grade B	60			
	ASTM A524	55	ASTM A658		65
	ASTM A526		ASTM A660	Grade WCA	60
	ASTM A527			Grade WCB	70
	ASTM A529			Grade WCC	70
	ASTM A537		ASTM A709	Grade 36	58
	ASTM A539	45		Grade 50	65
	ASTM A556			Grade 50W	
	Grade A2	47	ASTM A732	Grade 1	60
	Grade B2	62		Grade 2	65
	Grade C2			Grade 3	75
ASTM A557	Grade A2	47		Grade 4	
	Grade B2	60		Grade 5	
	Grade C2	70		Grade 6	
ASTM A570	Grade A	45		Grade 7	
	Grade B	49		Grade 8	
	Grade C	52		Grade 9	
	Grade D	55		Grade 10	
	Grade E	58		Grade 11	
ASTM A572	Grade 42	42		Grade 12	
	Grade 50	50		Grade 13	
	Grade 60	60		Grade 14	
	Grade 65	65	ABS	Grade A	58
ASTM A573	Grade 58	58		Grade B	58
	Grade 65	65		Grade D	58
	Grade 70			Grade E	58
ASTM A575	Grade 1008			Grade DS	
	Grade 1010			Grade CS	
	Grade 1012			Grade AH32	
	Grade 1015			Grade DH32	
	Grade 1017			Grade EH32	
	Grade 1020			Grade AH36	
	Grade 1023			Grade DH36	
	Grade 1025			Grade EH36	
	Grade 1044		110	ASTM A128	Grade C
ASTM A587		48	ASTM A182	Grade F5	
ASTM A588	Grade A			Grade F5a	
	Grade B			Grade F7	
	Grade C			Grade F9	
	Grade D				
	(ASTM A588 continues next column.)			(ASTM A182 continues next page.)	

Table B1
Base Metal Groups

BM No.	Specification	Minimum Tensile Strength ksi	BM No.	Specification	Minimum Tensile Strength ksi
Steels					
110	ASTM A182 Grade F11 (continued) Grade F12 Grade F21 Grade F22		110	ASTM A369 Grade FP3b Grade FP5 Grade FP7 Grade FP9	60 60 60 60
	ASTM A199 Grade T3b Grade T4 Grade T5 Grade T7 Grade T9 Grade T11 Grade T21 Grade T22	60 60 60 60 60 60 60 60		Grade FP11 Grade FP12 Grade FP21 Grade FP22	60 60 60 60
	ASTM A200 Grade T3b Grade T4 Grade T5 Grade T7 Grade T9 Grade T11 Grade T21 Grade T22	60 60 60 60 60 60 60 60		ASTM A387 Grade 5 Grade 7 Grade 9 Grade 11 Grade 12 Grade 21 Grade 22	60 60 60 60 60 60 60
	ASTM A213 Grade T3b Grade T5 Grade T5b Grade T5c Grade T7 Grade T9 Grade T11 Grade T12 Grade T17 Grade T21 Grade T22	60 60 60 60 60 60 60 60 60 60 60 60		ASTM A389 Grade C23 Grade C24	
	ASTM A217 Grade WC6 Grade WC9 Grade C5 Grade C12			ASTM A405 Grade P24	60
	ASTM A335 Grade P5 Grade P5b Grade P5c Grade P7 Grade P9 Grade P11 Grade P12 Grade P21 Grade P22	60 60 60 60 60 60 60 60 60 60		ASTM A423 Grade 1	
	ASTM A336 Class F5 Class F5a Class F12 Class F21 Class F21a Class F22 Class F22a Class F32	60 60 60 60 60 60		ASTM A426 Grade CP5 Grade CP5b Grade CP7 Grade CP9 Grade CP11 Grade CP12 Grade CP21 Grade CP22	60 60 60 60 60 60 70
	ASTM A352 Grade LC2-1			ASTM A473 Type 501 Type 501A Type 501B Type 502	60 60 60 60
	ASTM A356 Grade 6 Grade 8 Grade 9 Grade 10			ASTM A487 Class 8 Class 9	
				ASTM A513 Grade 4130	
				ASTM A519 Grade E3310 Grade 4130 Grade 4135 Grade 4137 Grade 4140 Grade 4142 Grade 4145 Grade 4147 Grade 4150 Grade 4320 Grade 5130 Grade 5135 Grade 5147 Grade 51100 Grade 52100 Grade 6150 Grade E9310	
				ASTM A595 Grade C	60
			120	ASTM A333 Grade 4	60
				ASTM A519 Grade E7140	
				ASTM A562	55

Table B1
Base Metal Groups

BM No.	UNS No.	Common Name	Minimum Tensile Strength ksi	BM No.	UNS No.	Common Name	Minimum Tensile Strength ksi
Stainless Steels							
130	J91540	CA6NM		130	S30452	XM21	85
	J92500	CF3	70		S30500	305	75
	J92600	CF8	70		S30900	309	70
	J92602	CF20	70		S30908	309S	75
	J92603	HF	70		S31000	310	75
	J92613	HC30			S31008	310S	85
	J9270	CF3	65		S31400	314	75
	J92701	CF16F	70		S31600	316	75
	J92710	CF8C	70		S31603	316L	70
	J92800	CF3M	65		S31609	316H	75
	J92803	HF30			S31651	316N	75
	J92900	CF8M	70		S31700	317	75
	J92971	CF10MC	65		S31703	317L	75
	J93000	CG8M	75		S33100	F10	80
	J93001	CG12	75		S34700	347	75
	J93005	HD	75		S34709	347H	75
	J93015	HD50			S34800	348	75
	J93303				S34809	348H	75
	J93400	CH8	65		S35000	AM350 PH	
	J93401	CH10	70		S35500	AM355 PH	
	J93402	CH20	70		S38100	XM15	75
	J93403	HE	85	140	S32100	321	75
	J93413	HE35			S32109	321H	75
	J93423	CE30	80	150	J91150	CA15	
	J93503	HH	75		J91151	CA15M	
	J93513	HH30			J91153	CA40	
	J94003	HI	70		J91540	CA6NM	
	J94013	HI35			J91803	CB30	65
	J94202	CK20	65		J92605	HC	55
	J94203	HK30	65		K91151	F6	
	J94204	HK40	62		S17400	17-4 PH	
	J94213	HN	63		S32900	329	90
	J94214	HN40			S40300	403	70
	J94224	HK	65		S41000	410	70
	J94603	HT30	65		S41008	410S	60
	J94604	HL	65		S41400	414	115
	J94613	HL30			S41600	416	60
	J94650	CN7MS	62		S41623	416Se	70
	J95150	CN7M	62		S42000	420	
	S16800	16-8-2H	70		S42900	429	65
	S20200	202	90		S43000	430	70
	S20910	XM19	100		S43020	430F	70
	S21400	XM31	105		S43023	430FSe	70
	S21600	XM17	90		S43100	431	115
	S21800	Nitronic 60	95		S44002	440A	
	S21900	XM10	90		S44003	440B	
	S21904	XM11	90		S44004	440C	
	S24000	18-3-Mn	100		S44300	443	70
	S30100	301	75		S44600	446	70
	S30200	302	75		S44700	28-4	70
	S30215	302B	75		S44800	28-4-2	70
	S30300	303	75	160	S40500	405	60
	S30323	303Se	75		S40900	409	60
	S30400	304	75		S43036	430Ti	60
	S30403	304L	70		S44400		60
	S30409	304H	75		S44626	26-1	68
	S30451	304N	75				

Table B1
Base Metal Groups

BM No.	UNS No.	Specification	Minimum Tensile Strength ksi	BM No.	UNS No.	Specification	Minimum Tensile Strength ksi
Cast Iron							
170	F22200	ASTM A47	Grade 32510	50	170	F14801	Class 70
	F22400		Grade 35018	53		F15501	Class 80
	F11401	ASTM A48	Class 20	20		F10001	ASTM A319 Class I
	F11701		Class 25	25		F10002	Class II
	F12101		Class 30	30		F10003	Class III
	F12401		Class 35	35			ASTM A338
	F12801		Class 40			F32800	ASTM A395 60-40-18
	F13101		Class 45			F34100	ASTM A476 80-60-03
	F13501		Class 50			F32800	ASTM A536 Grade 604018
	F13801		Class 55			F33100	Grade 654512
	F14101		Class 60			F33800	Grade 805506
	F11501	ASTM A126	Class A	21		F34800	Grade 1009003
	F12102		Class B	31		F36200	Grade 1209002
	F12802		Class C			F20000	ASTM A602 Grade M3210
	F10004	ASTM A159	Grade G1800				Grade M4504
	F10005		Grade G2500				Grade M5003
	F10006		Grade G3000				Grade M5503
	F10007		Grade G3500				Grade M7002
	F10008		Grade G4000				Grade M8501
	F22000	ASTM A197		40			
	F22830	ASTM A220	Grade 40010		180	F41000	ASTM A436 Type 1
	F23130		Grade 45008			F41001	Type 1b
	F23131		Grade 45006			F41002	Type 2
	F23530		Grade 50005			F41003	Type 2b
	F24130		Grade 60004			F41004	Type 3
	F24830		Grade 70003			F41005	Type 4
	F25530		Grade 80002			F41006	Type 5
	F26230		Grade 90001			F41007	Type 6
	F11401	ASTM A278	Class 20	20		F43000	ASTM A439 Type D2
	F11701		Class 25	25		F43001	Type D2b
	F12101		Class 30	30		F43002	Type D2C
	F12401		Class 35	35		F43003	Type D3
	F12803		Class 40			F43004	Type D3A
	F13101		Class 45			F41005	Type D4
	F13502		Class 50			F41006	Type D5
	F13801		Class 55			F41007	Type D5B
	F14102		Class 60			F43010	ASTM A571 Type D2M

Table B1
Base Metal Groups

BM No.	UNS No.	Common Name	Minimum Tensile Strength ksi	BM No.	UNS No.	Common Name	Minimum Tensile Strength ksi
Aluminum and Aluminum Alloys							
200	A91060	1060	8	210	A07100	710.0	32
	A91100	1100	11		A07110	711.0	26
	A93003	3003	14		A07120	712.0	34
	A93003 Alclad	Alc. 3003	13				
210	A93005	3005	17	220	A93004	3004	22
	A93105	3105	14		A95005	5005	15
	A96063	6063	13		A95050	5050	18
	A96951	6951	17		A96061	6061	18
					A96061 Alclad	Alc. 6061	17
Copper and Copper Alloys							
300	C10100	OFE		300	C23000	brass	40
	C10200	OF	30		C24000	brass	
	C10300	OFXLP	30		C26000	brass	40
	C10400	OFS	30		C26800	brass	
	C10500	OFS	30		C27000	brass	
	C10700	OFS	30		C28000	Muntz metal	50
	C10800	OFLP	30		C40500	brass	
	C10920				C40800	brass	
	C10930				C41100	brass	
	C10940				C41300	brass	
	C11000	ETP	30		C42200	brass	
	C11300	STP			C42500	brass	
	C11400	STP			C43000	brass	
	C11500	STP			C43200	brass	
	C11600	STP			C43400	brass	
	C12000	DLP	30		C43500	brass	
	C12100	DLP			C44300	bronze	45
	C12200	DHP	30		C44400	bronze	45
	C12500	FRTP	30		C44500	bronze	45
	C12700	FRSTP			C46400	brass	50
	C12800	FRSTP			C46500	brass	
	C12900	FRSTP			C46600	brass	
	C13000	FRSTP			C46700	brass	
	C14200	DPA	30		C50500	bronze	
	C14300	cadmium copper			C51000	bronze	40
	C14310	cadmium copper			C51100	bronze	40
	C14500	DPTE			C52100	bronze	53
	C14700	sulphur copper			C52400	bronze	58
	C14710	sulphur copper			C66700	brass	
	C14720	sulphur copper			C67500	bronze	55
	C15000	zirconium copper			C70400	copper nickel	
	C15500	silver copper			C70600	copper nickel	38
	C16200	cadmium copper			C71000	copper nickel	45
	C16500	cadmium copper			C71500	copper nickel	45
	C18200	chromium copper			C72200	copper nickel	
	C18400	chromium copper			C72500	copper nickel	
	C18500	chromium copper			C74500	nickel silver	
	C19000				C75200	nickel silver	
	C19100				C75400	nickel silver	
	C19200				C75700	nickel silver	
	C19400		45		C77000	nickel silver	
	C19500				C80100		19
	C19600				C80300		19
	C21000	gilding metal			C80500		19
	C22000	bronze	34		C80700		19
	C22600	bronze			C80900		19
					C81100		19

Table B1
Base Metal Groups

BM No.	UNS No.	Common Name	Minimum Tensile Strength ksi	BM No.	UNS No.	Common Name	Minimum Tensile Strength ksi
Copper and Copper Alloys							
300	C81300	beryllium copper		340	C81800	beryllium copper	
	C81400	chromium copper			C82000	beryllium copper	
	C81500	chromium copper			C82100	beryllium copper	
	C90200	bronze			C82200	beryllium copper	
	C90300	bronze	40		C85500	brass	55
	C90500	bronze	40		C85700	brass	40
	C90900	bronze			C87400	brass	50
	C91000	bronze	30		C87410	brass	
	C91100	bronze			C87420	brass	
	C91300	bronze			C87430	brass	
	C91600	bronze	35		C87500	brass	60
	C91700	bronze	35		C87510	brass	
	C94700	bronze	45		C87520	brass	
	C96200	copper nickel	45		C87530	brass	
	C96400	copper nickel	60				
310	C33000	brass		350	C17000	beryllium copper	60
	C33500	brass	46		C17200	beryllium copper	60
	C34900	brass			C17300	beryllium copper	60
	C36500	Muntz metal	50		C63600	bronze	
	C36600	Muntz metal	50		C63800	bronze	
	C36700	Muntz metal	50		C64400		
	C36800	Muntz metal	50		C67400	bronze	
	C48200	brass	50		C68700	brass	50
	C83400	brass			C68800		
	C90700	bronze	35		C69000		
	C92300	bronze	36		C82400	beryllium copper	
	C94800	bronze	45		C82500	beryllium copper	
					C82600	beryllium copper	
320	C18700		35		C82700	beryllium copper	
	C31400	bronze			C82800	beryllium copper	
	C31600	bronze			C86400	bronze	60
	C33200	brass			C86500	bronze	65
	C34000	brass	46		C86700	bronze	80
	C34200	brass			C86800	bronze	78
	C35000	brass	46		C87200	bronze	45
	C35300	brass	46				
	C37000	Muntz metal		360	C60800	bronze	50
	C37700	brass			C61000	bronze	
	C37800	brass			C61300	bronze	
	C48500	brass	50		C61400	bronze	70
	C69700	brass			C61500	bronze	
	C78200	nickel silver			C61800	bronze	
	C83300	brass			C61900	bronze	
	C92200	bronze	34		C62300	bronze	
	C92500	bronze	35		C62400	bronze	
	C92600	bronze	40		C62500	bronze	
	C92700	bronze	35		C63000	bronze	90
					C63200	bronze	
330	C65100	bronze	38		C64200	bronze	70
	C65500	bronze	50		C64210	bronze	
	C69400	brass			C95200	bronze	65
	C87600	brass	60		C95300	bronze	65
	C87800	bronze			C95400	bronze	75
	C87900	bronze			C95500	bronze	90
					C95600	bronze	60
340	C17500	beryllium copper	35		C95700	bronze	90
	C81700	beryllium copper			C95800	bronze	85

**Table B1
Base Metal Groups**

BM No.	UNS No.	Common Name	Minimum Tensile Strength ksi	BM No.	UNS No.	Common Name	Minimum Tensile Strength ksi
Nickel and Nickel Alloys							
400	N02200	nickel 200	55	420	N06455	Hastelloy C4	
	N02201	nickel 201	50		N08020	Carpenter 20Cb3	
	N04400	monel 400	70		N10002	Hastelloy C	100
410	N10001	Hastelloy B	100	430	N06625	Inconel 625	120
	N10665	Hastelloy B2	110		N08320	Haynes 20 Mod	
					N08800	Incoloy 800	75
420	N06600	Inconel 600	80		N08810	Incoloy 800H	65
	N06002	Hastelloy X	95		N08825	Incoloy 825	85
	N06007	Hastelloy G			N10003	Hastelloy N	
Titanium and Titanium Alloys							
500	R50250			500	R54520	Ti-5Al-2.5Sn	
	R50400				R54810	Ti-8Al-1Mo-1V	
	R50550				R56320	Ti-3Al-2.5V	
	R52400				R56400	Ti-6Al-4V	
Zirconium and Zirconium Alloys							
600	R60001			600	R60802		
	R60701				R60804		
	R60702				R60901		
	R60704						
Magnesium Alloys							
700	M11100	AZ10A		700	M16100	ZE10A1	
	M11311	AZ31B			M18010	K1A1	
	M15100	M1A					
Cobalt Alloys							
800	R30006	Stellite 6		800	R30031	Stellite 31	
	R30021	Stellite 21			R30188	HS 188	
	R30023	Stellite 23			R30605	L605	
	R30027	Stellite 27			R30816	S816	
	R30030	Stellite 30					

Appendix C

Filler Metal Groups

C1. Filler metals have been grouped by Filler Metal Number (FM No.) in Table C1 so that the required number of qualifications may be reduced. Substitution of one filler metal for another, for any purpose other than for qualification, even when permitted by the rules, should be made only after an evaluation of all the factors involved.

C2. The chemical compositions in Table C1 are approximate. For accurate values see the latest edition of ANSI/AWS A5.8, *Specification for Filler Metals for Brazing*.

C3. The solidus and liquidus are listed for information only.

Table C1
Filler Metal Groups

FM No.	AWS Classification	UNS No.	Approximate Chemical Composition, Weight Percent										Solidus °F	Liquidus °F	Brazing Temperature °F
			Ag	Cu	Zn	Cd	Ni	Sn	Li	Mn	Other				
100	BAG-1	P07450	45	15	16	24	—	—	—	—	—	1125	1145	1145–1400	
	BAG-1A	P07500	50	15	16	18	—	—	—	—	—	1160	1175	1175–1400	
	BAG-8	P07720	72	Rem.	—	—	—	—	—	—	—	1435	1435	1435–1650	
	BAG-8a	P07723	72	Rem.	—	—	—	0.4	—	—	—	1410	1410	1410–1600	
	BAG-22	P07490	49	16	23	—	4.5	—	7.5	—	—	1260	1290	1290–1525	
	BAG-23	P07850	85	—	—	—	—	—	Rem.	—	—	1760	1780	1780–1900	
	BVAg-0	P07017	100	—	—	—	—	—	—	—	—	1761	1761	1761–1900	
	BVAg-8	P07727	72	Rem.	—	—	—	—	—	—	—	1435	1435	1435–1650	
	BVAg-8b	P07728	72	Rem.	—	—	—	0.5	—	—	—	1435	1463	1470–1650	
	BVAg-30	P07687	68	Rem.	—	—	—	0.5	—	—	5 Pd	1485	1490	1490–1700	
110	BAG-2	P07350	35	26	21	18	—	—	—	—	—	1125	1295	1295–1550	
	BAG-2a	P07300	30	27	23	20	—	—	—	—	—	1125	1310	1310–1550	
	BAG-3	P07501	50	15	15	16	3.0	—	—	—	—	1170	1270	1270–1500	
	BAG-4	P07400	40	30	28	—	2.0	—	—	—	—	1240	1435	1435–1650	
	BAG-5	P07453	45	30	25	—	—	—	—	—	—	1225	1370	1370–1550	
	BAG-6	P07503	50	34	16	—	—	—	—	—	—	1270	1425	1425–1600	
	BAG-7	P07563	56	22	17	—	—	5	—	—	—	1145	1205	1205–1400	
	BAG-9	P07650	65	20	15	—	—	—	—	—	—	1240	1325	1325–1550	
	BAG-10	P07700	70	20	10	—	—	—	—	—	—	1275	1360	1360–1550	
	BAG-13	P07540	54	Rem.	5	—	1.0	—	—	—	—	1325	1575	1575–1775	
	BAG-13a	P07560	56	Rem.	—	—	2.0	—	—	—	—	1420	1640	1600–1800	
	BAG-18	P07600	60	Rem.	10	—	—	10	—	—	—	1115	1325	1325–1550	
	BAG-19	P07925	92	Rem.	—	—	—	—	—	0.2	—	1400	1635	1610–1800	
	BAG-20	P07301	30	38	32	—	—	—	—	—	—	1250	1410	1410–1600	
	BAG-21	P07630	63	28	—	—	2.5	6	—	—	—	1275	1475	1475–1650	
	BAG-24	P07505	50	20	28	—	2.0	—	—	—	—	1220	1305	1305–1550	
	BAG-26	P07250	25	38	33	—	2.0	—	—	—	—	1305	1475	1475–1600	
	BAG-27	P07251	25	35	26	14	—	—	—	—	—	1125	1375	1375–1575	
	BAG-28	P07401	40	30	28	—	—	2	—	—	—	1200	1310	1310–1550	
	BAG-33	P07252	25	30	28	18	—	—	—	—	—	1125	1260	1260–1400	
	BAG-34	P07380	38	32	28	—	—	2	—	—	—	1200	1330	1330–1550	
	BVAg-6b	P07507	50	Rem.	—	—	—	—	—	—	—	1435	1602	1600–1800	
	BVAg-18	P07607	60	Rem.	—	—	—	—	10	—	—	1115	1325	1325–1550	
	BVAg-29	P07627	62	Rem.	—	—	—	—	—	—	14 In	1155	1305	1305–1450	
	BVAg-31	P07587	58	32	—	—	—	—	—	—	Rem. Pd	1515	1565	1565–1625	
	BVAg-32	P07547	54	21	—	—	—	—	—	—	Rem. Pd	1650	1740	1740–1800	

(Continued)

Table C1
Filler metal groups

FM No.	AWS Classification	UNS No.	Approximate Chemical Composition, Weight Percent					Solidus °F	Liquidus °F	Brazing Temperature °F		
			Au	Cu	Pd	Ni						
120	BAu-1	P00375	37	Rem.	—	—		1815	1860	1860–2000		
	BAu-2	P00800	80	Rem.	—	—		1635	1635	1635–1850		
	BAu-3	P00350	35	Rem.	—	3		1785	1885	1885–1995		
	BAu-4	P00820	82	—	—	Rem.		1740	1740	1740–1840		
	BAu-5	P00300	30	—	34	36		2075	2130	2130–2250		
	BAu-6	P00700	70	—	8	22		1845	1915	1915–2050		
	BVAu-2	P00707	80	Rem.	—	—		1635	1635	1635–1850		
	BVAu-4	P00827	82	—	—	Rem.		1740	1740	1740–1840		
	BVAu-7	P00507	50	—	Rem.	25		2015	2050	2050–2110		
	BVAu-8	P00927	92	—	Rem.	—		2190	2265	2265–2325		
			Pd	Co								
130	BVPd-1		65	Rem.						2245	2255	2255–2285
			Al	Si	Cu	Mg	Other					
140	BAISI-2	A94343	Rem.	7	—	—	—	1070	1142	1110–1150		
	BAISI-3	A94145	Rem.	10	4	—	—	970	1085	1060–1120		
	BAISI-4	A94047	Rem.	12	—	—	—	1070	1080	1080–1120		
	BAISI-5	A94045	Rem.	10	—	—	—	1070	1110	1090–1120		
	BAISI-7	A94004	Rem.	10	—	1.5	—	1038	1105	1090–1120		
	BAISI-9	A94147	Rem.	12	—	0.3	—	1044	1080	1080–1120		
	BAISI-11	A94104	Rem.	10	—	1.5	0.1 Bi	1038	1105	1090–1120		
				Cu	P	Ag						
	150	BCuP-1	C55180	Rem.	5	—					1695	1450–1700
		BCuP-2	C55181	Rem.	8	—					1460	1350–1550
BCuP-3		C55281	Rem.	6	5					1495	1325–1500	
BCuP-4		C55283	Rem.	7	6					1325	1275–1450	
BCuP-5		C55284	Rem.	5	15					1475	1300–1500	
BCuP-6		C55280	Rem.	7	2					1190	1300–1500	
BCuP-7		C55282	Rem.	7	5					1420	1300–1500	

(Continued)

Table C1
Filler metal groups

FM No.	AWS Classification	UNS No.	Approximate Chemical Composition, Weight Percent							Solidus °F	Liquidus °F	Brazing Temperature °F
			Cu	P								
160	BCu-1	C14180	99.9	0.1					1981	1981	2000-2100	
	BCu-1a	—	99.0	—					1981	1981	2000-2100	
	BCu-2	—	86(a)	—					1981	1981	2000-2100	
	BVCu-1x	C14181	100	—					1981	1981	2000-2100	
(a) This composition requirement pertains only to the cuprous oxide powder, and does not include requirements for the organic vehicle in which the cuprous oxide is suspended.												
170			Cu	Zn	Sn	Fe	Mn	Ni	P			
	RBZn-A	C47000	59	Rem.	0.5	—	—	—	—	1630	1670-1750	
	RBZn-C	C68100	58	Rem.	0.9	0.8	0.3	—	0.1	1590	1670-1750	
	RBZn-D	C77300	48	Rem.	—	—	—	10	0.2	1690	1720-1800	
180			Ni	Cr	B	Si	Fe	C	P	Other		
	BNi-1	N99600	Rem.	14	3	4	4	0.8	—	1790	1950-2200	
	BNi-1a	N99610	Rem.	14	3	4	4	—	—	1790	1970-2200	
	BNi-2	N99620	Rem.	7	3	4	3	—	—	1780	1850-2150	
	BNi-3	N99630	Rem.	—	3	4	—	—	—	1800	1850-2150	
	BNi-4	N99640	Rem.	—	2	3	2	—	—	1800	1850-2150	
	BNi-5	N99650	Rem.	19	—	10	—	—	—	1975	2100-2200	
	BNi-6	N99700	Rem.	—	—	—	—	11	1610	1700-2000		
	BNi-7	N99710	Rem.	14	—	—	—	10	1630	1700-2000		
	BNi-8	N99800	Rem.	—	—	7	—	—	1800	1850-2000		
									23 Mn			
									4 Cu			
	BNi-9	N99612	Rem.	15	4	—	2	—	—	1930	1950-2200	
	BNi-10	N99622	Rem.	12	3	4	4	0.5	—	1780	2100-2200	
	BNi-11	N99624	Rem.	10	3	4	3	0.4	—	1780	2100-2200	
	190			Co	Cr	Ni	Si	Fe	C	P	Other	
BCo-1		R39001	Rem.	19	17	8	1	0.4	—	2050	2100-2250	
200			Mg	Al	Zn							
	BMg-1	M19001	Rem.	9	2					830	1120-1160	

Appendix D

Brazing Fluxes

Table D1
Brazing Flux Types

AWS Brazing Flux No.	Recommended Base Metals*	Recommended Filler Metals	Recommended Useful Temperature Range	Constituents
			°F	
1	All brazeable aluminum alloys	BAISi	700–1190	Chlorides Fluorides
2	All brazeable magnesium alloys	BMg	900–1200	Chlorides Fluorides
3A	All except those listed under 1, 2, and 4	BCuP, BAg	1050–1600	Boric acid Borates Fluorides Fluoborates Wetting agent
3B	All except those listed under 1, 2, and 4	BCu, BCuP, BAg, BAu, RBCuZn, BNi	1350–2100	Boric acid Borates Fluorides Fluoborates Wetting agent
4	Aluminum bronze, aluminum brass, iron- or nickel-base alloys containing Al or Ti	BAg, BCuP (Copper-base alloys only)	1050–1600	Chlorides Fluorides Borates Wetting agent
5	All except those listed under 1, 2, and 4	Same as 3B (excluding BAg-1 through BAg-7)	1400–2200	Borax Boric acid Borates Wetting agent

*This table is not applicable, in some cases, to Base Metal Nos. 500 and 600

Appendix E

Brazing Atmospheres

Table E1
Brazing Atmosphere Types

AWS Brazing Atmosphere No.	Source	Maximum Dew Point °F	Pressure Torr	Approximate Composition, %			
				H	N	CO	CO ₂
1	Combusted fuel gas	Room temp.		1-5	87	1-5	11-12
2	Combusted fuel gas	Room temp.		14-15	70-71	9-10	5-6
3	Combusted fuel gas	-40		15-16	73-75	10-11	
4	Combusted fuel gas	-40		38-40	41-45	17-19	
5	Dissociated ammonia	-65		75	25		
6	Hydrogen	Room temp.		97-100			
7	Hydrogen	-75		100			
8	Heated volatile materials			Inorganic vapors; e.g., Zn, Li, Mg, fluoride			
9	Purified inert gas						
10	Vacuum		> 2				
10A	Vacuum		> 0.5 to 2				
10B	Vacuum		> 0.001 to 0.5				
10C	Vacuum		≤ 0.001				

Appendix F

Brazing Joint Design

Table F1
Joint Clearance

Filler Metal AWS Classification	Flux or Brazing Atmosphere	Joint Clearance Range, in.
B _{Ag} and B _{VAg}	Flux Brazing Atmosphere	0.002–0.005 0.000–0.002
B _{Au} and B _{V_{Au}}	Flux Brazing Atmosphere	0.002–0.005 0.000–0.002
B _{AlSi}	Flux	0.002–0.008 ¹ 0.008–0.010 ²
B _{CuP}	Flux or fluxless	0.001–0.005
B _{Cu} and B _{V_{Cu}}	Brazing atmosphere	0.000–0.002
B _{CuZn} and R _{B_{CuZn}}	Flux	0.002–0.005
B _{Ni-1} through B _{Ni-5} , B _{Ni8} , B _{Co-1}	Flux or brazing atmosphere	0.002–0.005
B _{Ni-6} , B _{Ni-7}	Brazing atmosphere	0.000–0.002
B _{Mg}	Flux	0.004–0.010

Notes:

1. For a lap length of $\leq 1/4$ in.
2. For a lap length of $> 1/4$ in.

Metric Conversion Tables

in.	mm	in.	mm	in.	mm
0.001	0.02	0.010	0.25	1-1/2	38.1
0.002	0.05	1/16	1.6	2	50.8
0.004	0.10	1/4	6.4	3	76.2
0.005	0.13	3/8	9.5	4	102
0.008	0.20	3/4	19.0	10	255
		1	25.4		
°F	°C	°F	°C	°F	°C
-75	-59	1325	718	1730	943
-65	-48	1330	721	1740	949
-40	-40	1350	732	1750	954
700	371	1360	738	1760	960
830	443	1370	743	1761	961
900	482	1375	746	1775	968
970	521	1400	760	1780	971
1038	559	1410	766	1785	974
1044	562	1420	771	1790	977
1050	566	1425	774	1800	982
1060	571	1435	779	1815	991
1070	577	1440	782	1840	1004
1080	582	1450	788	1845	1007
1085	585	1460	793	1850	1010
1090	588	1463	795	1860	1015
1105	596	1470	799	1885	1029
1110	599	1475	802	1900	1038
1115	602	1485	807	1915	1046
1120	604	1490	810	1930	1054
1125	607	1495	813	1950	1066
1142	617	1500	816	1970	1077
1145	618	1515	824	1975	1079
1150	621	1525	829	1981	1083
1155	624	1550	843	1995	1091
1160	627	1565	852	2000	1093
1170	632	1575	857	2003	1095
1175	635	1590	866	2015	1102
1190	643	1600	871	2020	1104
1200	649	1602	872	2050	1121
1205	652	1610	877	2075	1135
1225	663	1625	885	2100	1149
1240	671	1630	888	2110	1154
1250	677	1635	891	2130	1166
1260	682	1640	893	2150	1177
1270	688	1650	899	2190	1199
1275	691	1670	910	2200	1204
1290	699	1690	921	2245	1229
1295	702	1695	924	2250	1232
1300	704	1700	927	2255	1235
1305	707	1715	935	2265	1241
1310	710	1720	938	2285	1252
				2325	1274
ksi	MPa	ksi	MPa	ksi	MPa
11	76	36	248	64	441
13	90	38	262	65	448
14	97	40	276	66	455
15	103	42	290	67	462
17	117	45	310	68	469
18	124	46	317	70	483
19	131	47	324	75	517
20	138	48	331	78	538
21	145	49	338	80	552
22	152	50	345	85	586
25	172	52	359	90	621
26	179	53	365	95	655
30	207	55	379	100	689
31	214	58	400	105	724
32	221	60	414	110	658
34	234	62	427	115	793
35	241	63	434	120	827

AWS Welding and Brazing Procedure and Performance Qualification Documents

AWS Designation	Title
B2.1-84	Standard for Welding Procedure and Performance Qualification
B2.2-91	Standard for Brazing Procedure and Performance Qualification
B2.1.001-90	Standard Welding Procedure Specification for Shielded Metal Arc Welding of Carbon Steel, (M-1/P-1, Group 1 or 2), 3/16 through 3/4 inch, in the As-Welded Condition, with Backing
B2.1.002-90	Standard Welding Procedure Specification for Gas Tungsten Arc Welding of Carbon Steel, (M-1/P-1, Group 1 or 2), 3/16 through 7/8 inch in the As-Welded Condition, with or without Backing
B1.2.003-89	Standard Welding Procedure Specification for Gas Metal Arc Welding of Galvanized Steel, 10 through 18 Gage, in the As-Welded Condition, with or without Backing
B2.1.004-90	Standard Welding Procedure Specification for Gas Metal Arc Welding of Carbon Steel, (M-1, Group 1), 10 through 18 Gage, in the As-Welded Condition, with or without Backing
B2.1.005-90	Standard Welding Procedure Specification for Gas Metal Arc Welding of Austenitic Stainless Steel, (M-8 or P-8), 10 through 18 Gage, in the As-Welded Condition, with or without Backing
B21.006-90	Standard Welding Procedure Specification for Gas Metal Arc Welding of Carbon Steel to Austenitic Stainless Steel, (M-1 to M-8 or P-8), 10 through 18 Gage, in the As-Welded Condition, with or without Backing
B2.1.007-90	Standard Welding Procedure Specification for Gas Tungsten Arc Welding of Galvanized Steel, 10 through 18 Gage, in the As-Welded Condition, with or without Backing
B2.1.008-90	Standard Welding Procedure Specification for Gas Tungsten Arc Welding of Carbon Steel, (M-1, Group 1), 10 through 18 Gage, in the As-Welded Condition with or without Backing
B2.1.009-90	Standard Welding Procedure Specification for Gas Tungsten Arc Welding of Austenitic Stainless Steel, (M-8 or P-8), 10 through 18 Gage, in the As-Welded Condition, with or without Backing
B2.1.010-90	Standard Welding Procedure Specification for Gas Tungsten Arc Welding of Carbon Steel to Austenitic Stainless Steel, (M-1 to M-8 or P-8), 10 through 18 Gage, in the As-Welded Condition with or without Backing
B2.1.011-91	Standard Welding Procedure Specification for Shielded Metal Arc Welding of Galvanized Steel, 10 through 18 Gage, in the As-Welded Condition, with or without Backing
B2.1.012-91	Standard Welding Procedure Specification for Shielded Metal Arc Welding of Carbon Steel, (M-1, Group 1), 10 through 18 Gage, in the As-Welded Condition, with or without Backing
B2.1.013-91	Standard Welding Procedure Specification for Shielded Metal Arc Welding of Austenitic Stainless Steel, (M-8 or P-8), 10 through 18 Gage, in the As-Welded Condition, with or without Backing
B2.1.014-91	Standard Welding Procedure Specification for Shielded Metal Arc Welding of Carbon Steel to Austenitic Stainless Steel, (M-1 to M-8 or P-8), 10 through 18 Gage, in the As-Welded Condition, with or without Backing
B2.1.015-91	Standard Welding Procedure Specification for Gas Tungsten Arc Welding of Aluminum, (M-22 or P-22), 10 through 18 Gage, in the As-Welded Condition, with or without Backing

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