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PART PB
REQUIREMENTS FOR BOILERS FABRICATED BY BRAZING

GENERAL

PB-1 GENERAL

PB-1.1 Scope. The rules in Part PB are applicable to pressure parts of boilers, including piping constructed under the provisions of this Section, that are fabricated by brazing. These rules shall be used in conjunction with the general requirements in Part PG and the specific requirements in the applicable Parts of this Section that pertain to the type of boiler under consideration. The rules in Part PB are not applicable to nonpressure bearing attachments to pressure parts that have essentially no load-carrying function (such as extended heat transfer surface, insulation support pins, etc.).

PB-1.1.1 Definition of Brazing. A group of welding processes that produces coalescence of materials by heating them to the brazing temperature in the presence of a filler metal having liquidus above 840°F (450°C) and below the solidus of the base metal. The filler metal is distributed between the closely fitted faying surfaces of the joint by capillary action.

PB-1.1.2 Brazing processes that are permitted for use under this Part are classified by method of heating as follows:

(a) torch brazing;
(b) furnace brazing;
(c) induction brazing;
(d) resistance brazing;
(e) dip brazing — salt and flux bath.

PB-1.2 Elevated Temperature. Maximum design temperature is dependent on the brazing filler metal and on the base metals being joined. The maximum design temperatures for some brazing filler metals are shown in Table PB-1.

PB-1.3 Service Restrictions. Brazed components may be used for service up to the temperatures as shown in Table PB-1 provided acceptable qualification tests are performed.

PB-1.4 Responsibility. Each Manufacturer[1] (Certificate of Authorization Holder) is responsible for the brazing done by his organization and shall establish the procedures and conduct the tests required by Section IX, and when necessary those required by this Section to qualify the brazing procedures used in the construction of brazed assemblies and the performance tests of brazers[2] who apply these procedures. Such brazing will ordinarily be done by employees of the Manufacturer who accepts the responsibility for Code construction of the boiler or part being brazed. Alternatively, the Manufacturer may perform Code brazing using the services of individual brazers who are not in his employ provided all the following conditions are met.

PB-1.4.1 All Code construction shall be the responsibility of the Manufacturer.

PB-1.4.2 All brazing shall be performed in accordance with Manufacturer's brazing procedure specifications that have been qualified by the Manufacturer in accordance with the requirements of Section IX and when necessary, based on design temperature, with the additional requirements of this Section.

PB-1.4.3 All brazers shall be qualified by the Manufacturer in accordance with the requirements of Section IX.

PB-1.4.4 The Manufacturer's quality control system shall include the following as a minimum.

PB-1.4.4.1 A requirement for complete and exclusive administrative and technical supervision of all brazers by the Manufacturer.

PB-1.4.4.2 Evidence of the Manufacturer's authority to assign and remove brazers at his discretion without involvement of any other organization.

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[1] Manufacturer includes contractor, Assembler, and installer.

[2] Brazer includes brazing operator.

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TABLE PB-1[1]
MAXIMUM DESIGN TEMPERATURES [°F (°C)] FOR BRAZING FILLER METAL

Filler Metal Classification	Temperature Below Which Section IX Tests Only Are Required, °F (°C)	Temperature Range Requiring Section IX and Additional Tests, °F (°C)
BCuP	300 (149)	300–350 (149–177)
BAg	400 (204)	400–500 (204–260)
BCuZn	400 (204)	400–500 (204–260)
BCu	400 (204)	400–650 (204–343)
BAlSi	300 (149)	300–350 (149–177)
BNi	1,200 (649)	1,200–1,500 (649–816)
BAu	800 (427)	800–900 (427–482)
BMg	250 (121)	250–275 (121–135)

NOTE:
(1) Temperatures based on AWS recommendations.

PB-1.4.4.3 A requirement for assignment of brazer identification symbols.

PB-1.4.4.4 Evidence that this program has been accepted by the Manufacturer's Authorized Inspection Agency.

PB-1.4.5 The Manufacturer shall be responsible for Code compliance of the brazement including Code symbol stamping and providing Data Report Forms properly executed and countersigned by the Authorized Inspector.

MATERIALS

PB-5 GENERAL

PB-5.1 Materials used in brazed construction of pressure parts shall conform to one of the specifications given in Section II and shall be limited to those specifically permitted in Parts PG, PWT, and PFT for which allowable stress values are given in Tables 1A and 1B of Section II, Part D for Section I Construction, and for which brazing group P-numbers are assigned in Section IX.

PB-5.2 Combinations of Dissimilar Metals. Combinations of dissimilar metals may be joined by brazing provided they meet the qualification requirements of Section IX and this Section.

PB-6 BRAZING FILLER METALS

The selection of the brazing filler metal for a specific application shall depend upon its suitability for the base metals being joined and the intended service. Satisfactory qualification of the brazing procedure under Section IX and when necessary based on design temperature, with the additional requirements of this Section, is considered proof of the suitability of the filler metal. Brazing with brazing filler metals other than those listed in Section II, Part C, SFA-5.8 shall be separately qualified for both procedure and performance qualification in accordance with Section IX and when necessary with the additional requirements of this Section.

PB-7 FLUXES AND ATMOSPHERES

Suitable fluxes or atmospheres or combinations of fluxes and atmospheres shall be used to prevent oxidation of the brazing filler metal and the surfaces to be joined. Satisfactory qualification of the brazing procedure under Section IX and when necessary, based on design temperature, with the additional requirements of this Section, is considered proof of the suitability of the flux and/or atmosphere.

DESIGN

PB-8 GENERAL

The rules in the following paragraphs apply to boilers and parts thereof that are fabricated by brazing and shall be used in conjunction with the general requirements for design in Part PG, as well as with the specific requirements for design in the applicable Parts of this Section that pertain to the type of boiler under consideration.

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PB-9 STRENGTH OF BRAZED JOINTS

It is the responsibility of the Manufacturer to determine from suitable tests or from experience that the specific brazing filler metal selected can produce a joint which will have adequate strength at design temperature. The strength of the brazed joint shall not be less than the strength of the base metal, or the weaker of the two base metals in the case of dissimilar metal joints.

PB-9.1 Qualification of Brazed Joints for Design Temperatures Up to the Maximum Shown in Column 1 of Table PB-1. Satisfactory qualification of the brazing procedure in accordance with part QB of Section IX is considered evidence of the adequacy of the base materials, the brazing filler metal, the flux and/or atmosphere, and other variables of the procedure.

PB-9.2 Qualification of Brazed Joints for Design Temperatures in the Range Shown in Column 2 of Table PB-1. For design temperatures in the range shown in Column 2 of Table PB-1, tests in addition to those in PB-9.1 are required. These tests shall be considered a part of the qualification procedure. For such design temperatures, two tension tests on production type joints are required, one at the design temperature and one at 1.05*T* (where *T* is the design temperature in degrees Fahrenheit). Neither of these production-type joints shall fail in the braze metal.

PB-10 BRAZED JOINT EFFICIENCY

The joint efficiency factor to be used in design of boilers with brazed joints shall be 1 for all joints.

PB-14 APPLICATION OF BRAZING FILLER METAL

The design of the joint shall provide for the application of the brazing filler metal. Where practicable, the brazing filler metal shall be applied in such a manner that it will flow into the joint or be distributed across the joint and produce visible evidence that it has penetrated the joint.

PB-14.1 Manual Application. The manual application of the brazing filler metal by face-feeding to a joint should be from one side only. Visual observation of the other side of the joint will then show if the required penetration of the joint by the filler metal has been obtained.

PB-14.2 Preplaced Brazing Filler Metal. The brazing filler metal may be preplaced in the form of slugs, powder, rings, strip, cladding, spraying, or other means. After brazing, the brazing filler metal should be visible on both sides of the joint.

PB-15 PERMISSIBLE TYPES OF JOINTS

Some permissible types of brazed joints are shown in Fig. PB-15. Lap joints shall have a sufficient overlap to provide a higher strength in the brazed joint than in the base metal.

The nominal thickness of base material used with lap joints tested using the test fixture shown in Section IX, QB-462.1(e) shall not exceed $\frac{1}{2}$ in. (13 mm). There is no thickness limitation when specimens are tested without the test fixture shown in QB-462.1(e).

PB-16 JOINT CLEARANCE

The joint clearance shall be kept sufficiently small so that the filler metal will be distributed by capillary action. Since the strength of a brazed joint tends to decrease as the joint clearance is increased, the clearance for the assembly of joints in pressure vessels or parts thereof shall be within the tolerances set up by the joint design and used for the corresponding qualification specimens made in accordance with Section IX.

NOTE: For guidance, see Table PB-16, which gives recommended joint clearances at brazing temperature for varying types of brazing filler metal. Brazing alloys will exhibit maximum strength if clearances are maintained within these limits.

PB-17 JOINT BRAZING PROCEDURE

A joint brazing procedure shall be developed for each different type of joint of a brazed assembly. A recommended form for recording the brazing procedure is shown in QB-482 of Section IX. If more than one joint occurs in a brazed assembly, the brazing sequence shall be specified on the drawing or in instructions accompanying the drawing. If welding and brazing are to be done on the same assembly, the welding shall precede the brazing unless it is determined that the heat of welding will not adversely affect the braze previously made.

PB-18 OPENINGS

PB-18.1 Openings for nozzles and other connections shall be far enough away from any main brazed joint so that the joint and the opening reinforcement plates do not interfere with one another.

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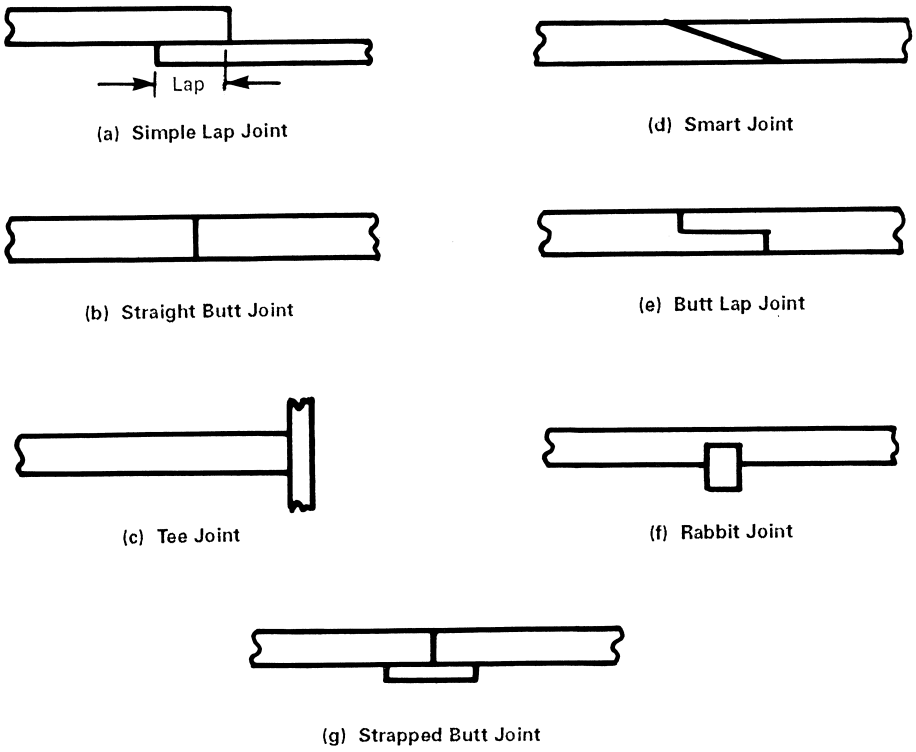


FIG. PB-15 SOME ACCEPTABLE TYPES OF BRAZED JOINTS

TABLE PB-16
RECOMMENDED JOINT CLEARANCE AT
BRAZING TEMPERATURE

	Clearance [Note (1)]	
Brazing Filler Metal	in.	mm
BAlSi	0.006–0.010 for laps less than or equal to $\frac{1}{4}$ in. 0.010–0.025 for laps greater than $\frac{1}{4}$ in.	0.15–0.25 for laps less than or equal to 6.35 mm 0.25–0.64 for laps greater than 6.35 mm
BCuP	0.001–0.005	0.02–0.13
BAg	0.002–0.005	0.05–0.13
BCuZn	0.002–0.005	0.05–0.13
BCu	0.000–0.002 [Note (2)]	0.000–0.05 [Note (2)]
BNi	0.001–0.005	0.02–0.13

NOTES:
(1) In the case of round or tubular members clearance on the radius is intended.
(2) For maximum strength use the smallest possible clearance.

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PB-18.2 Openings for pipe connections in boilers having brazed joints may be made by inserting pipe couplings, or similar devices not exceeding NPS 3 (DN 80) in the shell or heads and securing them by welding provided the welding is performed by welders who have been qualified under the provisions of Section IX for the welding position and type of joint used. Such attachments shall conform to the rules for welded connections PW-15 and PW-16.

PB-19 BRAZED CONNECTIONS

PB-19.1 Connections such as saddle type fittings and fittings inserted into openings formed by outward flanging of the vessel wall, in sizes not exceeding NPS 3 (DN 80), may be attached to boilers by lap joints of brazed construction. Sufficient brazing shall be provided on either side of the line through the center of the opening parallel to the longitudinal axis of the shell to develop the strength of the reinforcement through shear in the brazing.

PB-19.2 For nozzle fittings having a bolting flange and an integral flange for brazing, the thickness of the flange attached to the boiler shall not be less than the thickness of the neck of the fitting.

FABRICATION

PB-26 GENERAL

The rules in the following paragraphs apply specifically to the fabrication of boilers and parts thereof that are fabricated by brazing and shall be used in conjunction with the general requirements for fabrication in Part PG, as well as the specific requirements for fabrication in the applicable Parts of this Section that pertain to the type of boiler under consideration.

PB-28 QUALIFICATION OF BRAZING PROCEDURE

PB-28.1 Each brazing procedure shall be recorded in detail by the Manufacturer. Each brazing procedure shall be qualified in accordance with Section IX and when necessary determined by design temperature with the additional requirements of this Section.

PB-28.2 Brazing of all test coupons shall be conducted by the Manufacturer. Testing of all test coupons shall be the responsibility of the Manufacturer. Qualification of a brazing procedure by one Manufacturer shall not qualify that procedure for any other Manufacturer, except as provided in QB-201 of Section IX.

PB-29 QUALIFICATION OF BRAZERS AND BRAZING OPERATORS

PB-29.1 The brazers and brazing operators used in brazing pressure parts shall be qualified in accordance with Section IX.

The qualification test for brazing operators of machine or furnace brazing equipment shall be performed on a separate test plate prior to the start of brazing or on the first work piece.

PB-29.2 Each brazer or brazing operator shall be assigned an identifying number, letter, or symbol by the Manufacturer that shall be used to identify the work of that brazer or brazing operator.

PB-29.3 The Manufacturer shall maintain a record of the brazers and brazing operators showing the date and result of tests and the identification mark assigned to each. These records shall be certified by the Manufacturer and be accessible to the Inspector.

PB-29.4 Brazing of all test coupons shall be conducted by the Manufacturer. Testing of all test coupons shall be the responsibility of the Manufacturer. A performance qualification test conducted by one Manufacturer shall not qualify a brazer or brazing operator to do work for any other Manufacturer.

PB-30 CLEANING OF SURFACES TO BE BRAZED

The surfaces to be brazed shall be clean and free from grease, paint, oxides, scale, and foreign matter of any kind. Any chemical or mechanical cleaning method may be used that will provide a surface suitable for brazing.

PB-31 CLEARANCE BETWEEN SURFACES TO BE BRAZED

The clearances between surfaces to be brazed shall be maintained within the tolerances provided for by the joint design and used in the qualifying procedure. If greater tolerances are to be used in production, the joint must be requalified for those greater tolerances. The control of tolerances required may be obtained by using spot welding, crimping, or other means that will not interfere with the quality of the braze. If such means are employed in production, they must also be

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employed in qualification of procedure, brazer, and operator.

PB-32 POSTBRAZING OPERATIONS

Brazed joints shall be thoroughly cleaned of flux residue by any suitable means after brazing and prior to inspection.[3] Other postbrazing operations such as thermal treatments shall be performed in accordance with the qualified procedure.

PB-33 REPAIR OF DEFECTIVE BRAZING

Brazed joints that have been found to be defective may be rebrazed, where feasible, after thorough cleaning, by employing the same brazing procedure used for the original braze. If a different brazing procedure is employed, i.e., torch repair of furnace brazed parts, a repair brazing procedure shall be established and qualified.

When a repair brazing procedure is established it shall meet Section IX and other conditions set forth in this Section.

INSPECTION AND TESTS

PB-46 GENERAL

PB-46.1 The rules in the following paragraphs apply specifically to the inspection and testing of power boiler parts that are fabricated by brazing and shall be used in conjunction with the general requirements for inspection and tests in Part PG as well as the specific requirements for inspection and tests in the applicable Parts of this Section that pertain to the type of boiler under consideration.

PB-46.2 Inspection During Fabrication. The Manufacturer shall submit the boiler or other pressure part for inspection at such stages of the work as may be designated by the Inspector.

PB-47 CHECK OF BRAZING PROCEDURE

PB-47.1 The Inspector shall assure himself that the brazing procedure for each type of joint being produced is qualified in accordance with the requirements of Section IX and when necessary the additional requirements of this Section. He shall satisfy himself that each joint has been fabricated in accordance with the procedure. Where there is evidence of consistent poor quality, the Inspector shall have the right at any time to call for and witness tests of the brazing procedure.

PB-48 BRAZER AND BRAZING OPERATOR

PB-48.1 The Manufacturer shall certify that the brazing on a boiler or part thereof has been done by brazers or brazing operators who are qualified under the requirements of Section IX. The Inspector shall assure himself that only qualified brazers or brazing operators have been used.

PB-48.2 The Manufacturer shall make available to the Inspector a certified copy of the record of the qualification tests of each brazer and brazing operator. The Inspector shall have the right at any time to call for and witness tests of the ability of a brazer or brazing operator.

PB-49 VISUAL EXAMINATION

PB-49.1 When possible, the Inspector shall visually inspect both sides of each brazed joint after flux residue removal. It is recognized that for certain joints (blind joints) this is not possible.

PB-49.2 When visually possible there shall be evidence that the brazing filler metal has penetrated the joint. In a butt braze there shall be no concavity. The braze may be repaired or rebrazed.

PB-49.3 The presence of a crack in the brazing filler metal shall be cause for rejection. Dye penetrant inspection may be used if desired. The braze may be repaired or rebrazed (see PB-33).

PB-49.4 The presence of a crack in the base metal adjacent to a braze shall be cause for rejection even if the crack is filled with brazing alloy. Repair is not permitted.

PB-49.5 Pinholes or open defects in the braze shall be cause for rejection. The joint may be rebrazed.

PB-49.6 Rough fillets, particularly those with a convex appearance, are cause for rejection. Such joints may be repaired or rebrazed.

[3] Flux residues can be extremely corrosive as well as interfering with visual inspection.

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PB-50 EXEMPTIONS

Certain brazed joints regardless of their service temperatures may be exempt from the additional mechanical testing of this Section providing that the design application does not assume any benefit from the brazed joint strength. It shall however meet the requirements of those qualification tests required by Section IX of the Code (see PB-1.1, Scope).

MARKING AND REPORTS

PB-51 GENERAL

The provisions for marking and reports given in PG-104 through PG-113 shall apply to brazed boilers and parts thereof.

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