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PART PW
REQUIREMENTS FOR BOILERS FABRICATED BY WELDING

GENERAL

PW-1 GENERAL

PW-1.1 Scope. The rules in Part PW are applicable to boilers and component parts thereof, including piping constructed under the provisions of this Section, that are fabricated by welding and shall be used in conjunction with the general requirements in Part PG as well as with the specific requirements in the applicable Parts of this Section that pertain to the type of boiler under consideration.

PW-1.2 Responsibility. Each Manufacturer[1] (Certificate of Authorization holder) is responsible for the welding done by his organization and shall establish the procedures and conduct the tests required in Section IX to qualify the welding procedures he uses in the construction of the weldments built under Section I and the performance tests of welders[2] who apply these procedures. Alternatively, AWS Standard Welding Procedure Specifications that have been accepted by Section IX may be used for Section I construction, provided the welding meets the requirements of this Section. A particular AWS Standard Welding Procedure may contain a range for a welding variable where only part of the range meets the requirements of this Section. This could apply to one or more welding variables. The Section I requirements always take precedence. Manufacturers intending to use AWS Standard Welding Procedures shall describe in their Quality Control System (A-302.7) control measures used to assure that the welding meets the requirements of this Section and Section IX. Other occurrences of the phrase "qualified in accordance with Section IX" in this Part shall be construed to permit use of AWS Standard Welding Procedures accepted by Section IX and controlled as described above. Such welding will ordinarily be done by employees of the Manufacturer who accepts the responsibility for Code construction of the boiler or part being welded. Alternatively, the Manufacturer may perform Code welding using the services of individual welders who are not in his employ provided all the following conditions are met.

PW-1.2.1 All Code construction shall be the responsibility of the Manufacturer.

PW-1.2.2 All welding shall be performed in accordance with Manufacturer's Welding Procedure Specifications that have been qualified by the Manufacturer in accordance with the requirements of Section IX.

PW-1.2.3 All welders shall be qualified by the Manufacturer in accordance with the requirements of QW-301.2, Section IX.

PW-1.2.4 The Manufacturer's quality control system shall include as a minimum:

PW-1.2.4.1 A requirement for complete and exclusive administrative and technical supervision of all welders by the Manufacturer.

PW-1.2.4.2 Evidence of the Manufacturer's authority to assign and remove welders at his discretion without involvement of any other organization.

PW-1.2.4.3 A requirement for Assignment of Welder identification symbols.

PW-1.2.4.4 Evidence that this program has been accepted by the Manufacturer's Authorized Inspection Agency which provides the inspection service.

PW-1.2.5 The Manufacturer shall be responsible for Code compliance of the weldment including Code Symbol Stamping and providing Data Report Forms properly executed and countersigned by the Authorized Inspector.

PW-1.3 Welding Definitions. For some of the more common terms related to welding, refer to QW-492 of Section IX.

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[1] *Manufacturer* includes contractor, assembler, and installer.

[2] *Welder* includes welding operator.

MATERIALS

PW-5 GENERAL

PW-5.1 Materials used in welded construction of pressure parts shall conform to one of the specifications given in Section II and shall be limited to those specifically permitted in Part PG, Part PWT, and Part PFT and for which allowable stress values are given in Tables 1A and 1B of Section II, Part D, for Section I construction and for which weld Group P-Numbers are assigned in Section IX.

PW-5.2 Carbon or alloy steel having a carbon content of more than 0.35% shall not be used in welded construction or be shaped by oxygen cutting or other thermal cutting processes.

PW-5.3 Austenitic stainless steel materials joined by electroslag welding shall be limited to SA-240 Grades 304 and 316, SA-182 Grades F304 and F316, and SA-351 Grade CF 8.

PW-5.4 Welding electrodes and filler metal shall be selected to provide deposited weld metal of chemical composition and mechanical properties compatible with the materials to be joined and the service conditions anticipated.

PW-5.5 Rimmed and semi-killed steels shall not be joined by the inertia and continuous drive friction welding processes.

PW-5.6 For pressure retaining welds in $2\frac{1}{4}$Cr-1Mo materials, other than circumferential buttwelds less than or equal to $3\frac{1}{2}$ in. (89 mm) in outside diameter, when design metal temperatures exceed 850°F (454°C), the weld metal shall have a carbon content greater than 0.05%.

DESIGN

PW-8 GENERAL

The rules in the following paragraphs apply specifically to the design of boilers and parts thereof that are fabricated by welding 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.

PW-9 DESIGN OF WELDED JOINTS

PW-9.1 Longitudinal, circumferential, and other joints, uniting the material used for drums, shells, or other pressure parts, except as otherwise provided in PG-31, PG-39, PW-41, PWT-11, and Part PFT shall be full penetration butt welds. The welds should preferably be of the double-welded butt type, but may also be of the single-welded butt type with the filler metal added from one side only when made to be the equivalent of the double-welded butt joint by providing means for accomplishing complete penetration.

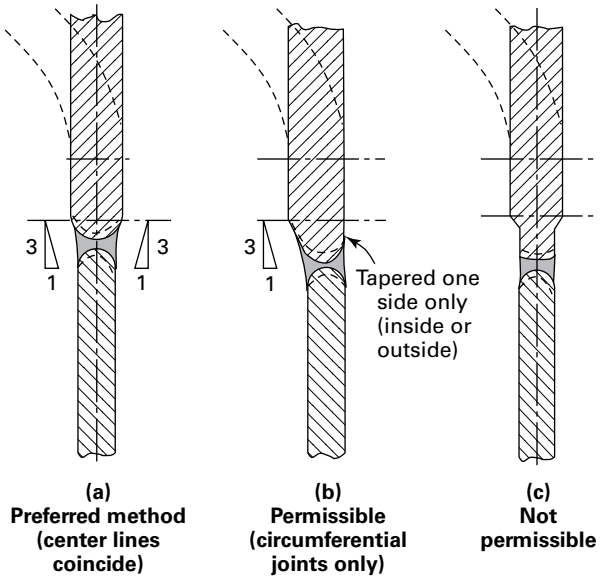


FIG. PW-9.1 BUTTWELDING OF PLATES OF UNEQUAL THICKNESS

PW-9.2 Welding Grooves. The dimensions and shape of the edges to be joined by butt welds shall be such as to permit complete fusion and complete joint penetration.

PW-9.3 Joints Between Materials of Unequal Thickness. Except as provided in PW-9.3.2, a tapered transition section having a length not less than three times the offset between the adjoining surfaces, as shown in Fig. PW-9.1, shall be provided at joints between materials that differ in thickness by more than one-fourth of the thickness of the thinner material or by more than $\frac{1}{8}$ in. (3.2 mm). The transition section may be formed by any process that will provide a uniform taper. The weld may be partly or entirely in the tapered section or adjacent to it as indicated in Fig. PW-9.1. 01

This paragraph is not intended to apply to joint design specifically provided for elsewhere in this Code or to joints between tubes, between tubes and headers, and between tubes and tubesheets.

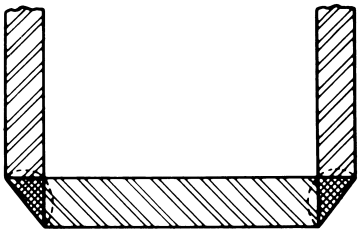


FIG. PW-9.2 PROHIBITED WELDED JOINT

01 **PW-9.3.1 Alignment of Shells and Vessels (Including Pipe or Tube Used as a Shell).** In longitudinal shell joints, the middle lines of the adjoining thicknesses shall be in alignment within the fabricating tolerances specified in PW-33.

Alternatively, the middle lines of plates of differing thickness may be offset so that the inside or outside diameters of the thinner and thicker prortions of the shell form a continuous surface, provided the following conditions are met:

(a) The ratio of the thickness of the thicker plate to the thickness of the thinner plate shall not exceed 2:1; and

(b) The maximum design temperature shall not exceed 750°F.

PW-9.3.2 Circumferential Welds in Tube and Pipe. When components of different diameters or thicknesses are welded together, the transition shall not exceed a slope of 30 deg from the smaller to the larger diameter. The transition may be formed by any process that will provide a uniform taper. Alignment shall meet the provisions of PW-34.

PW-9.4 Prohibited Welded Joints. Corner joints as depicted in Fig. PW-9.2 are prohibited.

PW-10 HEAT TREATMENT

Vessels and vessel parts shall be preheated and postweld heat treated in accordance with the requirements in PW-38 and PW-39.

PW-11 RADIOGRAPHIC AND ULTRASONIC EXAMINATION OF WELDED BUTT JOINTS

PW-11.1 Welded butt joints requiring radiographic and ultrasonic examination are specified in Table PW-11. Experience has demonstrated that welded butt joints not requiring radiographic and ultrasonic examination by these rules have given safe and reliable service even if they contain imperfections that may be disclosed upon further examination. Any examination and acceptance standards beyond the requirements of this Section are beyond the scope of this Code and shall be a matter of agreement between the Manufacturer and the user.

PW-11.2 Definitions. For use with Table PW-11, the following definitions apply.

butt joint — a joint between two members aligned approximately in the same plane.

circumferential butt weld — includes circumferential welded butt joints in drums, headers, pipes, and tubes, and welded butt joints attaching formed heads to drums, shells, and headers.

longitudinal butt weld — includes longitudinal and spiral welded butt joints in drums, shells, headers, pipes, and tubes; any welded butt joint within a sphere or within a formed or flat head or tube sheet; and welded butt joints attaching insert-nozzles of the type shown in Fig. PW-16.1, sketches (q-1), (q-2), (q-3), and (q-4).

NPS — nominal pipe size.

RT — radiographic examination.

UT — ultrasonic examination.

PW-11.3 For use with Table PW-11, the size and 01
thickness of welded butt joints is defined as the larger and thicker of the two abutting edges after edge preparation.

The geometric unsharpness U_g is defined by the equation

$$U_g = Fd/D$$

where

D = distance from source of radiation to the weld, in. (mm)

d = distance from the source side of the weld to the film, in. (mm)

F = source size; the maximum projected dimension of the radiating source (or effective focal spot) in the plane perpendicular to the distance D from the weld, in. (mm)

U_g = geometric unsharpness, in. (mm)

01
A02

TABLE PW-11
REQUIRED RADIOGRAPHIC AND ULTRASONIC EXAMINATION OF WELDED BUTT JOINTS

	Pressure Part Service Conditions [Note (1)]			
	In Contact With Furnace Gases > 850°F (450°C)		Not In Contact With Furnace Gases > 850°F (450°C)	
	Subject to Furnace Radiant Heat [Note (2)]	Not Subject to Furnace Radiant Heat [Note (2)]	Not Subject to Furnace Radiant Heat [Note (2)]	
Butt Weld Type	Contains Steam and/or Water		Contains Water	Contains Steam
Longitudinal	RT all sizes and thicknesses	RT all sizes and thicknesses	RT all sizes and thicknesses	RT all sizes and thicknesses
Circumferential welds in drums and shells	RT > NPS 10 (DN 250) or > $1\frac{1}{8}$ in. (29 mm) thick	RT > NPS 10 (DN 250) or > $1\frac{1}{8}$ in. (29 mm) thick	RT > NPS 10 (DN 250) or > $1\frac{1}{8}$ in. (29 mm) thick	RT > NPS 10 (DN 250) or > $1\frac{1}{8}$ in. (29 mm) thick
Circumferential welds in pipes, tubes, and headers	RT > NPS 4 (DN 100) or > $\frac{1}{2}$ in. (13 mm) thick	RT > NPS 6 (DN 150) or > $\frac{3}{4}$ in. (19 mm) thick	RT > NPS 10 (DN 250) or > $1\frac{1}{8}$ in. (29 mm) thick	RT > NPS 16 (DN 400) or > $1\frac{5}{8}$ in. (41 mm) thick

GENERAL NOTES:

(a) Unless exempted by this table, all longitudinal and circumferential welded butt joints are to be radiographically examined (RT) throughout their entire length. Ultrasonic examination (UT) of the welds shall be performed in lieu of RT when it is impracticable to use a combination of radiographic parameters such that a geometric unsharpness of 0.07 in. (1.8 mm) will not be exceeded. When RT is required for welds in ferritic materials using the electroslag process, UT shall also be performed in addition to RT. When RT is required for welds made in any material using the inertia or continuous drive friction welding processes, UT shall be performed in addition to RT.

(b) If a grain refining (austenitizing) heat treatment is used for electroslag welds, the UT examination shall be performed after the heat treatment is completed. If an austenitizing heat treatment is not used, the UT examination shall be done after an intermediate postweld heat treatment or after the final postweld heat treatment is completed.

(c) Radiographic examination shall be performed in accordance with Article 2 of Section V. UT examination shall be performed in accordance with Article 4 of Section V.

(d) Acceptance criteria for the nondestructive examination performed are PW-51 for RT and PW-52 for UT.

(e) RT is required when either the size or wall thickness limit is exceeded (i.e., the diameter and thickness limitations apply independently).

(f) For electric boilers, RT is not required when the maximum allowable working pressure is ≤ 100 psig (690 kPa), and the shell ID is ≤ 16 in. (406 mm) (see PEB-9.1).

(g) For firetube boilers, RT of longitudinal welded butt joints, made with the addition of filler metal, in furnaces is not required provided a bend test of a sample of the welded joint for each section of the furnace meets the requirements of PW-53. RT of circumferential welded butt joints in furnaces is not required (see PFT-14). For firetube boilers, RT is not required for butt welds in fireboxes and waterlegs provided the construction meets the requirements of PFT-21.2 and PFT-21.3.

(h) For miniature boilers, RT is not required (see PMB-9).

(i) RT is not required for the longitudinal weld in ERW products that comply with an acceptable material specification when used for construction within the limitations of PG-9.5.

NOTES:

(1) Service conditions and pressure part contents are as determined by the designer.

(2) A weld will not be considered subject to radiant heat from the furnace when in a portion of a pressure part that has five or more rows of tubes between it and the furnace.

PW-13 HEAD-TO-FLANGE REQUIREMENTS

Dished heads, other than hemispherical, concave to pressure to be attached by butt welding, and flanged heads or flanged furnace connections to be fillet welded, shall have a length of flange not less than 1 in. (25 mm) for heads or furnace openings not over 24 in. (610 mm) in external diameter and not less than $1\frac{1}{2}$ in. (38 mm) for heads or furnace openings over 24 in. (610 mm) in diameter.

PW-14 OPENINGS IN OR ADJACENT TO WELDS

Any type of opening that meets the requirements for compensation given in PG-32 through PG-44 may be located in a welded joint.

PW-15 WELDED CONNECTIONS

A02 **PW-15.1** Nozzles, other connections, and their compensation may be attached to vessels by arc or gas welding. Sufficient weld and compensation shall be provided on either side of the plane through the center of the opening, parallel to the longitudinal axis of the vessel, to develop the required strength, as prescribed in PG-37, in shear or tension, whichever is applicable. (See Fig. PW-15 for example calculations.)

PW-15.1.1 The stress correction factors in PW-15.2 shall apply to all welds.

PW-15.1.2 The strength of fillet welds shall be based on one-half the area subjected to shear, computed on the inside diameter of the weld.

PW-15.1.3 The strength of groove welds shall be based on one-half the area subjected to shear or tension, as applicable, computed using the minimum weld depth dimension in the direction under consideration.

PW-15.1.4 DELETED

PW-15.1.5 DELETED

PW-15.1.6 PW-15.1.6 The strength calculations for nozzle attachment welds are not required for the weld configurations shown in Fig. PW-16.1, sketches (a), (b), (c), (g), (h), (o), (q-1), (q-2), (q-3), (q-4), (u-1), (v-1), (w-1), (y), and (z).

PW-15.1.6.1 DELETED

PW-15.1.6.2 DELETED

PW-15.1.6.3 DELETED

PW-15.1.6.4 DELETED

PW-15.1.6.5 DELETED

PW-15.2 Stress Values for Weld Metal. The allowable stress values for groove and fillet welds in percentages of stress values for the vessel material are as follows: A02

Groove-weld tension	74%
Groove-weld shear	60%
Fillet-weld shear	49%

NOTE: These values are obtained by combining the following factors: $87\frac{1}{2}$% for combined end and side loading, 80% for shear strength, and the applicable joint efficiency factors.

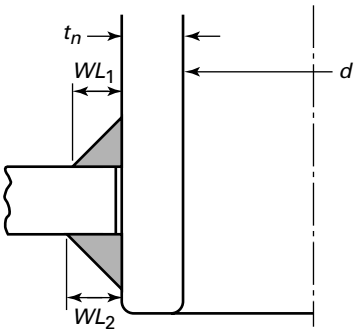
PW-15.3 Compensation plates and saddles of nozzles attached to the outside of a vessel shall be provided with at least one telltale hole (maximum size $\frac{1}{4}$ in. pipe tap) that may be tapped for a preliminary compressed-air and soapsuds test for tightness of welds that seal off the inside of the vessel. These telltale holes shall be left open when the vessel is in service.

PW-15.4 Figure PW-16.1 illustrates some types of fusion welded connections which are acceptable.

When end faces of nozzle or manhole necks are to remain unwelded in the completed vessel, these end faces shall not be cut by shearing unless at least $\frac{1}{8}$ in. (3.2 mm) of additional metal is removed by any method that will produce a smooth finish.

PW-16 MINIMUM REQUIREMENTS FOR ATTACHMENT WELDS

PW-16.1 General. Except as permitted in PW-16.5 and PW-16.6, nozzles and other connections to shells, A02



(a)

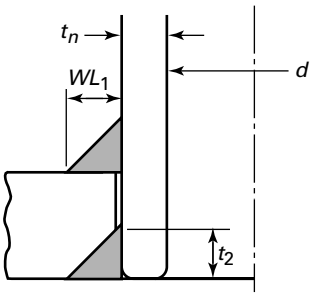
For sketch (a):

Required weld strength (PG-37.2):

$$W = (A - A_1)S_v$$

Weld strength = WL_1 in shear + WL_2 in shear

$$= 0.49\ (1/2)\ WL_1\ \pi\ (d + 2t_n)\ S_v\ f_{r1} + 0.49\ (1/2)\ WL_2\ \pi\ (d + 2t_n)\ S_v\ f_{r1}$$



(b)

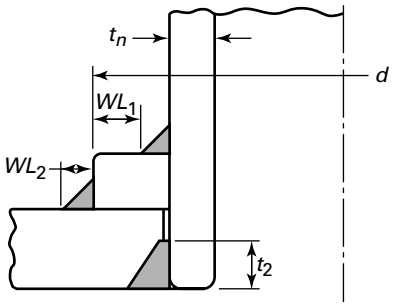
For sketch (b):

Required weld strength (PG-37.2):

$$W = (A - A_1)S_v$$

Weld strength = WL_1 in shear + t_2 in shear

$$= 0.49\ (1/2)\ WL_1\ \pi\ (d + 2t_n)\ S_v\ f_{r1} + 0.74\ (1/2)\ t_2\ \pi\ (d + 2t_n)\ S_v\ f_{r1}$$



(c)

For sketch (c):

(1) Required weld strength (PG-37.2):

$$W = (A - A_1)S_v$$

Weld strength = WL_2 in shear + t_2 in tension

$$= 0.49\ (1/2)\ WL_2\ \pi\ (D_p)\ S_v\ f_{r3} + 0.74\ (1/2)\ t_2\ \pi\ (d + 2t_n)\ S_v\ f_{r1}$$

(2) Check nozzle to pad and shell (PG-37.3):

$$W = (A - A_1 - A_2 - A_{42} - A_3)S_v$$

Weld strength = WL_1 in shear + t_2 in tension

$$= 0.49\ (1/2)\ WL_1\ \pi\ (d + 2t_n)\ S_v\ f_{r1} + 0.74\ (1/2)\ t_2\ \pi\ (d + 2t_n)\ S_v\ f_{r1}$$

A02 FIG. PW-15 EXAMPLES OF WELD STRENGTH CALCULATIONS

A02 FIG. PW-16
DELETED

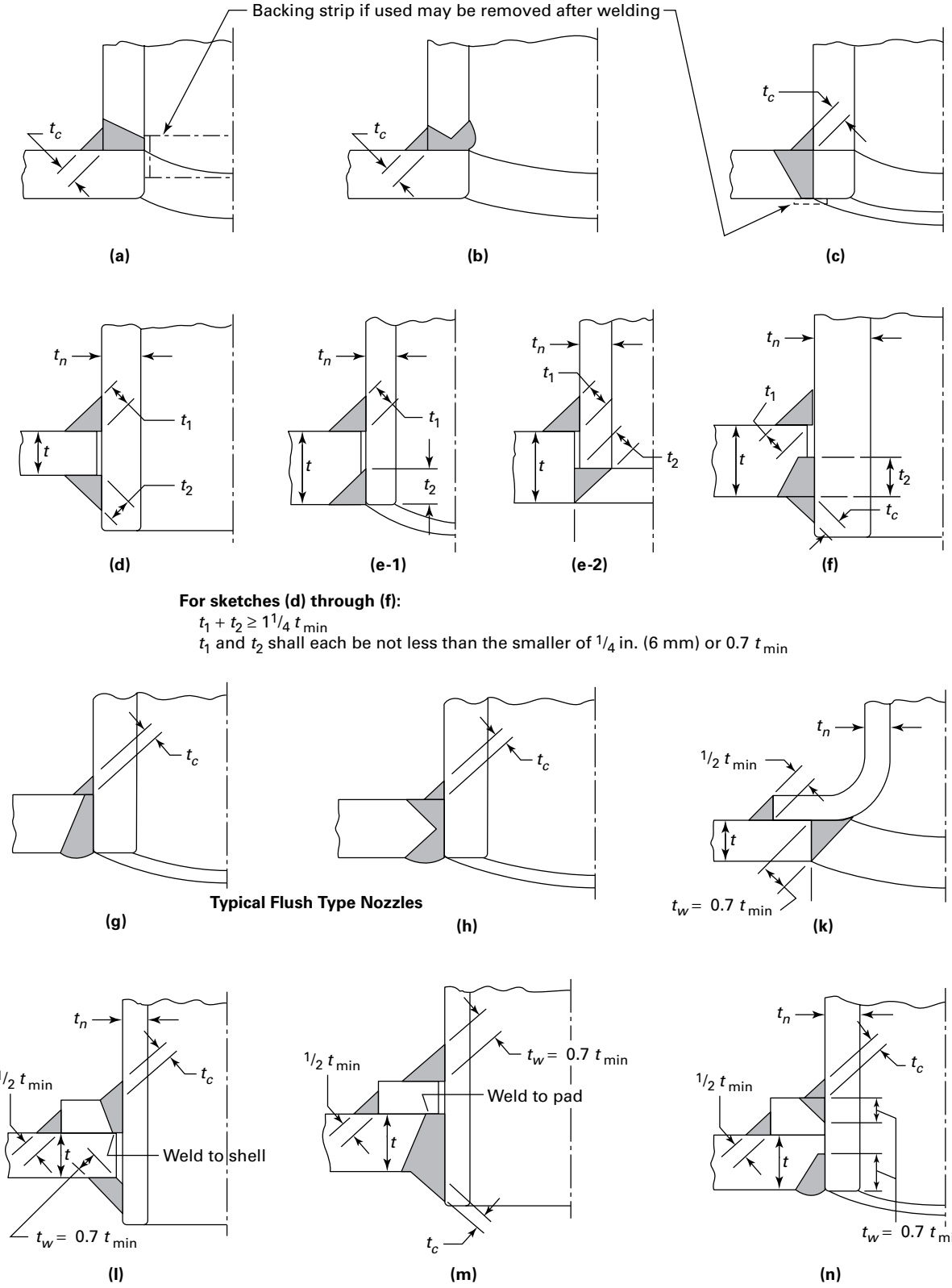
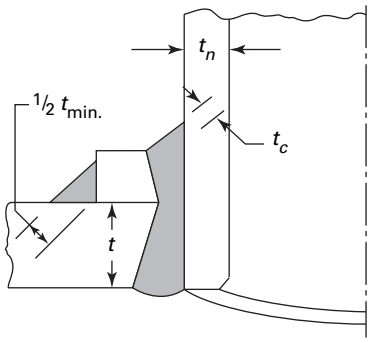
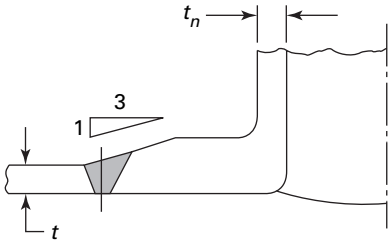


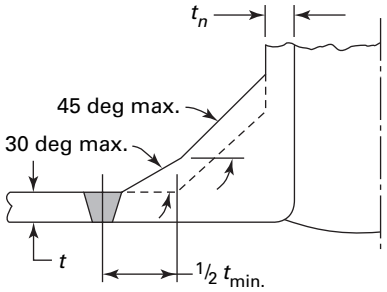
FIG. PW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, DRUMS, AND HEADERS **A02**



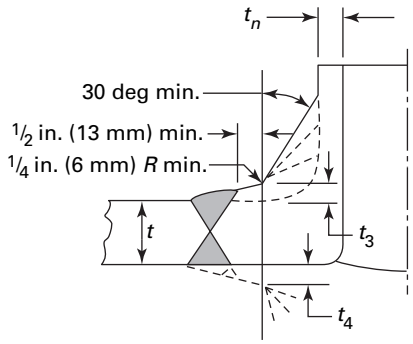
(o)



(q-1)

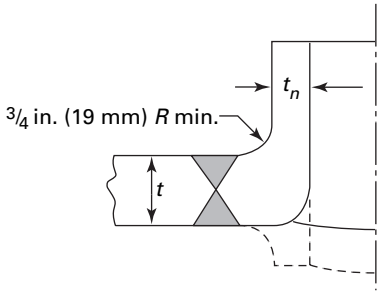


(q-2)



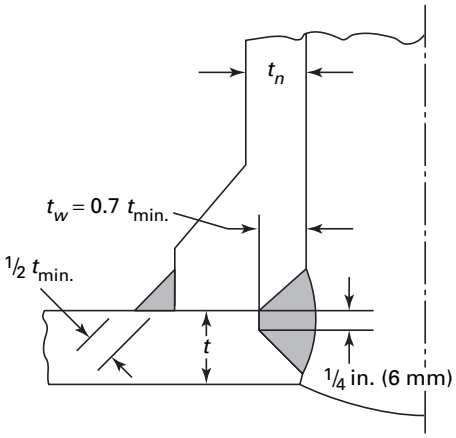
$t_1 + t_4 \le 0.2\ t$ but not greater than $1/4$ in. (6 mm)

(q-3)

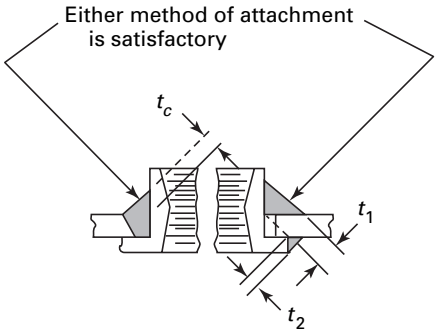


(q-4)

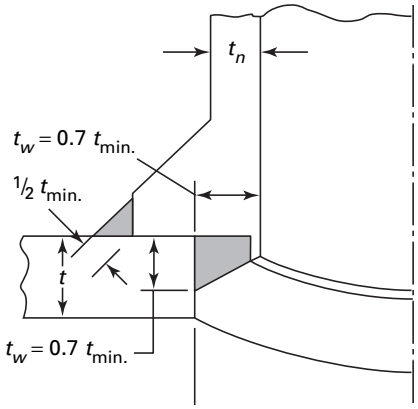
A02 FIG. PW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, DRUMS, AND HEADERS (CONT'D)



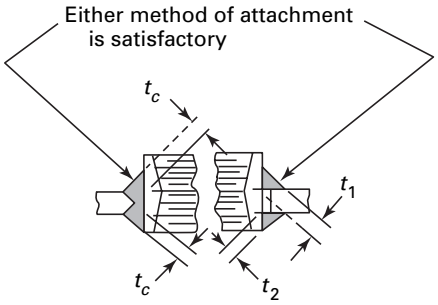
(r)



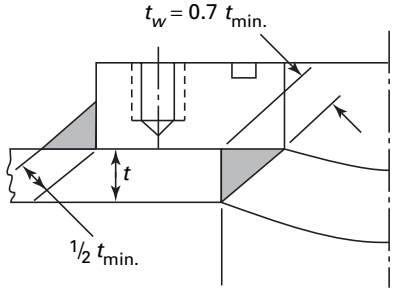
(u-1) **(u-2)**



(s)



(v-1) **(v-2)**



(t)

For sketches (u) and (v):

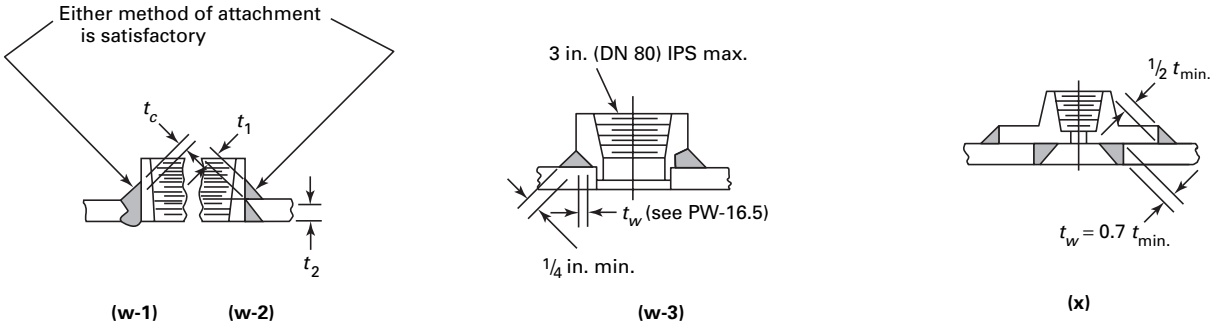
$t_1 + t_2 \geq 1\,1/4\ t_{min.}$

t_1 and t_2 shall each be not less than the smaller of $1/4$ in. (6 mm) or $0.7\ t_{min.}$

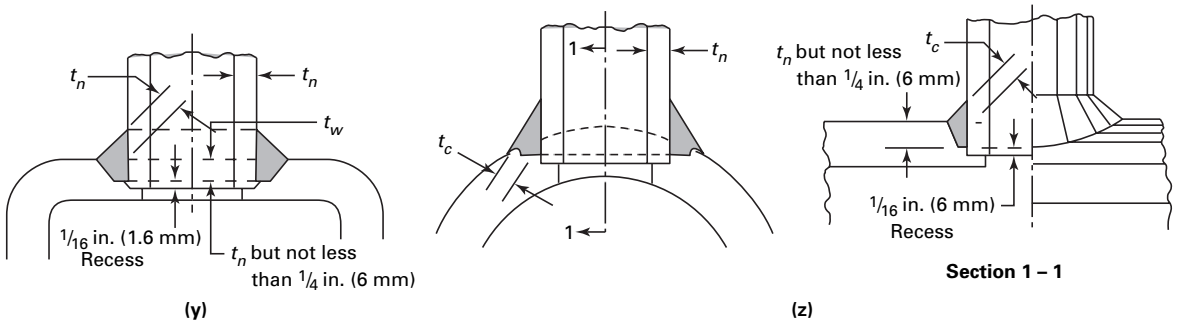
For sketches (u-2) and (v-2):

For 3 in. (76 mm) pipe and smaller, see exemption in PW-16.4.

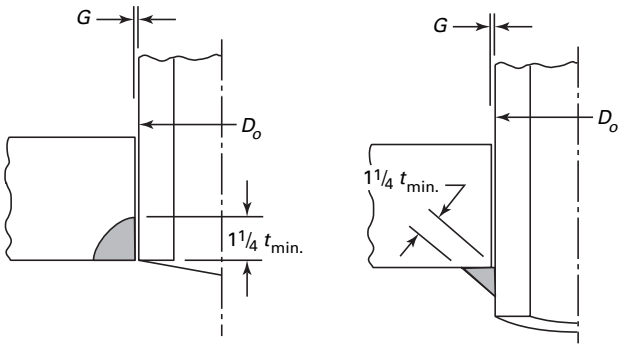
FIG. PW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, DRUMS, AND HEADERS (CONT'D) **A02** **A03**



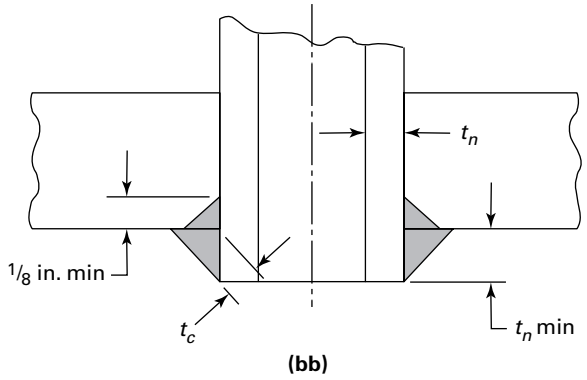
For sketches (w-2) and (x):
For 3 in. (DN 80) pipe and smaller, see exemption in PW-16.4.



For sketch (aa):
(a) For applications where there are no external loads:
G = 1/8 in. (3.2 mm) max.
(b) With external loads:
G = 0.005 for D_o < 1 in. (25 mm)
G = 0.010 for 1 in. < D_o < 4 in. (102 mm)
G = 0.015 for 4 in. < D_o < 6 5/8 in. (168 mm)



A03 FIG. PW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, DRUMS, AND HEADERS (CONT'D)



GENERAL NOTE [sketch (bb)]: NPS 2 max. $t_n \le 1/4$ in.

FIG. PW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, DRUMS, AND HEADERS (CONT'D) 01

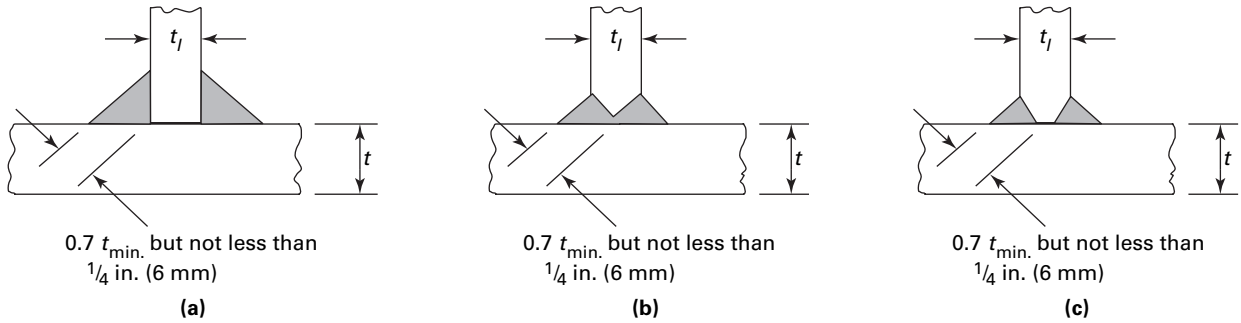


FIG. PW-16.2 SOME ACCEPTABLE FORMS OF WELDS FOR LUGS, HANGERS, AND BRACKETS ON SHELLS, DRUMS, AND HEADERS (See PG-55)

drums, and headers shall be attached by full penetration welds applied from one or both sides, partial penetration welds applied from both sides, fillet welds applied from both sides, or fillet and partial penetration welds on opposite sides. In addition to the strength calculations required in PG-37, the location and minimum size of attachment welds for nozzles and other connections shall conform to the requirements in this paragraph.

A02 **PW-16.2 Nomenclature.** The symbols used in this paragraph and in Fig. PW-16.1 and Fig. PW-16.2 are defined as follows:

t = thickness of vessel shell or head, in. (mm)

t_n = thickness of nozzle wall, in. (mm)

t_w = dimension of partial penetration attachment welds (fillet, single bevel, or single J), measured as shown in Fig. PW-16.1, in. (mm)

t_c = not less than the smaller of 1/4 in. (6 mm) or 0.7 t_{min} (inside corner welds may be further limited by a lesser length of projection of the nozzle wall beyond the inside face of the vessel wall)

t_{min} = the smaller of 3/4 in. (19 mm) or the thickness of either of the weld parts joined by a fillet, single bevel, or single J-weld, in. (mm)

$t_1+t_2 \ge 1\frac{1}{4}\ t_{min}$ measured as shown in Fig. PW-16.1, in., both t_1 and t_2 shall each be not less than the smaller of 1/4 in. (6 mm) or 0.7 t_{min}

t_l = thickness of lug, hanger, or bracket, as shown in Fig. PW-16.2, in. (mm)

PW-16.3 All welding shall be equivalent to that required under the rules within this Section. Radiographic examination of attachment welds may be omitted except as specifically required in other paragraphs of this Code, and except for inserted-type nozzles

similar to those illustrated in Fig. PW-16.1, sketches (q-1), (q-2), (q-3), and (q-4).

PW-16.4 Fittings shown in Fig. PW-16.1, sketches (u-2), (v-2), (w-2), and (x) not exceeding NPS 3 (DN 80) may be attached by welds that are exempt from size requirements other than those specified in PW-15.1.

PW-16.5 Internally threaded fittings not exceeding NPS 3 (DN 80) may be attached by a fillet groove weld from the outside only as shown in Fig. PW-16.1, sketch (w-3). The groove weld t_w shall not be less than the thickness of Schedule 160 pipe (ANSI/ASME B36.10M).

01 A02 **PW-16.6 Necks and Tubes Up To and Including NPS 6 Attached From One Side Only.** Necks and tubes not exceeding NPS 6 may be attached by partial penetration or fillet welds from one side only on either the outside or inside of the vessel in accordance with the provisions given below:

(a) When the neck or tube is attached from the outside only, a welding groove shall be cut into the surface to a depth of not less than t_n on the longitudinal axis of the opening. It is recommended that a recess $\frac{1}{16}$ in. (1.6 mm) deep be provided at the bottom of the groove in which to center the nozzle. The dimension t_w of the attachment weld shall not be less than t_n nor less than $\frac{1}{4}$ in. (6 mm). See Fig. PW-16.1 sketches (y) and (z).

(b) When the neck or tube is attached from the inside only, the depth of welding groove or throat of fillet weld shall be at least equal to $1\frac{1}{4}\ t_{\min.}$. Radial clearance between the vessel hole and nozzle outside diameter at the unwelded side shall not exceed tolerances given in Fig. PW-16.1, sketch (aa). Such attachments shall satisfy the rules for reinforcement of opening except that no material in the nozzle neck shall be counted as reinforcement.

(c) Watertubes may be welded into a tubesheet or header in accordance with the following provisions, where t_w, t_c, and $t_{\min}$ are as defined in PW-16.2 and illustrated in Fig. PW-16.1, sketch (bb).

(1) The size shall not exceed NPS 2 (DN 50).

(2) The thickness shall not exceed $\frac{1}{4}$ in. (6 mm).

(3) The groove depth t_w shall not be less than $\frac{1}{8}$ in. (3.2 mm) and t_c shall not be less than $\frac{1}{4}$ in. (6 mm) or 0.7 $t_{\min}$, whichever is smaller.

(4) The tube shall be welded from the waterside of the boiler.

(5) The application shall be limited to 650°F (343°C) maximum.

PW-19 WELDED-IN STAYS

Welded-in stays may be used in lieu of threading and shall meet the following requirements.

PW-19.1 The stays shall be inserted into countersunk holes through the sheet, except as provided in PW-19.4, and attached by full penetration welds. The area of the weld in shear measured parallel to that portion of the stay extending through the sheet shall be not less than 1.25 times the required cross-sectional area of the stay, but in no case shall the size of the weld be less than $\frac{3}{8}$ in. (10 mm).

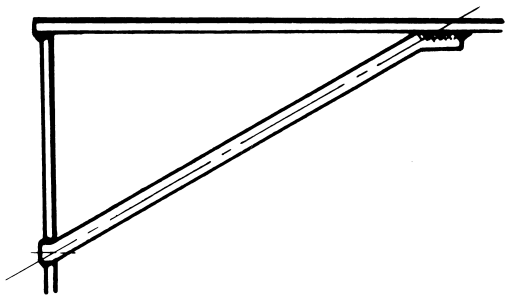
PW-19.2 The ends of the stays shall not be covered by weld metal and the face of the welds shall not be below the outside surface of the plates.

PW-19.3 The ends of stays inserted through the sheet shall not project more than $\frac{3}{8}$ in. (10 mm) beyond surfaces exposed to products of combustion.

PW-19.4 Diagonal stays shall be attached to the inner surface of the shell, but not the head, by fillet welds only. See Fig. PW-19.4(a) and Fig. PW-19.4(b), provided:

PW-19.4.1 Fillet welds shall be not less than $\frac{3}{8}$ in. (10 mm) size and shall continue the full length of each side of the portion of the stay in contact with the shell. The product of the aggregate length of these fillet welds times their throat shall be not less than 1.25 times the required cross-sectional area of the stay. A fillet weld across the end of the stay is optional but shall not be credited in calculating the required area of fillet welds.

PW-19.4.3 The longitudinal center line of the stay, projected if necessary, shall intersect the inner surface of the plate to which the stay is attached within the outer boundaries of the attaching welds, also projected if necessary.



GENERAL NOTE: A round bar or a round bar with a forged palm

FIG. PW-19.4(a) SOME ACCEPTABLE TYPES OF DIAGONAL BRACES FOR INSTALLATION BY WELDING

PW-19.5 The pitch of stays attached by welding to flat surfaces shall comply with the requirements of PFT-27.

PW-19.6 The welding shall be done in such a manner that excessive weld deposits do not project through the surface of the plate at the root of the weld.

PW-19.7 The welding shall be postweld heat treated in accordance with PW-39.

PW-19.8 Telltale holes are not required in staybolts attached by welding.

FABRICATION

PW-26 GENERAL

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

PW-27 WELDING PROCESSES

The welding processes that may be used under this Part shall meet all the test requirements of Section IX and are restricted to the following.

PW-27.1 The following welding processes may be used for any Section I construction: shielded metal arc, submerged arc, gas metal arc, flux cored arc, gas tungsten arc, plasma arc, atomic hydrogen arc, oxyhydrogen, oxyacetylene, laser beam, electron beam, flash, induction, resistance, pressure thermit, pressure gas, and inertia and continuous drive friction welding.

PW-27.2 Arc stud welding and resistance stud welding may be used for nonpressure-bearing attachments having a load- or non-load-carrying function. Stud size shall be limited to 1 in. (25 mm) diameter maximum for round studs or an equivalent cross-sectional area for studs with other shapes. For load-carrying attachments, the requirements of PW-28.6 shall be met prior to the start of production welding, and the postweld heat treatment requirements of PW-39 shall also be complied with.

PW-27.3 The electroslag welding process may be used for butt welds only in austenitic stainless steels of types listed in PW-5.3 and ferritic steels, provided the requirements of PW-11.2.2 and PW-39.7 are satisfied.

PW-27.4 Definitions are given in Section IX, which include variations of these processes.

PW-28 WELDING QUALIFICATION AND WELD RECORDS

PW-28.1 Requirements for Qualification of Welding Procedures, Welders, and Welding Operators

PW-28.1.1 The Welding Procedure Specifications, the welders, and the welding operators used in welding pressure parts and in joining load-carrying nonpressure parts, such as all permanent or temporary clips and lugs, to pressure parts shall be qualified in accordance with Section IX.

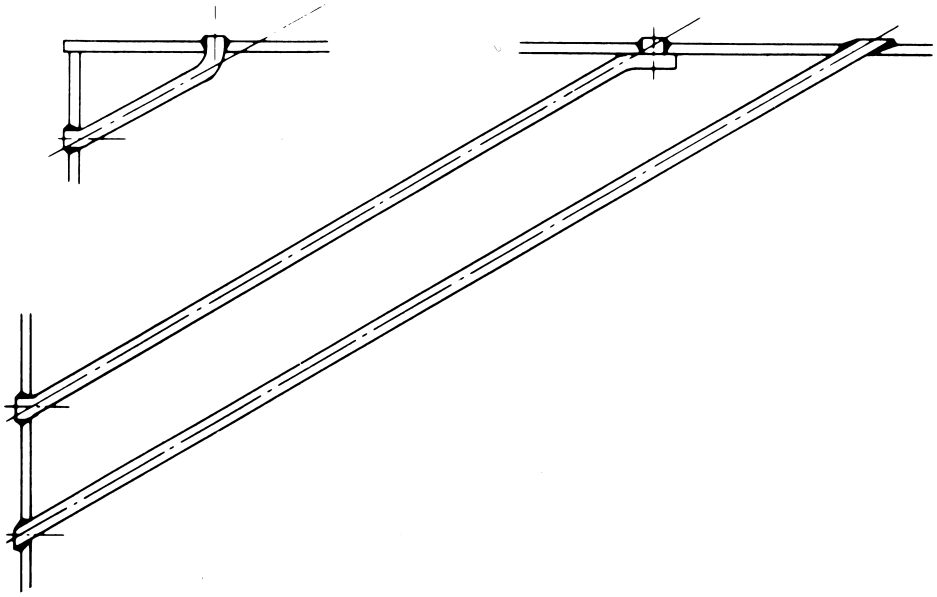


FIG. PW-19.4(b) UNACCEPTABLE TYPES OF DIAGONAL BRACES FOR INSTALLATION BY WELDING

PW-28.1.2 Except as provided in (a) and (b) below, the Welding Procedure Specification, the welders and the welding operators used in welding nonpressure-bearing attachments which have essentially no load-carrying function (such as extended heat transfer surfaces, insulation support pins, etc.) to pressure parts shall be qualified in accordance with Section IX.

(a) When the welding process is automatic, welding procedure and performance qualification testing is not required.

(b) When the material used for the nonpressure part makes the mechanical test requirements for procedure qualification and performance qualifications impracticable (i.e., insufficient material ductility), a weld test coupon may be evaluated using the macro-examination method for both groove and fillet welds. The test coupon may be of production configuration and shall be of sufficient length to contain a specimen for macro-examination. Heat treatment shall be considered a nonessential variable. The weldable quality of the nonpressure part materials shall be verified by the macro-examination of a single cross-section of the weld. Visual examination of the weld metal and heat-affected zone of both the pressure part and nonpressure part material shall show complete fusion and freedom from cracks.

PW-28.1.3 Welding 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 welding procedure, a welder, or a welding operator by one Manufacturer shall not qualify that procedure, welder, or the welding operator for any other Manufacturer except as provided in QW-201 and QW-300 of Section IX and PW-28.5.

PW-28.2 No production work shall be undertaken until the procedures, the welders, and the welding operators have been qualified, except that performance qualification by radiography, in conformance with Section IX, QW-304 for welders or QW-305 for welding operators, may be performed within the first 3 ft (0.9 m) of the first production weld.

PW-28.4 The Manufacturer shall maintain a record of the welding procedures, welders, and welding operators employed, showing the date, results of the tests, and the identification mark assigned to each welder. These records shall be certified by the Manufacturer and be accessible to the Authorized Inspector.

PW-28.4.1 The Manufacturer shall also establish a procedure whereby all welded joints, except as permitted in PW-28.4.2 and PW-28.4.3, can be identified as to the welder or welding operator who made them. This procedure shall use one or more of the following methods and be acceptable to the Authorized Inspector. The welder or welding operator may stamp his identification mark on or adjacent to all welded joints made by him, or he may stamp on or adjacent to a continuous

weld or a series of similar joints made by him at intervals of not greater than 3 ft (0.9 m), or, in lieu of stamping, the Manufacturer may keep a record of welded joints and the welders or welding operators used in making the joints.

A03 **PW-28.4.2** When making multiple load-carrying or non-load-carrying structural attachment welds on pressure parts, the Manufacturer need not identify the welder or welding operator that welded each individual joint provided:

(a) the Manufacturer's Quality Control System includes a procedure whereby the identity of the welders or welding operators that made such welds on each pressure part will be maintained so that the Inspector can verify that the welders or welding operators were all properly qualified; and

(b) the welds are all the same type and configuration and are welded with the same welding procedure specification.

PW-28.4.3 Identification of welders or welding operators making tack welds that become part of a final pressure-retaining weld or structural attachment weld is not required provided the Quality Control System of the Manufacturer includes a procedure to permit the Inspector to verify that such tack welds were made by qualified welders or welding operators.

PW-28.5 To avoid duplication of qualification tests, it is recommended that procedures, welders, and welding operators qualified as required above be acceptable for any similar welding work on piping using the same procedure (see PW-1.2).

PW-28.6 In the case where stud welding is used to attach load-carrying studs, a production stud weld test of the procedure and welding operator shall be performed on a separate test plate or tube prior to the start of production welding on the first work piece. This weld test shall consist of five studs, welded and subjected to either the bend or torque stud weld testing described in Section IX.

A03 **PW-28.7** If tube butt welds are made using the flash welding process, production testing shall be performed in accordance with Section IX, QW-199.1.3 as follows:

(a) one sample shall be tested at the start of production

(b) one sample shall be tested at the beginning, midpoint, and end of each work shift

(c) when production shifts are consecutive, a test at the end of the shift may serve as the test for the beginning of the next shift

(d) when a welding operator is replaced during production

(e) if any machine settings are changed

When any production run weld fails to pass the required tests, the welding parameters shall be adjusted until two consecutive welds pass the bend test. In addition, all welds that were made subsequent to the previous successful test shall be either cut out and rewelded or cut out and tested in reverse sequence of welding until two successive welds pass the tests.

PW-29 BASE METAL PREPARATION

PW-29.1 The preparation of joints prior to welding may involve any of the conventional methods in use such as machining, thermal cutting, chipping, grinding, or combinations of these.

PW-29.2 Where thermal cutting is used, the effect on the mechanical and metallurgical properties of the base metal shall be taken into consideration.

PW-29.3 The method of base metal preparation used shall leave the welding groove with reasonably smooth surfaces and free from deep notches, striations, or irregularities. The surfaces for welding shall be free of all scale, rust, oil, grease, or other foreign materials.

PW-29.4 Cast surfaces to be welded shall be machined, chipped, or ground where necessary to remove foundry scale and to expose sound metal.

PW-31 ASSEMBLY

PW-31.1 Parts that are being welded shall be fitted, aligned, and retained in position during the welding operation within the tolerance specified in PW-33.

PW-31.2 Bars, jacks, clamps, tack welds, or other appropriate means may be used to hold the edges of the parts to be welded in alignment.

PW-31.3 Tack welds used to secure alignment shall either be removed completely when they have served their purpose or their stopping and starting ends shall be properly prepared by grinding or other suitable means so that they may be satisfactorily incorporated into the final weld. Tack welds, whether removed or left in place, shall be made using a fillet weld or butt weld procedure qualified in accordance with Section IX. Tack welds to be left in place shall be made by welders qualified in accordance with Section IX and shall be examined visually for defects and, if found to be defective, shall be removed.

PW-31.4 When joining two parts by the inertia and continuous drive friction welding processes, one of the two parts must be held in a fixed position and the other part rotated. The two faces to be joined must be essentially symmetrical with respect to the axis of rotation. Some of the basic types of applicable joints are solid round-to-solid round, tube-to-tube, solid round-to-tube, solid round-to-plate, and tube-to-plate.

PW-33 ALIGNMENT TOLERANCE, SHELLS AND VESSELS (INCLUDING PIPE OR TUBE USED AS A SHELL)

PW-33.1 Alignment of sections at edges to be butt welded shall be such that the maximum offset is not

greater than the applicable amount as listed in Table PW-33, where t is the nominal thickness of the thinner section at the joint.

PW-33.2 Joints in spherical vessels and within heads and joints between cylindrical shells and hemispherical heads shall meet the requirements in PW-33.1 above for longitudinal joints in cylindrical shells.

PW-33.3 Any offset within the allowable tolerance provided above shall be faired at a 3 to 1 taper over the width of the finished weld, or if necessary, by adding additional weld metal beyond what would otherwise be the edge of the weld.

TABLE PW-33
ALIGNMENT TOLERANCE OF SECTIONS TO BE BUTTWELDED

Section Thickness, in. (mm)	Direction of Joints in Cylindrical Shells	
	Longitudinal in. (mm)	Circumferential in. (mm)
Up to 1/2 (13), incl.	1/4t	1/4t
Over 1/2 (13) to 3/4 (19), incl.	1/8 (3.2)	1/4t
Over 3/4 (19) to 1 1/2 (38), incl.	1/8 (3.2)	3/16 (4.8)
Over 1 1/2 (38) to 2 (51), incl.	1/8 (3.2)	1/8t
Over 2 (51)	Lesser of 1/16t or 3/8 (10)	Lesser of 1/8t or 3/4 (19)

PW-34 ALIGNMENT, TUBE AND PIPE

PW-34.1 When tubes or pipes are welded together, the alignment shall be such that the inside surfaces provide for complete weld penetration. The weld shall meet the reinforcement requirements of PW-35.

PW-35 FINISHED LONGITUDINAL AND CIRCUMFERENTIAL JOINTS

PW-35.1 Butt welds shall have complete joint penetration. To assure that the weld grooves are completely filled so that the surface of the weld metal at any point is not below the surface of the adjoining base materials, weld metal may be added as reinforcement on each face of the weld. The thickness of the weld reinforcement on each face shall not exceed the following:

Nominal Thickness, in. (mm)	Maximum Reinforcement, in. (mm)	
	Circumferential Joints in Pipe and Tubing	Other Welds
Up to 1/8 (3.2)	3/32 (2.4)	3/32 (2.4)
Over 1/8 (3.2) to 3/16 (4.8), incl.	1/8 (3.2)	3/32 (2.4)
Over 3/16 (4.8) to 1/2 (13), incl.	5/32 (4.0)	3/32 (2.4)
Over 1/2 (13) to 1 (25), incl.	3/16 (3.8)	3/32 (2.4)
Over 1 (25) to 2 (51), incl.	1/4 (6.4)	1/8 (3.2)
Over 2 (51) to 3 (76), incl.	[Note (1)]	5/32 (4.0)
Over 3 (76) to 4 (102), incl.	[Note (1)]	7/32 (5.6)
Over 4 (102) to 5 (127), incl.	[Note (1)]	1/4 (6.4)
Over 5 (127)	[Note (1)]	5/16 (8.0)

NOTE:
(1) The greater of 1/4 in. (6 mm) or 1/8 times the width of the weld in inches (mm).

As-welded surfaces are permitted; however, the surface of the welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys to avoid stress raisers. Undercuts shall not exceed 1/32 in. (0.8 mm) or 10% of the wall thickness, whichever is less, and shall not encroach on the required section thickness. The surfaces of the finished weld shall be suitable to permit proper interpretation of radiographic and other required nondestructive examinations. If there is a question regarding the surface condition of the weld when interpreting radiographic film, the film shall be compared to the actual weld surface for determination of acceptability.

PW-35.2 The weld reinforcement need not be removed except to the extent necessary to meet the thickness requirements in PW-35.1.

PW-35.3 Backing strips used at longitudinal welded joints shall be removed. Inside backing rings may remain at circumferential joints of cylinders provided they meet the requirements of PW-41.

PW-35.4 The welded joint between two members joined by the inertia and continuous drive friction welding processes shall be full penetration weld. Visual examination of the as-welded flash roll of each weld shall be made as an in-process check. The weld upset shall meet the specified amount with ±10%. The flash shall be removed to sound metal.

PW-36 MISCELLANEOUS WELDING REQUIREMENTS

PW-36.1 Before applying weld metal on the second side to be welded, the root of double-welded butt joints shall be prepared by suitable methods such as chipping, grinding, or thermal gouging, so as to secure sound metal at the base of weld metal deposited on the face side, except for those processes of welding by which

proper fusion and penetration are otherwise obtained and by which the root of the weld remains free from impurities.

A03 **PW-36.2 Fillet Welds.** In making fillet welds, the weld metal shall be deposited in such a way as to secure adequate penetration into the base metal at the root of the weld. Undercuts on pressure-retaining boundaries shall not exceed the lesser of $^1/_{32}$ in. (0.8 mm) or 10% of the nominal thickness of the adjoining surface and shall not encroach upon the required section thickness. The surface of the welds shall be free from coarse ripples or grooves, and shall merge smoothly with the surfaces being joined. Concavity of the face of the weld is permissible, provided it does not encroach on the required weld thickness.

PW-38 PREHEATING

PW-38.1 The need for and the temperature of preheat are dependent upon a number of factors such as chemical analysis, degree of restraint of the parts being joined, elevated temperature mechanical properties, and material thicknesses. Some practices used for preheating are described in Appendix A-100 as a general guide for the materials listed by P-Numbers of Section IX. It is cautioned that the preheating suggested in A-100 does not necessarily ensure satisfactory completion of the welded joint and that the requirements for individual materials within the P-Number listing may have preheating more or less restrictive than this general guide. The welding procedure specification for the material being welded shall specify the minimum preheating requirements described in the welding procedure qualification requirements of Section IX.

PW-38.2 Preheat for welding or thermal cutting may be applied by any method that does not harm the base material or any weld metal already applied, or that does not introduce into the welding area foreign material that is harmful to the weld.

PW-39 REQUIREMENTS FOR POSTWELD HEAT TREATMENT

The rules in the following paragraphs apply specifically to the fabrication of the boiler proper and parts thereof and do not apply to the external piping as defined in the Preamble.

01 **PW-39.1** Before applying the detailed requirements and exemptions in these paragraphs, satisfactory weld procedure qualifications of the procedures to be used shall be performed in accordance with all the essential variables of Section IX including conditions of postweld heat treatment or lack of postweld heat treatment and including other restrictions listed below. Except as otherwise specifically provided in PFT-29, PMB-9, PW-40.2, PW-40.3, and in the notes within Table PW-39, all welded pressure parts of power boilers shall be given a postweld heat treatment at a temperature not less than that specified in Table PW-39. The materials in Table PW-39 are listed in accordance with the materials P-Number grouping of QW-420 of Section IX.

PW-39.2 When pressure parts of two different P-Number groups are joined by welding, the postweld heat treatment shall be that specified in Table PW-39 and applicable notes for the material requiring the higher postweld heat treatment temperature, except as noted in PW-39.2.1. When nonpressure parts are welded to pressure parts, the postweld heat treatment temperature of the pressure parts shall control.

PW-39.2.1 Fillet welds, partial penetration welds, and full penetration welds through the tube or pipe thickness, attaching P-No. 5A tubes and pipe to headers of lower P-Number material, may be postweld heat treated at the temperature specified in Table PW-39 for the lower P-Number material provided the tubes or pipe comply with all the following conditions: 01 A03

(a) a maximum specified chromium content of 3.0%;

(b) a maximum size of NPS 4 (DN 100);

(c) a maximum thickness of $^1/_2$ in. (13 mm);

(d) a maximum specified carbon content of not more than 0.15%.

PW-39.3 In the procedures that follow, the volume of metal required to be heated, to meet or exceed the minimum post weld heat treatment temperatures listed in Table PW-39, is defined as the soak band. As a minimum, the soak band shall contain the weld and a portion of the base metal on each side of the weld being heat treated, including the weld heat affected zones. The width of each portion of base metal to be included in the soak band shall be equal to the lesser of the vessel or shell thickness, or 2 in. (51 mm). A greater amount of base material, on either or both sides of the weld, may also be heated to permit temperature gradient control. 01

The weldment shall be heated slowly to the temperature specified in Table PW-39 and held for the specified time, and shall be allowed to cool slowly in a still atmosphere to a temperature not exceeding 800°F (427°C). Several weldments of varied thickness may be postweld heat treated in the same furnace at the same time.

The term nominal thickness in Table PW-39 is the thickness of the weld, pressure retaining material, or the thinner of the sections being joined, whichever is

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TABLE PW-39
MANDATORY REQUIREMENTS FOR POSTWELD HEAT TREATMENT OF PRESSURE PARTS AND ATTACHMENTS

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (51 mm)	Over 2 in. (51 mm) to 5 in. (127 mm)	Over 5 in. (127 mm)
P-No. 1 Group No. 1,2,3	1,100 (593)	1 hr/in. (1 hr/25 mm), 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (51 mm)	2 hr plus 15 min for each additional inch over 2 in. (51 mm)

NOTES:

(1) Postweld heat treatment is not mandatory for P-No. 1 materials under the following conditions:
- (a) for circumferential butt welds in pressure parts with a nominal wall thickness of $^3/_4$ in. (19 mm) or less at the joint
- (b) for fillet welds used on slip-on and socket welding flanges and fittings conforming to the rules of PW-41, when the following conditions are met:
  - (1) a fillet weld throat thickness of $^1/_2$ in. (13 mm) or less, regardless of base metal thickness
  - (2) a minimum preheat of 200°F (93°C) when the thickness of a pressure part at the weld exceeds $^3/_4$ in. (19 mm)
- (c) for fillet welds attaching nonpressure parts to pressure parts that have a throat thickness of $^1/_2$ in. (13 mm) or less, provided preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of the pressure part exceeds $^3/_4$ in. (19 mm)
- (d) for welds used to attach extended heat absorbing surface to tubes and insulation attachment pins to pressure parts
- (e) for tubes or pressure retaining handhole and inspection plugs or fittings that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of $^3/_8$ in. (10 mm) or less, and preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of either part exceeds $^3/_4$ in. (19 mm)
- (f) for studs welded to pressure parts for purposes not included in (d) above, provided preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of the pressure part exceeds $^3/_4$ in. (19 mm)
- (g) for tube-to-tubesheet welded attachment of P-No. 1, Group Nos. 1 and 2 material in firetube boilers in accordance with Fig. PFT-12.1 sketches (f) and (g), if the depth of the weld groove or preparation does not exceed 0.375 in. (10 mm), provided a minimum preheat of 200°F (93°C) is applied when the tubesheet thickness exceeds $^3/_4$ in. (19 mm)
- (h) for fillet welds attaching connections to a vessel, provided that all of the following conditions are met:
  - (1) the diameter of the finished opening (diameter *d* in Figs. PG-33.1, PG-33.2, and PW-15) does not exceed that allowed in PG-32.1.2 or 2 in. (51 mm), whichever is less
  - (2) the throat thickness does not exceed $^3/_8$ in. (10 mm)
  - (3) preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of either part exceeds $^3/_4$ in. (19 mm)
  - (4) the connections are not placed in the vessel such as to form ligaments, the efficiency of which would affect the vessel thickness
- (i) for combination groove and fillet welds attaching nonpressure parts to pressure parts, with a weld thickness of $^1/_2$ in. (13 mm) or less, provided preheat to a minimum of 200°F (93°C) is applied when the thickness of the pressure part exceeds $^3/_4$ in. (19 mm)
- (j) for corrosion-resistant weld metal overlay cladding of pipe or tube materials, provided that all of the following conditions are met:
  - (1) the thickness of the overlay cladding is $^1/_4$ in. (6 mm) or less
  - (2) preheat to a minimum temperature of 200°F is applied when the thickness of the pressure part exceeds $^3/_4$ in. (19 mm)
  - (3) the pipe or tube material:
    - (a) does not exceed 5 in. (127 mm) outside diameter; and
    - (b) is not used as a header, drum, or shell.

(2) When it is impractical to postweld heat treat at the temperature specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table PW-39.1.

(3) For all P-No. 1 Group No. 1 materials, and for P-No. 1 Group No. 2 materials having a maximum actual carbon content of 0.30%, the postweld heat treatment requirement of PWT 11.2 for tubes welded to tubular manifolds or headers is not mandatory when all of the following conditions are met:
- (a) the tubes do not exceed 2 in. (51 mm) O.D.
- (b) the header does not exceed NPS 8 (DN 200)
- (c) the header thickness does not exceed $^1/_2$ in. (13 mm)
- (d) a minimum preheat of 200°F (93°C) is applied

TABLE PW-39 A02
MANDATORY REQUIREMENTS FOR POSTWELD HEAT TREATMENT A03
OF PRESSURE PARTS AND ATTACHMENTS (CONT'D)

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (51 mm)	Over 2 in. (51 mm) to 5 in. (127 mm)	Over 5 in. (127 mm)
P-No. 3 Group No. 1,2,3	1,100 (593)	1 hr/in. (1 hr/25 mm), 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (51 mm)	2 hr plus 15 min for each additional inch over 2 in. (51 mm)

NOTES:

(1) Except for P-No. 3 Group No. 3, postweld heat treatment of P-No. 3 materials is not mandatory under the following conditions (postweld heat treatment is mandatory for P-No. 3 Group No. 3 materials for all thicknesses):
- (a) for circumferential butt welds in pressure parts with both a nominal wall thickness of $\frac{5}{8}$ in. (16 mm) or less, and a specified maximum carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.25%
- (b) for fillet welds used on socket welding fittings conforming to the rules of PW-41, when the following conditions are met:
  - (1) a fillet weld throat thickness of $\frac{1}{2}$ in. (13 mm) or less, regardless of base metal thickness
  - (2) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.25%
  - (3) a minimum preheat of 200°F (93°C) when the thickness of a pressure part at the weld exceeds $\frac{5}{8}$ in. (16 mm)
- (c) for fillet welds with a throat thickness of $\frac{1}{2}$ in. (13 mm) or less and combination groove and fillet welds with a weld thickness of $\frac{1}{2}$ in. (13 mm) or less attaching nonpressure parts having a specified maximum carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.25% provided preheat to a minimum temperature of 200°F (93°C) is applied when the pressure part exceeds $\frac{5}{8}$ in. (16 mm)
- (d) for welds used to attach extended heat-absorbing surface to tubes and insulation attachment pins to pressure parts
- (e) for tubes or pressure retaining handhole and inspection plugs or fittings that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of $\frac{3}{8}$ in. (10 mm) or less, and preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of either part exceeds $\frac{5}{8}$ in. (16 mm)
- (f) postweld heat treatment is not mandatory for studs welded to pressure parts for purposes not included in (d) above and which have a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by Purchaser to a value within the specification limits), provided a preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of the pressure part exceeds $\frac{5}{8}$ in. (16 mm)
- (g) for fillet welds attaching connections to a vessel, provided that all of the following conditions are met:
  - (1) the diameter of the finished opening (diameter *d* in Figs. PG-33.1, PG-33.2, and PW-15) does not exceed that allowed in PG-32.1.2 or 2 in. (51 mm), whichever is less
  - (2) the throat thickness does not exceed $\frac{3}{8}$ in. (10 mm)
  - (3) preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of either part exceeds $\frac{5}{8}$ in. (16 mm)
  - (4) the connections are not placed in the vessel such as to form ligaments, the efficiency of which would affect the vessel thickness
  - (5) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.25%
- (h) for corrosion-resistant weld metal overlay cladding of pipe or tube materials, provided that all of the following conditions are met:
  - (1) the thickness of the overlay cladding is $\frac{1}{4}$ in. (6 mm) or less
  - (2) preheat to a minimum temperature of 200°F is applied when the thickness of the pressure part exceeds $\frac{5}{8}$ in. (16 mm)
  - (3) the pipe or tube material:
    - (a) does not exceed 5 in. (127 mm) outside diameter; and
    - (b) is not used as a header, drum, or shell.

(2) When it is impractical to postweld heat treat at the temperature specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table PW-39.1.

(3) Note (1) does not apply to welds using the inertia and continuous drive friction welding processes. Postweld heat treatment is mandatory for all thicknesses of materials welded using inertia and continuous drive friction welding.

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A03

TABLE PW-39
MANDATORY REQUIREMENTS FOR POSTWELD HEAT TREATMENT OF PRESSURE PARTS AND ATTACHMENTS (CONT'D)

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (51 mm)	Over 2 in. (51 mm) to 5 in. (127 mm)	Over 5 in. (127 mm)
P-No. 4 Group No. 1,2	1,100 (593)	1 hr/in. (1 hr/25 mm), 15 min minimum	1 hr/in. (1 hr/25 mm)	5 hr plus 15 min for each additional inch over 5 in. (127 mm)

NOTES:

(1) Postweld heat treatment is not mandatory for P-No. 4 materials under the following conditions:
- (a) for circumferential butt welds in pressure parts with all the following conditions:
  - (1) DELETED
  - (2) a maximum thickness of $\frac{5}{8}$ in. (16 mm)
  - (3) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%
  - (4) a minimum preheat of 250°F (121°C). This minimum preheat is not required for SA-213 Grade T11 tube materials with a maximum outside diameter of 1.5 in. (38 mm) and a maximum thickness of 0.165 in. (4.2 mm) when buttwelded using a multipass GTAW process
- (b) for fillet welds used on socket welding fittings conforming to the rules of PW-41, when the following conditions are met:
  - (1) a fillet weld throat thickness of $\frac{1}{2}$ in. (13 mm) or less, regardless of base metal thickness
  - (2) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%
  - (3) a minimum preheat of 250°F (121°C)
- (c) for pipe and tube materials meeting the requirements of (a)(2) and (a)(3) above and having fillet welds attaching nonpressure parts to them, provided the fillet weld has a throat thickness of $\frac{1}{2}$ in. (13 mm) or less and the material is preheated to 250°F (121°C) minimum; or combination groove and fillet welds attaching nonpressure parts to pressure parts, with a weld thickness of $\frac{1}{2}$ in. (13 mm) or less, provided the material is preheated to a minimum of 250°F (121°C); or heat-absorbing surfaces and non-load-carrying studs attached to them, provided the material is preheated to 250°F (121°C) minimum. A lower preheating temperature may be used, provided specifically controlled procedures necessary to produce sound joints are used. Such procedures shall include but shall not be limited to the following:
  - (1) the throat thickness of fillet welds shall be $\frac{1}{2}$ in. (13 mm) or less
  - (2) the maximum continuous length of fillet welds shall be not over 4 in. (102 mm)
  - (3) electrodes or filler metal shall be dry and shall provide a low-hydrogen weld deposit. Chromium-molybdenum filler metals shall have a maximum specified chromium content of not more than 2.50% and a maximum specified carbon content of not more than 0.05%
  - (4) the thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded
- (d) for tubes or pressure retaining handhole and inspection plugs or fittings that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of $\frac{3}{8}$ in. (10 mm) or less, and preheat to a minimum temperature of 250°F (121°C) is applied when the thickness of either part exceeds $\frac{5}{8}$ in. (16 mm)
- (e) for corrosion-resistant weld metal overlay cladding of pipe or tube materials, provided that all of the following conditions are met:
  - (1) the thickness of the overlay cladding is $\frac{1}{4}$ in. (6 mm) or less
  - (2) preheat to a minimum temperature of 250°F is applied when the thickness of the pressure part exceeds $\frac{1}{2}$ in. (13 mm)
  - (3) the pipe or tube material:
    - (a) does not exceed 5 in. (127 mm) outside diameter; and
    - (b) is not used as a header, drum, or shell.
- (f) for electric resistance welds used to attach extended heat-absorbing fins to pipe and tube materials, provided the following requirements are met:
  - (1) a maximum pipe or tube size of NPS 4 (DN 100)
  - (2) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within specification limits) of not more than 0.15%.
  - (3) a maximum fin thickness of $\frac{1}{8}$ in. (3.2 mm)
  - (4) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat affected zone does not encroach upon the minimum wall thickness

(2) Note (1) does not apply to welds using the inertia and continuous drive friction welding processes. Postweld heat treatment is mandatory for all thicknesses of materials welded using inertia and continuous drive friction welding.

TABLE PW-39 A02
MANDATORY REQUIREMENTS FOR POSTWELD HEAT TREATMENT A03
OF PRESSURE PARTS AND ATTACHMENTS (CONT'D)

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (51 mm)	Over 2 in. (51 mm) to 5 in. (127 mm)	Over 5 in. (127 mm)
P-No. 5A Group No. 1 and P-No. 5B Group No. 1	1,250 (677)	1 hr/in. (1 hr/25 mm), 15 min minimum	1 hr/in. (1 hr/25 mm)	5 hr plus 15 min for each additional inch over 5 in. (127 mm)
P-No. 5B Group No. 2	1,300 (704)	1 hr/in. (1 hr/25 mm), 15 min minimum	1 hr/in. (1 hr/25 mm)	5 hr plus 15 min for each additional inch over 5 in. (127 mm)

NOTES:

(1) Except for P-No. 5B Group No. 2 materials, postweld heat treatment is not mandatory under the following conditions:
- (a) for circumferential butt welds in pressure parts with all of the following conditions:
  - (1) a maximum specified chromium content of 3.0%
  - (2) DELETED
  - (3) a maximum thickness of $^{5}/_{8}$ in. (16 mm)
  - (4) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%
  - (5) a minimum preheat of 300°F (149°C)
- (b) for fillet welds used on socket welding fittings conforming to the rules of PW-41, when the following conditions are met:
  - (1) a maximum specified chromium content of 3.0%
  - (2) a fillet weld throat thickness of $^{1}/_{2}$ in. (13 mm) or less, regardless of base metal thickness
  - (3) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%
  - (4) a minimum preheat of 300°F (149°C)
- (c) for pipe and tube materials meeting the requirements of (a)(1), (a)(3), and (a)(4) above having fillet welds attaching nonpressure parts to them, provided the fillet weld has a throat thickness of $^{1}/_{2}$ in. (13 mm) or less and the material is preheated to 300°F (149°C) minimum; or combination groove and fillet welds attaching nonpressure parts to pressure parts, with a weld thickness of $^{1}/_{2}$ in. (13 mm) or less, and the material is preheated to a minimum of 300°F (149°C); or heat-absorbing surfaces and non-load-carrying studs attached to them, provided the material is preheated to 300°F (149°C) minimum. A lower preheating temperature may be used, provided specifically controlled procedures necessary to produce sound joints are used. Such procedures shall include but shall not be limited to the following:
  - (1) the maximum throat thickness of fillet welds shall be $^{1}/_{2}$ in. (13 mm)
  - (2) the maximum continuous length of fillet welds shall be not over 4 in. (102 mm)
  - (3) electrodes or filler metal shall be dry and shall provide a low-hydrogen weld deposit. Chromium-molybdenum filler metals shall have a maximum specified chromium content of not more than 2.50% and a maximum specified carbon content of not more than 0.05%
  - (4) the thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded
- (d) for tubes or pressure retaining handhole and inspection plugs or fittings with a specified maximum chromium content of 6% that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of $^{3}/_{8}$ in. (10 mm) or less, and preheat to a minimum temperature of 300°F (149°C) is applied when the thickness of either part exceeds $^{5}/_{8}$ in. (16 mm)

(2) Postweld heat treatment is not mandatory for electric resistance welds used to attach extended heat-absorbing fins to pipe and tube materials, provided the following requirements are met:
- (a) a maximum pipe or tube size of NPS 4 (DN 100)
- (b) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%
- (c) a maximum fin thickness of $^{1}/_{8}$ in. (3.2 mm)
- (d) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat affected zone does not encroach upon the minimum wall thickness

(3) Note (1) does not apply to welds using the inertia and continuous drive friction welding processes. Postweld heat treatment is mandatory for all thicknesses of materials welded using inertia and continuous drive friction welding.

A03

TABLE PW-39
MANDATORY REQUIREMENTS FOR POSTWELD HEAT TREATMENT
OF PRESSURE PARTS AND ATTACHMENTS (CONT'D)

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (51 mm)	Over 2 in. (51 mm) to 5 in. (127 mm)	Over 5 in. (127 mm)
P-No. 6 Group No. 1,2,3	1,400 (760)	1 hr/in. (1 hr/25 mm), 15 min minimum	1 hr/in. (1 hr/25 mm)	5 hr plus 15 min for each additional inch over 5 in. (127 mm)

NOTES:
(1) Postweld heat treatment is not mandatory for P-No. 6 materials under the following conditions:
  (a) for Type 410 material where the material and construction shall comply with the following conditions:
    (1) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.08%
    (2) the electrodes used shall produce an austenitic chromium-nickel weld deposit, or a non-air-hardening nickel-chromium-iron weld deposit, and provided the following additional requirements are met:
      (a) the material thickness at the welded joint does not exceed $\frac{3}{8}$ in. (10 mm)
      (b) or material thickness over $\frac{3}{8}$ in. (10 mm) through $1\frac{1}{2}$ in. (38 mm), the following additional conditions shall be required:
        (1) a preheat of 450°F (232°C) shall be maintained during welding
        (2) the welded joints shall be fully radiographically examined
  (b) for electric resistance welds used to attach extended heat-absorbing fins to pipe and tube materials, provided the following requirements are met:
    (1) a maximum pipe or tube size of NPS 4 (DN 100)
    (2) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within specification limits) of not more than 0.15%
    (3) a maximum fin thickness of $\frac{1}{8}$ in. (3.2 mm)
    (4) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat affected zone does not encroach upon the minimum wall thickness
(2) Note (1) does not apply to welds using the inertia and continuous drive friction welding processes. Postweld heat treatment is mandatory for all thicknesses of materials welded using inertia and continuous drive friction welding.

least. For fillet welds, the nominal thickness is the throat thickness, and for partial penetration and material repair welds, the nominal thickness is the depth of the weld groove or preparation. For combination groove and fillet welds, nominal thickness is the total combined thickness of the deposited weld, groove depth plus fillet weld throat.

The holding time at temperature as specified in Table PW-39 need not be continuous. It may be an accumulation of time of multiple postweld heat treat cycles.

PW-39.4 The weldments shall be postweld heat treated by any of the following methods.

PW-39.4.1 Heating the complete assembly as a unit.

PW-39.4.2 Heating sections of assemblies.

PW-39.4.3 In cases where the vessel is postweld heat treated in sections, the heat treatment of the final joints may be performed by one of the following methods. 01

PW-39.4.3.1 By uniformly heating a circumferential band around the vessel, to the temperature and for the time specified in Table PW-39 for postweld heat treatment. 01

PW-39.4.3.2 Alternatively, the post weld heat treatment of the final joints may be performed by 01

TABLE PW-39 (CONT'D) A03
MANDATORY REQUIREMENTS FOR POSTWELD HEAT TREATMENT
OF PRESSURE PARTS AND ATTACHMENTS

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (51 mm)	Over 2 in. (51 mm) to 5 in. (127 mm)	Over 5 in. (127 mm)
P-No. 7 Group No. 1,2	1,350 (732)	1 hr/in. (1 hr/25 mm), 15 min minimum	1 hr/in. (1 hr/25 mm)	5 hr plus 15 min for each additional inch over 5 in. (127 mm)

NOTES:
(1) Postweld heat treatment for P-No. 7 material shall be performed as described in PW-39.3, except that the cooling rate shall be a maximum of 100°F/hr (56°C/hr) in the range above 1,200°F (649°C) after which the cooling rate shall be sufficiently rapid to prevent embrittlement.
(2) Postweld heat treatment is not mandatory for P-No. 7 materials under the following conditions:
  (a) for Type 405 material where the material and construction shall comply with the following conditions:
    (1) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification) of not more than 0.08%
    (2) the electrodes used shall produce an austenitic chromium-nickel weld deposit, or a non-air-hardening nickel–chromium–iron weld deposit, and provided the following additional requirements are met:
      (a) the material thickness at the welded joint does not exceed $\frac{3}{8}$ in. (10 mm)
      (b) for material thickness over $\frac{3}{8}$ in. (10 mm) through $1\frac{1}{2}$ in. (38 mm), the following additional requirements are met:
        (1) a preheat of 450°F (232°C) shall be maintained during welding
        (2) the welded joints shall be fully radiographically examined
  (b) for electric resistance welds used to attach extended heat-absorbing fins to pipe and tube materials, provided the following requirements are met:
    (1) a maximum pipe or tube size of NPS 4 (DN 100)
    (2) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%
    (3) a maximum fin thickness of $\frac{1}{8}$ in. (3.2 mm)
    (4) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat affected zone does not encroach upon the minimum wall thickness

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (51 mm)	Over 2 in. (51 mm) to 5 in. (127 mm)	Over 5 in. (127 mm)
P-No. 8	None	None	None	None

NOTE:
(1) Postweld heat treatment is neither required nor prohibited for joints between austenitic stainless steels of the P-No. 8 group.

heating in the furnace, provided the overlap of the heated sections of the vessel is at least 5 ft. When this procedure is used, the portion outside of the furnace shall be thermally shielded (using blankets, brick, etc.) so that the temperature gradient is not harmful.

01 **PW-39.4.3.2.1** Where the cross section of the vessel that projects from the furnace contains a nozzle, consideration shall be given to controlling the temperature in the nozzle, so that the temperature gradient is not harmful.

01 **PW-39.5** Nozzles or other welded attachments for which postweld heat treatment is required may be locally postweld heat treated by one of the following methods.

01 **PW-39.5.1** By heating a circumferential band around the entire vessel with the welded connection located at the middle of the band. Except as modified below, the soak band shall extend around the entire vessel, and shall include the nozzle of welded attachment.

PW-39.5.1.1 By heating a circumferential band around the entire vessel with the welded connection located at the middle of the band. Provided the required soak band around the nozzle or attachment weld, as defined in PW-39.3, is heated to the required temperature and held for the required time, as specified in Table PW-39, the remainder of the circumferentially-heated band may be varied in width around the circumference of the vessel. The temperature within the heated band shall be controlled to prevent harmful gradients. 01

PW-39.5.1.2 By heating a circumferential band around the entire vessel with the welded connection located at the middle of the band. Provided the required soak band around the nozzle or attachment weld, as defined in PW-39.3, is heated to the required temperature and held for the required time, as specified in Table PW-39, the remainder of the circumferentially-heated band need not reach the required post weld heat treatment temperature. The temperature within the heated band shall be controlled to prevent harmful gradients. 01

TABLE PW-39 (CONT'D)
MANDATORY REQUIREMENTS FOR POSTWELD HEAT TREATMENT
OF PRESSURE PARTS AND ATTACHMENTS

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (51 mm)	Over 2 in. (51 mm) to 5 in. (127 mm)	Over 5 in. (127 mm)
P-No. 10I Group No. 1	1,250 (677)	1 hr/in. (1 hr/25 mm), 15 min minimum	1 hr/in. (1 hr/25 mm)	1 hr/in. (1 hr/25 mm)

NOTES:
(1) Postweld heat treatment for P-No. 10I (SA-268 TP446 material only) shall be performed as described in PW-39.3, except that the cooling rate shall be a maximum of 100°F/hr (56°C/hr) above 1,200°F (649°C) after which the cooling rate shall be sufficiently rapid to prevent embrittlement.

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (51 mm)	Over 2 in. (51 mm) to 5 in. (127 mm)	Over 5 in. (127 mm)
P-No. 31	None	None	None	None

NOTE:
(1) Postweld heat treatment is neither required nor prohibited for joints between materials of the P-No. 31 group.

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (51 mm)	Over 2 in. (51 mm) to 5 in. (127 mm)	Over 5 in. (127 mm)
P-No. 45	None	None	None	None

NOTE:
(1) Postweld heat treatment is neither required nor prohibited for joints between materials of the P-No. 45 group.

TABLE PW-39.1
ALTERNATE POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS
(Applicable only when permitted in Table PW-39)

Decrease in Temperature Below Minimum Specified Temperature, °F (°C)	Minimum Holding Time [Note (1)] at Decreased Temperature, hr/in. (hr/25 mm) of Thickness	Notes
50 (28)	2	...
100 (56)	4	...
150 (83)	10	(2)
200 (111)	20	(2)

NOTES:
(1) Minimum holding time per inch for thickness up to and including 2 in. (51 mm). Add 15 min per inch of thickness for thickness greater than 2 in. (51 mm).
(2) These lower postweld heat treatment temperatures permitted only for P-No. 1, Group 1 and 2 materials.

01 **PW-39.5.2** Local areas around nozzles or welded attachments in the larger radius sections of double curvature heads, or spherical shells or heads, may be post weld heat treated by heating a circular region around the nozzle. This region, or soak band, shall include the nozzle or welded attachment and shall be measured from the center of the nozzle or attachment. The soak band shall be a circle whose radius is equal to the radius at the widest width of the width of the weld attaching the nozzle or attachment to the shell, plus the thickness of the shell or head, or 2 in., whichever is less. The portion of the vessel outside of the circular region shall be thermally shielded using blankets, brick, or other suitable insulation material so that the temperature gradient is not harmful. A greater amount of base material may also be heated to permit temperature gradient control.

01 **PW-39.5.3** Nozzles that contain circumferential welds in close proximity to a vessel or shell have additional thermal restraint imposed by this close proximity. Adequate length between the weld on the nozzle and the shell shall be provided so that the post weld heat treatment does not introduce harmful stresses at the nozzle attachment weld. Alternatively, the weld may be post weld heat treated by heating a full circumferential band around the entire vessel or shell, which shall include the nozzle in the center of the band.

01 **PW-39.6** In the case of local postweld heat treatment of welded joints in pipes, tubes, and headers, the soak band shall extend around the entire pipe tube or header.

PW-39.7 Electroslag welds in ferritic materials over $1\frac{1}{2}$ in. (38 mm). in thickness at the joint shall be given a grain refining (austenitizing) heat treatment.

PW-40 REPAIR OF DEFECTS 01

PW-40.1 Weld imperfections, such as cracks, pinholes, and incomplete fusion, detected visually or by leakage tests or by the examinations described in PW-11 and found to be rejectable, shall be removed by mechanical means or by thermal grooving processes, after which the joint shall be rewelded and reexamined. 01

PW-40.2 When tube-to-header or tube-to-drum welded joints have already received the postweld heat treatment required by PWT-11 and PW-39, minor local additional welding for rework of the joint or to improve the fillet weld contour may be performed on the materials listed in (b) below without repeating the postweld heat treatment, subject to all the following limitations. 01 A03

(a) The depth of any rework welding below the surface shall not exceed the smaller of 10% of the thickness of the drum or header, or 50% of the wall thickness of the tube.

(b) The area to be rework welded shall be preheated to at least the minimum temperatures as indicated below for the material:

Material Welding P-Number Group	Minimum Preheat,°F (°C), for Rework Welding
P-No.1	200 (93)
P-No.3, Groups 1 & 2	200 (93)
P-No.4	250 (121)
P-No.5A	300 (149)

(c) The tubes shall not exceed 4 in. (102 mm) O.D. except for P-No. 1 material, which shall not exceed $6\frac{5}{8}$ in. (168 mm) O.D.

(d) The welding procedure used for the rework welding shall have been qualified to the requirements of Section IX for the thickness of rework welding to be performed and for the omission of postweld heat treatment.

PW-40.3 Defects in P-No. 1 Group Nos. 1, 2, and 3 materials, and in P-No. 3 Group Nos. 1 and 2 materials, and in the welds joining these materials, may be weld repaired after the final PWHT but prior to the final hydrostatic test. The welded repairs shall meet the requirements below. 01

PW-40.3.1 Defect Removal for Base Materials. The defect shall be removed or reduced to an acceptable size. Before repair welding, the groove shall be exam- 01 A03

ined to verify that the defect has been reduced to an acceptable size, using either the magnetic particle or the liquid penetrant examination methods. When the material is nonmagnetic, only the liquid penetrant method shall be used. Methods for magnetic particle examination and liquid penetrant examination shall be in accordance with A-260 and A-270, respectively; however, the acceptance standards for the examination shall be in accordance with the requirements of the original base material specification.

01 A03 **PW-40.3.2 Defect Removal for Welds and Welded Repairs.** The defect shall be removed, and the groove examined to verify defect removal, using either the magnetic particle or the liquid penetrant examination methods. When the material is nonmagnetic, only the liquid penetrant method shall be used. Methods and acceptance standards for magnetic particle examination and liquid penetrant examination shall be in accordance with A-260 or A-270, respectively.

01 **PW-40.3.3** The total repair depth shall not exceed 10% of the base material thickness. The total depth of a weld repair shall be taken as the sum of the depths for repairs made from both sides of a weld at a given location. The total area of such repairs shall not exceed 100 sq in.

01 A02 **PW-40.3.4** In addition to the requirements of Section IX for qualification of welding procedure specifications for groove welds, the following requirements shall apply.

(a) The weld procedure qualification shall have been made using material of the same P-No. and Group No. as the material to be repaired. The specific welding technique or combination of welding techniques used shall have been developed and tested to assure adequate tempering of the underlying weld bead heat affected zones.

(b) The weld metal shall be deposited by the manual shielded metal-arc process. Only low hydrogen welding electrodes shall be used. The electrodes shall be properly conditioned in accordance with Section II, Part C, SFA-5.5, Appendix A6.11.

(c) The maximum heat input for each weld layer shall not exceed that used in the procedure qualification test.

(d) The maximum deposited weld bead width for any electrode shall be four times the electrode core diameter.

(e) The repair area, including a band equal in width to 4 in. or four times the thickness of the weld repair, whichever is greater, on either side of the groove, shall be preheated and maintained at a minimum temperature of 350°F during welding. The maximum interpass temperature shall be 450°F.

(f) The repair weld method shall be limited to the half bead weld repair technique as follows. The initial layer of weld metal shall be deposited over the entire area using $\frac{1}{8}$ in. maximum diameter electrodes. Approximately one half the thickness of this layer shall then be removed by grinding before depositing subsequent layers. The subsequent weld layers shall be deposited using $\frac{5}{32}$ in. maximum diameter electrodes, in such a manner as to assure tempering of the prior weld beads and their heat affected zones. A final temper bead weld shall be applied to a level above the surface being repaired without contacting the base material, but close enough to the edge of the underlying weld bead, to assure tempering of the base material heat affected zone.

PW-40.3.5 For materials greater than 1 in. thick, after completing all welding, the repair area shall be heated to and maintained at a temperature of 450°–550°F for a minimum period of 4 hr. 01

PW-40.3.6 Any final temper bead reinforcement shall then be removed substantially flush with the surface of the base material. 01

PW-40.3.7 After the finished repair weld has reached ambient temperature, it shall be examined to the requirements of PW-40.3.2, using the same nondestructive examination technique that was used to examine the weld groove. 01

PW-40.3.8 The vessel shall be hydrostatically tested in accordance with PW-54. 01

PW-40.3.9 The Manufacturer shall obtain the approval of the Authorized Inspector, prior to making the repair. 01

PW-41 CIRCUMFERENTIAL JOINTS IN PIPES, TUBES, AND HEADERS

The rules in the following paragraphs apply specifically to the boiler proper and parts thereof.

PW-41.1 Circumferential welded butt joints in pipe, tubes, and headers shall meet the radiographic and ultrasonic examination requirements of Table PW-11.

PW-41.2 All circumferential arc or gas welded joints of parts covered by this paragraph and welded in accordance therewith shall have a double-welded butt joint or a single-welded butt joint made the equivalent of a double-welded butt joint, except as otherwise provided in PW-41.4 and PW-41.5.

PW-41.2.1 The strength of the weld shall be sufficient to develop the full strength of the part in the longitudinal direction. There shall be no valley or groove along the edge or in the center of the weld except as permitted by PW-35.1. Weld reinforcement may be removed if so desired. The design of the joint and the method of welding shall be such that there will be no appreciable projection of weld metal past the inside surface.

PW-41.2.2 In welding single-welded butt joints, complete penetration at the root is required. This shall be demonstrated by the qualification of the procedure to be used. If complete penetration cannot otherwise be secured, the procedure shall include a backing ring or equivalent. The depth of weld measured between the inside surface of the weld preparation and the outside surface of the pipe or tube shall be not less than the minimum thickness permitted by the applicable material specifications for the particular size and thickness of pipe or tubing used. Where backing rings are not used, concavity of the root surface is permitted if the depth of the concavity of the weld metal does not exceed the lesser of $^{3}/_{32}$ in. or 20% of the thinner of the two sections being joined. The contour of the concavity shall be smooth and the resulting thickness of the weld, including reinforcement, shall be at least equal to the required thickness of the thinner section. Concavity depth allowed under the rules of this paragraph shall be reduced by an amount equal to any net section replacement used, as permitted in PW-41.2.3.

A03 **PW-41.2.3** When the wall is recessed for a backing ring or to assure a uniform inside diameter of the weld preparation, the depth of such recess shall be so limited that the remaining net section of the wall is not less than the minimum required thickness. For boiler and superheater tubes where the diameter does not exceed 4 in. (102 mm), the recess may reduce the required thickness by not more than $^{1}/_{32}$ in. (0.8 mm), provided the reduced net section is replaced by weld metal in the outside reinforcement such that the resulting thickness of the weld, including reinforcement, is at least equal to the minimum required thickness.

PW-41.2.4 Backing rings may be of any size or shape suitable for the welding process and may be left in place or removed as desired. Materials for backing rings shall be compatible with the weld metal and base material and shall not cause harmful alloying or contamination. If left in place they must be properly secured to prevent dislodgment and shall have a contour on the inside to minimize the restriction to flow, if needed, and be of such inside diameter as to permit the passage of a tube cleaner where such cleaner is to be used.

PW-41.2.5 When welded joints in tubes or pipes are not postweld heat treated, the procedure qualification test shall be made under the same conditions, but the performance qualification test may be made on either postweld heat treated or nonpostweld heat treated samples.

PW-41.3 Pipe connections not exceeding NPS $^{1}/_{2}$ (DN 15) may be welded to pipe or headers under the provisions of this paragraph without the inspection required by this Section.

PW-41.4 For attachment of nozzles to boiler drums or headers see PW-15.

PW-41.5 Welded socket type joints or sleeve type joints may be used to connect pipe or tubes to valves or fittings, or to each other, provided the following conditions are met.

PW-41.5.1 Pipe shall not exceed NPS 3 (DN 80) and tubing shall not exceed $3^{1}/_{2}$ in. (89 mm) nominal outside diameter (see PG-42, for ANSI socket welding components).

PW-41.5.2 The depth of insertion of a pipe or tube into a socket shall be at least $^{1}/_{4}$ in. (6 mm). There shall be at least $^{1}/_{16}$ in. (1.6 mm) clearance between the end of the pipe or tube and the internal shoulder of the socket, before welding.

PW-41.5.3 The fit between the socket or sleeve and the pipe or tube shall conform to applicable standards for socket weld fittings, and in no case shall the inside diameter of the socket or sleeve exceed the outside diameter of the pipe or tube by more than 0.080 in. (2.03 mm).

PW-41.5.4 The average outside diameter of the hub or sleeve (collar or end portion of socket welding fittings) shall be sufficient to make the average hub or sleeve thickness not less than 1.09 times the nominal thickness of the pipe or tube.

PW-41.5.5 The throat dimension of the fillet weld shall be not less than 0.77 times the nominal thickness of the pipe or tube.

A02 **PW-41.5.6** The welded joint shall not be in contact with furnace gases greater than 850°F (454°C).

PW-41.5.7 The depth of the insertion of a pipe or tube into a sleeve shall be at least $^1/_4$ in. (6 mm). There shall be at least $^1/_{16}$ in. (1.6 mm) clearance between the butting ends of the pipe or tube, before welding.

PW-42 JOINTS IN VALVES AND OTHER BOILER APPURTENANCES

Valves, other boiler appurtenances such as water columns, and casings of pumps that are part of a boiler circulation system, may have fusion-welded joints other than longitudinal, complying with the requirements of this Part except that inspection of these joints is not required. The Manufacturer shall furnish, if requested, a statement certifying that these requirements have been met.

PW-43 LOADING ON STRUCTURAL ATTACHMENTS

PW-43.1 Loads imposed on steel tube walls by welded or mechanical attachments which produce bending stresses that are additive to bursting stresses shall conform to the following:

PW-43.1.1 $L \le L_a$

where

L = actual unit load calculated from PW-43.1.2, lb/in. (kN/m)

L_a = maximum allowable unit load, lb/linear in. of attachment from PW-43.2, lb/in. (kN/m)

PW-43.1.2 $L = W_r/\ll \pm 6We/\ll^2$

where

W_r = load component normal to tube axis, lb (kN)

W = eccentric load applied to lug, lb (kN)

$\ll$ = length of attachment of tube, in. (mm)

e = eccentricity of W, in. (mm) (see Fig. PW-43.2)

In determining the allowable loading per inch (25 mm) of length of attachment on a tube bend, the allowable unit load determined by using the outside diameter of the tube shall be increased by the amount of allowable compression unit load for a tube having an outside diameter equivalent to the outside diameter of the bend and having a wall thickness the same as that of the tube bend (see Fig. A-74). For an alternative method of determining the maximum allowable loading on structural attachments to tubes, see A-73.2 for conducting tests on full-size sections of tubes.

PW-43.2 Procedure for determining L_a in the equation in PW-43.1.1.

Step 1: Determine K from Table PW-43.1.

Step 2: Determine load factor L_f for compression or tension loading on lug from Fig. PW-43.1, or from PW-43.2.1 or PW-43.2.2, when the range of the curves in Fig. PW-43.1 does not extend far enough to cover specific cases.

PW-43.2.1 Compression Loading

$$L_f = 1.618X^{[-1.020 - 0.014 \log X + 0.005 (\log X)^2]}$$

PW-43.2.2 Tension Loading

$$L_f = 49.937X^{[-2.978 + 0.898 \log X - 0.139 (\log X)^2]}$$

Step 3: Determine S_t.

PW-43.2.3 Available Stress

$$S_t = 2.0\ S_a - S$$

Step 4: Using values obtained in Steps 1 through 3, determine maximum allowable unit load, lb/in. (kN/m)

PW-43.2.4 Allowable Unit Load

$$L_a = K(L_f)S_t$$

where

K = tube attachment width design factor from Table PW-43.1, dimensionless

L_f = a compression or tension load factor, in. (mm)

S_t = portion of allowable stress available for attachment loading, from PW-43.2.3, psi (kPa)

D = outside diameter of tube, in. (mm)

t = tube wall thickness, in. (mm)

X = D/t^2, a parameter used to determine L_f, 1/in. (1/mm)

S_a = allowable stress value from Table 1A of Section II, Part D

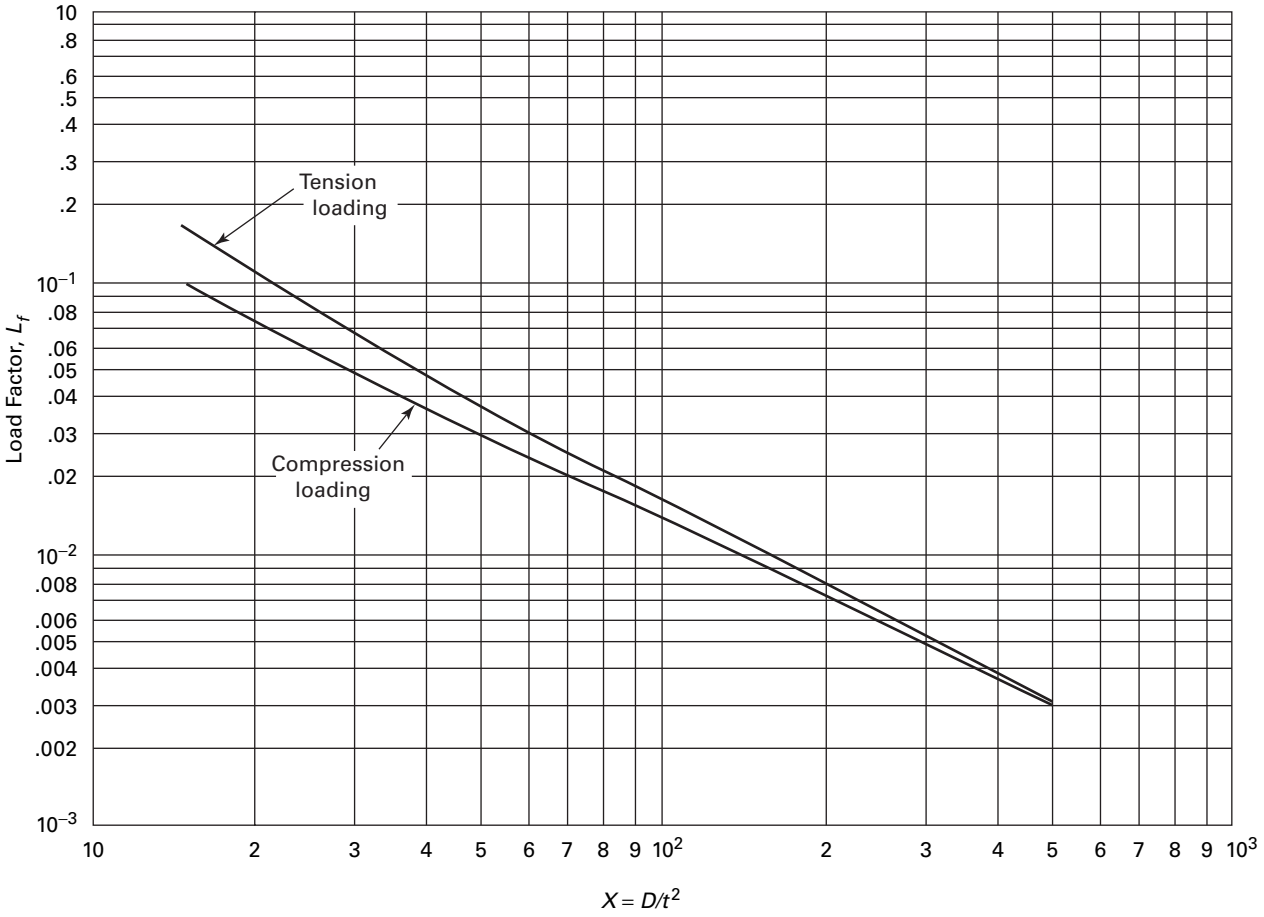


FIG. PW-43.1 CHART FOR DETERMINING LOAD FACTOR, L_f

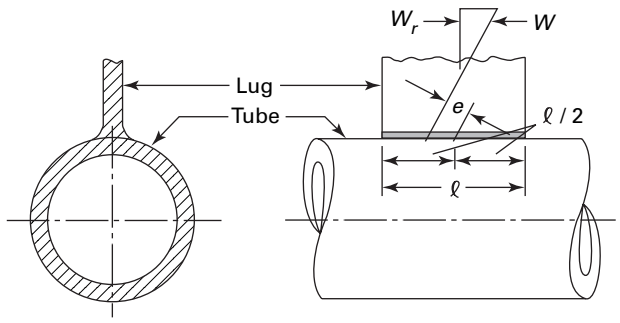


FIG. PW-43.2 METHOD OF COMPUTATION OF ATTACHMENTS TO TUBES

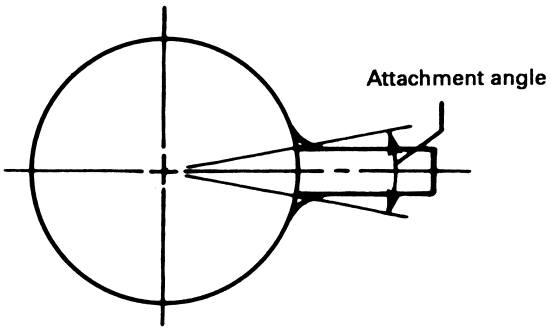


TABLE PW-43.1
TUBE ATTACHMENT ANGLE DESIGN FACTOR, *K*

Angle of attachment, deg	0	5	10	15	20	25	30	35	40	45
Design factor, *K*	1.000	1.049	1.108	1.162	1.224	1.290	1.364	1.451	1.545	1.615
Angle of attachment, deg	50	55	60	65	70	75	80	85	90	
Design factor, *K*	1.730	1.836	1.949	2.076	2.221	2.341	2.513	2.653	2.876	

S = pressure stress in tube determined by the equation in PG-27.2.1, psi (kPa)
log = logarithm to base 10

INSPECTION AND TESTS

PW-46 GENERAL

PW-46.1 The rules in the following paragraphs apply specifically to the inspection and testing of power boilers and power boiler parts that are fabricated by welding 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.

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

PW-47 CHECK OF WELDING PROCEDURE

PW-47.1 It is the duty of the Inspector to assure himself that the welding procedures employed in construction have been qualified under the provisions of Section IX. The Manufacturer shall submit evidence to the Inspector that those requirements have been met.

PW-47.2 The Inspector has the right at any time to call for and witness the test welding and testing although it is not mandatory that he witness the test welding and the testing unless he so desires.

PW-48 CHECK OF WELDER AND WELDING OPERATOR PERFORMANCE QUALIFICATIONS

PW-48.1 It is the duty of the Inspector to assure himself that all welding is done by welders or welding operators qualified under the provisions of Section IX. The Manufacturer shall make available to the Inspector a certified copy of the record of performance qualification tests of each welder and welding operator as evidence that these requirements have been met.

PW-48.2 The Inspector has the right at any time to call for and witness the test welding and testing although it is not mandatory that he witness the test welding and the testing unless he so desires.

PW-49 CHECK OF HEAT TREATMENT PRACTICE

The Inspector shall satisfy himself that all heat treating operations required by the Code have been correctly performed.

PW-51 ACCEPTANCE STANDARDS FOR RADIOGRAPHY

PW-51.1 All welds for which a complete radiographic examination is required by PW-11 shall be radiographically examined throughout their entire length by the X-ray or gamma-ray method in accordance with Article 2 of Section V, except that the requirements of T-285 are to be used as a guide but not for the rejection of radiographs unless the geometrical unsharpness exceeds 0.07 in. (1.8 mm).

PW-51.2 A single-welded circumferential butt joint with backing strip may be radiographed without removing the backing strip, provided it is not to be removed subsequently and provided the image of the backing strip does not interfere with the interpretation of the resultant radiographs.

PW-51.3 Indications shown on the radiographs of welds and characterized as imperfections are unacceptable under the following conditions, and shall be repaired as provided in PW-40 and the repair radiographed to PW-51:

PW-51.3.1 Any indication characterized as a crack, or zone of incomplete fusion or penetration.

PW-51.3.2 Any other elongated indication on the radiograph that has a length greater than:

(a) $\frac{1}{4}$ in. (6 mm) for t up to $\frac{3}{4}$ in. (19 mm);

(b) $\frac{1}{3}$ t for t from $\frac{3}{4}$ in. (19 mm) to $2\frac{1}{4}$ in. (57 mm);

(c) $\frac{3}{4}$ in. (19 mm) for t over $2\frac{1}{4}$ in. (57 mm)

where t is the thickness of the weld.

PW-51.3.3 Any group of aligned indications that have an aggregate length greater than t in a length of $12t$, except when the distance between the successive imperfections exceeds $6L$ where L is the length of the longest imperfection in the group.

PW-51.3.4 Rounded indications in excess of those shown in Appendix A-250.

PW-51.4 A complete set of radiographs for each job shall be retained by the Manufacturer and kept on file for a period of at least 5 years.

PW-51.5 The Manufacturer shall certify that personnel performing and evaluating radiographic examinations required by Section I have been qualified and certified in accordance with their employer's written practice. SNT-TC-1A[3] or CP-189 shall be used as a guideline for employers to establish their written practice for qualifications and certification of their personnel. Alternatively, the ASNT Central Certification Program (ACCP) may be used to fulfill the examination and demonstration requirements of SNT-TC-1A and the employer's written practice. Provisions for training, experience, qualification, and certification of NDE personnel shall be described in the Manufacturer's quality control system (see PG-105.4). 01

When personnel have been certified according to their employer's written practice based upon an edition of SNT-TC-1A, ACCP, or CP-189 earlier than that referenced in A-360, their certification shall be valid for performing nondestructive examination required by this Section until their next scheduled recertification. Any recertifications, reexaminations, or new examinations shall be performed to the employer's written practice based on the edition of SNT-TC-1A, ACCP, or CP-189 referenced in A-360.

PW-52 ACCEPTANCE STANDARDS FOR ULTRASONIC EXAMINATION

PW-52.1 Technique and standards for ultrasonic examination shall follow Section V, Article 4. A02

PW-52.2 The Manufacturer's report, as required by T-490 of Section V, shall be retained by the Manufacturer for a minimum of 5 years. A02

PW-52.3 Acceptance-Rejection Standards. Imperfections that cause an indication greater than 20% of the reference level shall be investigated to the extent that the ultrasonic examination personnel can determine their shape, identity, and location, and evaluate them in terms of PW-52.3.1 and PW-52.3.2.

PW-52.3.1 Cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

PW-52.3.2 Other imperfections are unacceptable if the indication exceeds the reference level and their length exceeds the following:

(a) $\frac{1}{4}$ in. (6 mm) for t up to $\frac{3}{4}$ in. (19 mm);

[3] SNT-TC-1A, ACCP, and CP-189 are published by the American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228-0518. 01

(b) 1/3 *t* for *t* from 3/4 in. (19 mm) to 2 1/4 in. (57 mm);

(c) 3/4 in. (19 mm) for *t* over 2 1/4 in. (57 mm)

where *t* is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, *t* is the thinner of these two thicknesses.

01 **PW-52.4** The Manufacturer shall certify that personnel performing and evaluating ultrasonic examinations required by Section I have been qualified and certified in accordance with their employer's written practice. SNT-TC-1A[3] or CP-189 shall be used as a guideline for employers to establish their written practice for qualification and certification of their personnel. Alternatively, the ASNT Central Certification Program (ACCP) may be used to fulfill the examination and demonstration requirements of SNT-TC-1A and the employer's written practice. Provisions for training, experience, qualification, and certification of NDE personnel shall be described in the Manufacturer's quality control system (see PG-105.4).

When personnel have been certified according to their employer's written practice based upon an edition of SNT-TC-1A, ACCP, or CP-189 earlier than that referenced in A-360, their certification shall be valid for performing nondestructive examination required by this Section until their next scheduled recertification. Any recertifications, reexaminations, or new examinations shall be performed to the employer's written practice based on the edition of SNT-TC-1A, ACCP, or CP-189 referenced in A-360.

PW-53 TEST PLATES

PW-53.1 Vessel Test Plates. Cylindrical pressure parts subject to internal pressure, except such cylindrical pressure parts constructed of P-No. 1 materials as defined in Section IX, that are fabricated by fusion welding, such as drums and shells but not pipe, tubes, and headers shall meet the test requirements in PW-53.2 through PW-53.10.

PW-53.2 Welded Test Plates. A welded test plate having the dimensions shown in Fig. PW-53.1 shall be prepared from plate of the same material specification,[4] the same or greater thickness as the weld at the joint and using the same welding procedure as used for the shell plates that it represents. The plate shall be welded by one of the following methods. Either method may represent both longitudinal and circumferential joints.

PW-53.2.1 Attach the test plate as shown in Fig. PW-53.2 to one end of one longitudinal joint of each vessel so that the edges to be welded are a continuation of the corresponding edges of the longitudinal joint. In this case the weld metal shall be deposited in the weld joint of the test plate continuously with that deposited in the shell joint. This procedure is not applicable to vessels with circumferential joints only.

PW-53.2.2 Weld the joint in the test plate without attaching it as a continuation of a joint in the shell plate.

PW-53.3 When noncylindrical pressure parts are not integral with the vessel, a test plate shall be provided having a thickness not less than that of the parts.

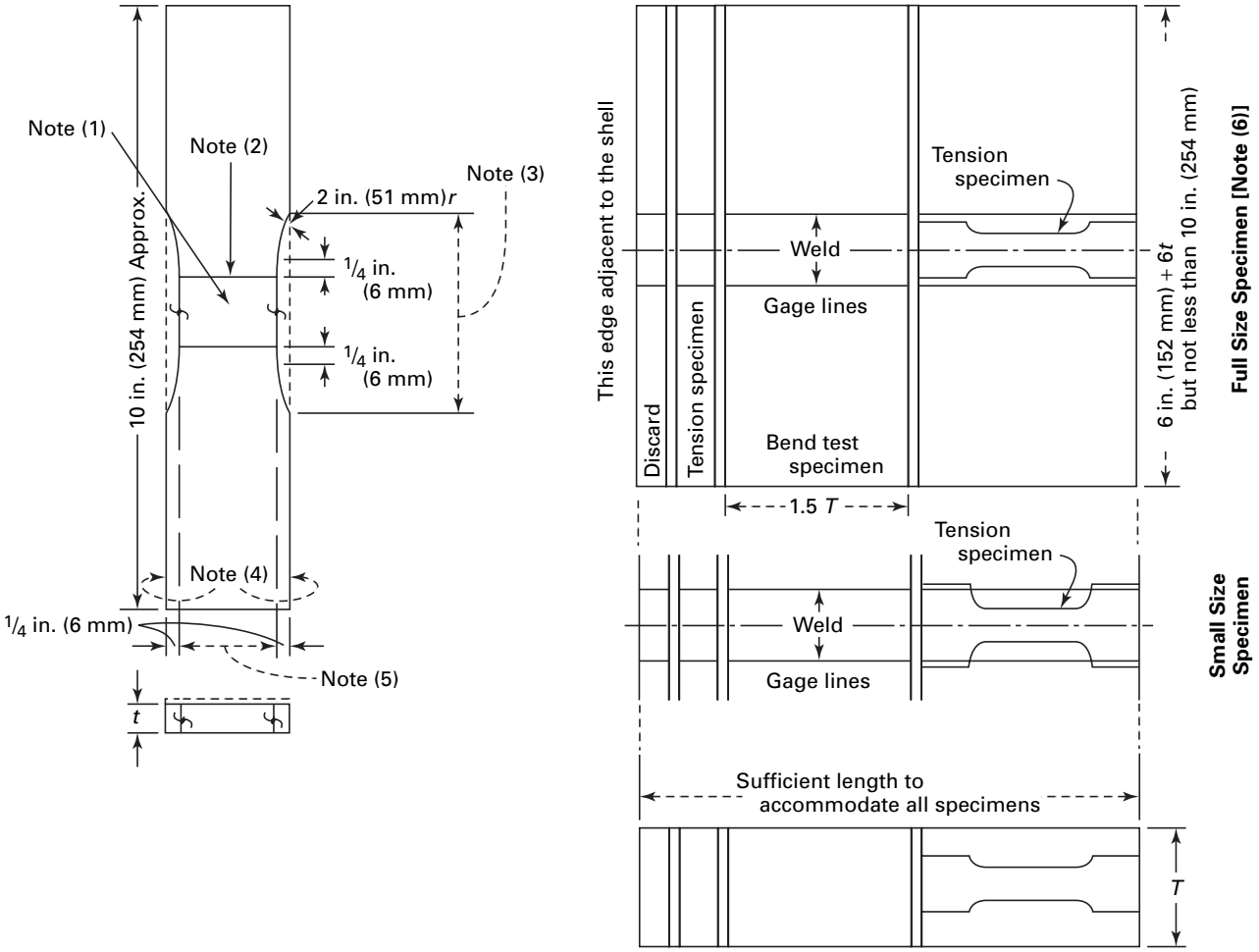
PW-53.4 Where there are several pressure parts of any one design being welded in succession, the plates of which are of the same material that is covered by the welding procedure, a test plate shall be furnished for each 200 ft (61 m), or fraction thereof, of the main welded joints. The thickness of the thinnest plate and of the thickest plate shall not differ by more than 1/4 in. (6 mm).

PW-53.5 Where more than one welder or welding operator is used on a vessel, the inspector may designate the welder or welding operator who shall make the required test plate.

PW-53.6 The test plate shall be so supported that the welding does not warp the plate out of line by an angle greater than 5 deg. The plate shall be straightened before postweld heat treatment to remove any warping that has occurred. The test plate shall be given the same preheat treatment and the same postweld heat treatment as the vessel that it represents. In no case shall the temperature of preheat or postweld heat treatment be higher than that used for the vessel.

PW-53.7 Test Specimens. The coupons for tension A03
and bend test shall be removed as shown in Fig. PW-53.1 and shall be of the dimensions shown in Fig. PW-53.1 and Fig. PW-53.3. If the dimensions of the weld groove are such that a full size tension specimen cannot be obtained, then a small size specimen as shown in Fig. 3 or Fig. 4 of SA-370 may be used. The specimen removed shall be the largest specimen that contains only all-weld metal in the reduced section.

[4] To be of the same specification as the steel being welded the chemical composition must be within the specification limits and the melting practice, i.e. killed, semikilled, or rimmed, must be the same.



NOTES:
(1) Weld reinforcement shall be machined flush with base metal.
(2) Edge of widest face of weld.
(3) This section machined preferably by milling.
(4) These edges may be flame cut.
(5) $W = 1\frac{1}{2}$ in. (38 mm) ± 0.01 in. (0.2 mm), if t does not exceed 1 in. (25 mm);
$W = 1$ in. (25 mm) ± 0.01 in. (0.2 mm), if t exceeds 1 in.
(6) Small size specimens in accordance with Fig. 3 of SA-370.

FIG. PW-53.1 TEST SPECIMENS FROM LONGITUDINAL WELDED TEST PLATES A03

PW-53.8 Tension Tests

PW-53.8.1 Except as provided in PW-53.8.5 two types of tension test specimen are required, one of the joint and the other of the weld metal.

PW-53.8.2 The tension specimen of the joint shall be transverse to the welded joint and shall be the full thickness of the welded plate after the outer and inner surfaces of the weld have been machined to a plane surface flush with the surface of the plate. When the capacity of the available testing machine does not permit testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall be tested and shall meet the requirements.

PW-53.8.3 If the tension test specimen shown in Fig. PW-53.1 breaks in the weld, its tensile strength shall be not less than the minimum of the specified tensile range of the base material. (The tension test of

the joint specimen as specified herein is intended as test of the welded joint and not of the plate.) When the specimen breaks outside the weld at not less than 95% of the minimum of the specified tensile range of the base material and the weld shows no sign of weakness, the test shall be accepted as meeting the requirements. When the specimen or a portion thereof breaks in the base material below this strength tolerance because of a local defect, one additional specimen shall be tested and shall meet the requirements.

PW-53.8.4 The tension test specimen of the weld metal shall be taken such that the reduced portion of the specimen shall consist entirely of deposited weld metal and shall meet the following requirements: A03

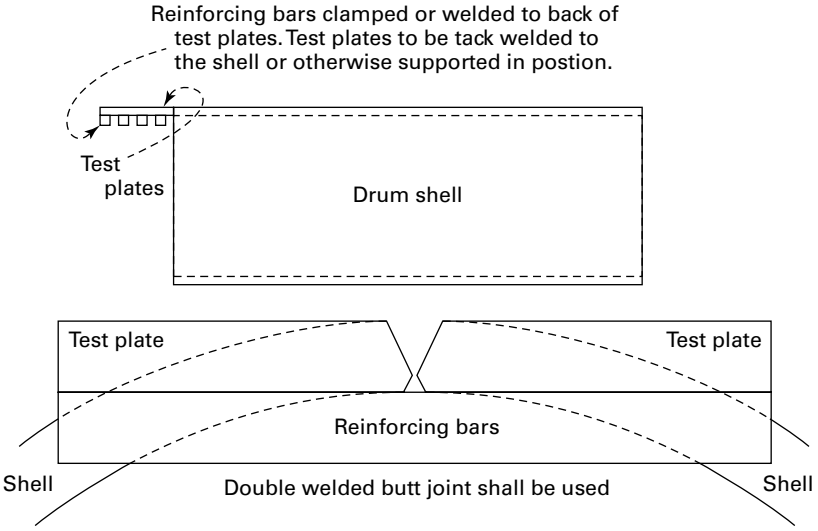


FIG. PW-53.2 METHOD OF FORMING LONGITUDINAL TEST PLATES

Tensile strength = at least that of the minimum of the range of the plate which is welded

Elongation, minimum, %, in 2 in. (51 mm) = 20,

or = 700,000/*U* (4 820 000/*U* metric) + 10, whichever is less

where

U = minimum specified tensile strength of the material to be welded, psi, as given in the applicable stress table

PW-53.8.5 For plate thicknesses less than $\frac{5}{8}$ in. (16 mm), the all-weld metal tension test may be omitted.

PW-53.9 Bend Tests

PW-53.9.1 The bend test specimen shall be transverse to the welded joint of the full thickness of the plate and shall be of rectangular cross section with a width $1\frac{1}{2}$ times the thickness of the specimen. When the capacity of the available testing machines does not permit testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall be tested and shall meet the requirements. The inside and outside surfaces of the weld shall be machined to a plane surface flush with the surface of the specimen. The edges of this surface shall be rounded to a radius not over 10% of the thickness of the test specimen. The specimen shall be bent cold under free bending conditions until the least elongation measured within or across approximately the entire weld on the outside fibers of the bend test specimen is 30%, or 700,000/*U* (4 820 000/*U*) + 20%, whichever is less.

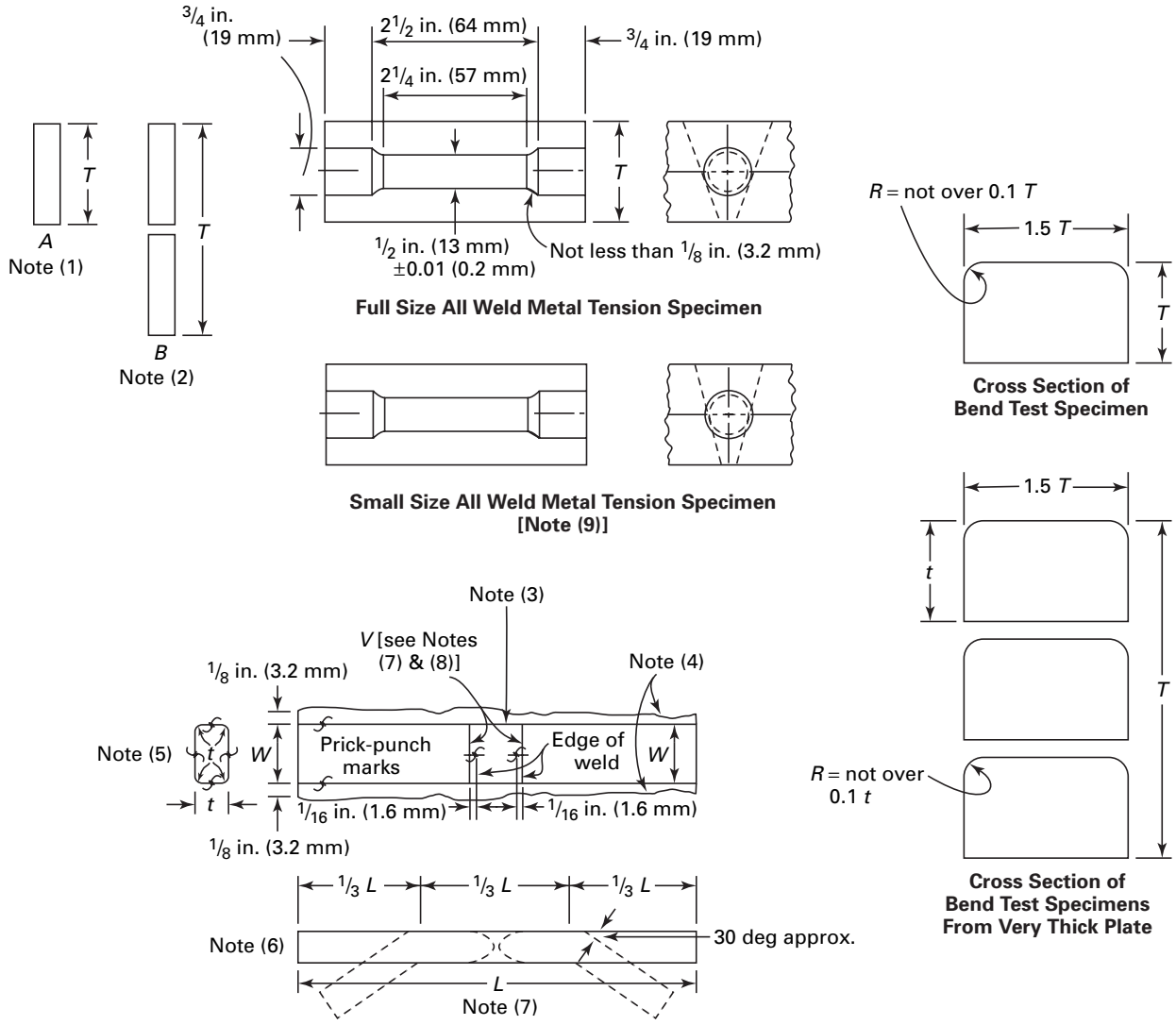
PW-53.9.2 When a crack is observed in the convex surface of the specimen between the edges before the elongation required in PW-53.8.1 is attained, the specimen shall be considered to have failed and the test shall be stopped. Cracks at the corners of the specimen shall not be considered as a failure. The appearance of small imperfections in the convex surface shall not be considered as a failure if the greatest dimension does not exceed $\frac{1}{16}$ in. (1.6 mm).

PW-53.10 Retests

PW-53.10.1 Should any of the specimens fail to meet the requirements by more than 10%, no retest shall be allowed except that in the case of failure of the free-bend test specimen due to permissible imperfections, free-bend specimen retests may be allowed at the discretion of the Inspector.

PW-53.10.2 Should any of the specimens fail to meet the requirements by 10% or less, retests shall be allowed. A second test plate shall be welded by the same operator who welded the plate which did not meet the test requirements. The retest shall be made on specimens cut from the second plate.

PW-53.10.3 The retests shall comply with the requirements. For either of the tension retests, two specimens shall be cut from the second test plate, and both of these shall meet the requirements.



NOTES:
(1) *A* — Cross section through tension specimen.
(2) *B* — Cross section through tension specimens on very thick plate.
(3) This surface to be reasonably smooth. Any tool marks remaining must be lengthwise of specimen.
(4) If coupons have been cut apart by a fusion process, the flame cut surfaces are to be machined off as indicated.
(5) Round corners to radius of not over $^1/_{10}$ *t*: $W = 1^1/_2$ *t*.
(6) "*f*" indicates light finish cut. Weld reinforcement to be removed.
(7) *L* (appropriate minimum) = 3 in. (76 mm) + 3 *V*. The length of the bend specimen is immaterial, provided the bend occurs at the weld. The minimum length indicated is only suggestive and is not mandatory.
(8) *V* = width of the surface of the weld.
(9) Specimen sizes in accordance with Fig. 3 or 4 of SA-370.

FIG. PW-53.3 DETAILS OF TEST SPECIMENS A03

PW-53.10.4 When there is more than one specimen of the same type and one or more of the specimens fail to meet the requirements by 10% or less, a retest may be made for each specimen required for the weld under consideration. Each such specimen shall meet the requirements.

PW-53.10.5 If the percentage of elongation of all-weld metal tension specimen is less than that specified and any part of the fracture is more than $^{3}/_{4}$ in. (19 mm) from the center of the 2 in. (51 mm) gage length of the specimen, a retest shall be allowed.

PW-54 HYDROSTATIC TEST

PW-54.1 Except as modified in PG-99.3, PG-106.8, and PW-54.3, all welded drums and other welded pressure parts shall be subjected to a hydrostatic test pressure of not less than 1.5 times the maximum allowable working pressure. The hydrostatic test may be made either in the Manufacturer's shop or in the field.

PW-54.2 When repairs are made, the part shall again be tested in the regular way, and if it passes the test the Inspector shall accept it. If it does not pass the test the Inspector may permit supplementary repairs, or if in his judgment the pressure part is not suitable for service, he may permanently reject it.

A02 **PW-54.3** Welding of non-pressure parts to pressure parts and seal welding of pressure retaining handhole and inspection plugs or fittings secured by physical means may be performed after the hydrostatic test without requiring another hydrostatic test provided the following criteria are met.

PW-54.3.1 Welding is done in conformance with this Part and the completed weld is inspected by the Authorized Inspector. The Manufacturers' Data Report Form shall be signed only after completion of the welding.

PW-54.3.2 For nonpressure parts welded to pressure parts, the following additional conditions shall be met: A03

(a) The pressure part material is limited to P-No. 1 materials.

(b) The nonpressure attachment material is limited to carbon steel with a carbon content not exceeding 0.2% or any P-No. 1 material.

(c) The welding is done by stud welding or by fillet welding having a throat not exceeding the lesser of 0.70 times the thickness of the pressure part or $^{1}/_{4}$ in. (6 mm).

(d) A minimum 200°F (93°C) preheat shall be applied when the pressure part thickness exceeds $^{3}/_{4}$ in. (19 mm).

PW-54.3.3 For seal welding of pressure retaining handhole and inspection plugs or fittings secured by physical means, the following additional conditions shall be met.

(a) The seal welds must be exempted from postweld heat treatment by rules elsewhere in this section.

(b) The completed weld is examined using either the magnetic particle or liquid penetrant examination method in accordance with Appendix A-260 or A-270, respectively. When the base materials or welds are nonmagnetic, only the liquid penetrant method shall be used.