PART UW

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PART UW
REQUIREMENTS FOR PRESSURE VESSELS FABRICATED BY WELDING

GENERAL

UW-1 SCOPE

The rules in Part UW are applicable to pressure vessels and vessel parts that are fabricated by welding and shall be used in conjunction with the general requirements in Subsection A, and with the specific requirements in Subsection C that pertain to the class of material used.

UW-2 SERVICE RESTRICTIONS

(a) When vessels are to contain lethal[1] substances, either liquid or gaseous, all butt welded joints shall be fully radiographed, except under the provisions of UW-2(a)(2) and UW-2(a)(3) below, and UW-11(a)(4). When fabricated of carbon or low alloy steel, such vessels shall be postweld heat treated. When a vessel is to contain fluids of such a nature that a very small amount mixed or unmixed with air is dangerous to life when inhaled, it shall be the responsibility of the user and/or his designated agent to determine if it is lethal. If determined as lethal, the user and/or his designated agent [see U-2(a)] shall so advise the designer and/or Manufacturer. It shall be the responsibility of the Manufacturer to comply with the applicable Code provisions (see UCI-2 and UCD-2).

(1) The joints of various categories (see UW-3) shall be as follows.

(a) Except under the provisions of (a)(2) or (a)(3) below, all joints of Category A shall be Type No. (1) of Table UW-12.

(b) All joints of Categories B and C shall be Type No. (1) or No. (2) of Table UW-12.

(c) All joints of Category C for the fabricated lap joint stub ends shall be as follows.

(1) The weld is made in two steps as shown in Fig. UW-13.5.

(2) Before making weld No. 2, weld No. 1 is examined by full radiography in accordance with UW-51, regardless of size. The weld and fusion line between the weld buildup and neck is examined by ultrasonics in accordance with Appendix 12.

(3) Weld No. 2 is examined by full radiography in accordance with UW-51.

(4) The finished stub end may either conform to ASME B16.9 dimensional requirements or be made of an intermediate size, provided all requirements of this Division are met.

(d) All joints of Category D shall be full penetration welds extending through the entire thickness of the vessel wall or nozzle wall.

(2) Radiographic examination of the welded seam in exchanger tubes and pipes, to a material specification permitted by this Division, which are butt welded without the addition of filler metal may be waived, provided the tube or pipe is totally enclosed within a shell of a vessel which meets the requirements of UW-2(a). In the case of an exchanger, the shell and channel sides must be constructed to the rules for lethal vessels.

(3) If only one side of a heat exchanger contains a lethal substance, the other side need not be built to the rules for a vessel in lethal service if:

(a) exchanger tubes are seamless; or

(b) exchanger tubes conform to a tube specification permitted by this Division, are butt welded without addition of filler metal, and receive in lieu of full radiography all of the following nondestructive testing and examination:

(1) hydrotest in accordance with the applicable specification;

(2) pneumatic test under water in accordance with the applicable material specification, or if not specified, in accordance with SA-688;

[1] By "lethal substances" are meant poisonous gases or liquids of such a nature that a very small amount of the gas or of the vapor of the liquid mixed or unmixed with air is dangerous to life when inhaled. For purposes of this Division, this class includes substances of this nature which are stored under pressure or may generate a pressure if stored in a closed vessel.

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(3) ultrasonic or nondestructive electric examination of sufficient sensitivity to detect surface calibration notches in any direction in accordance with SA-557, S1 or S3.

No improvement in longitudinal joint efficiency is permitted because of the additional nondestructive tests.

(b) When vessels are to operate below certain temperatures designated by Part UCS (see UCS-68), or impact tests of the material or weld metal are required by Part UHA, the joints of various categories (see UW-3) shall be as follows.

(1) All joints of Category A shall be Type No. (1) of Table UW-12 except that for austenitic chromium–nickel stainless steels listed in UHA-51(d)(1)(a) which satisfy the requirements of UHA-51(f), Type No. (2) joints may be used.

(2) All joints of Category B shall be Type No. (1) or No. (2) of Table UW-12.

(3) All joints of Category C shall be full penetration welds extending through the entire section at the joint.

(4) All joints of Category D shall be full penetration welds extending through the entire thickness of the vessel wall or nozzle wall except that partial penetration welds may be used between materials listed in Table UHA-23 as follows:

(a) for materials shown in UHA-51(d)(1)(a) and (b) and UHA-51(d)(2)(a) at minimum design metal temperatures (MDMTs) of −320°F and warmer;

(b) for materials shown in UHA-51(d)(1)(c) and UHA-51(d)(2)(b) at MDMTs of −50°F and warmer.

(c) Unfired steam boilers with design pressures exceeding 50 psi (343 kPa) shall have all joints of Category A (see UW-3) in accordance with Type No. (1) of Table UW-12 and all joints in Category B in accordance with Type No. (1) or No. (2) of Table UW-12. All butt welded joints shall be fully radiographed except under the provisions of UW-11(a)(4). When fabricated of carbon or low-alloy steel, such vessels shall be postweld heat treated. See also U-1(g), UG-16(b), and UG-125(b).

(d) Pressure vessels or parts subject to direct firing [see U-1(h)] may be constructed in accordance with all applicable rules of this Division and shall meet the following requirements.

(1) All welded joints in Category A (see UW-3) shall be in accordance with Type No. (1) of Table UW-12, and all welded joints in Category B, when the thickness exceeds $\frac{5}{8}$ in. (16 mm), shall be in accordance with Type No. (1) or No. (2) of Table UW-12. No welded joints of Type No. (3) of Table UW-12 are permitted for either Category A or B joints in any thickness.

(2) When the thickness at welded joints exceeds $\frac{5}{8}$ in. (16 mm) for carbon (P-No. 1) steels and for all thicknesses for low alloy steels (other than P-No. 1 steels), postweld heat treatment is required. For all other material and in any thickness, the requirements for postweld heat treatment shall be in conformance with the applicable Subsections of this Division. See also U-1(g), UG-16(b), UCS-25 and UCS-56.

(3) The user, his agent, or the Manufacturer of the vessel shall make available to the Inspector the calculations used to determine the design temperature of the vessel. The provisions of UG-20 shall apply except that pressure parts in vessel areas having joints other than Type Nos. (1) and (2) of Table UW-12, subject to direct radiation and/or the products of combustion, shall be designed for temperatures not less than the maximum surface metal temperatures expected under operating conditions.

UW-3 WELDED JOINT CATEGORY

(a) The term "Category" as used herein defines the location of a joint in a vessel, but not the type of joint. The "Categories" established by this paragraph are for use elsewhere in this Division in specifying special requirements regarding joint type and degree of inspection for certain welded pressure joints. Since these special requirements, which are based on service, material, and thickness, do not apply to every welded joint, only those joints to which special requirements apply are included in the categories. The special requirements will apply to joints of a given category only when specifically so stated. The joints included in each category are designated as joints of Categories A, B, C, and D below. Figure UW-3 illustrates typical joint locations included in each category.

(1) Category A. Longitudinal welded joints within the main shell, communicating chambers,[2] transitions in diameter, or nozzles; any welded joint within a sphere, within a formed or flat head, or within the side plates[3] of a flat-sided vessel; circumferential welded joints connecting hemispherical heads to main shells, to transitions in diameters, to nozzles, or to communicating chambers.[2]

---

[2] *Communicating chambers* are defined as appurtenances to the vessel which intersect the shell or heads of a vessel and form an integral part of the pressure containing enclosure, e.g., sumps.

[3] *Side plates of a flat-sided vessel* are defined as any of the flat plates forming an integral part of the pressure containing enclosure.

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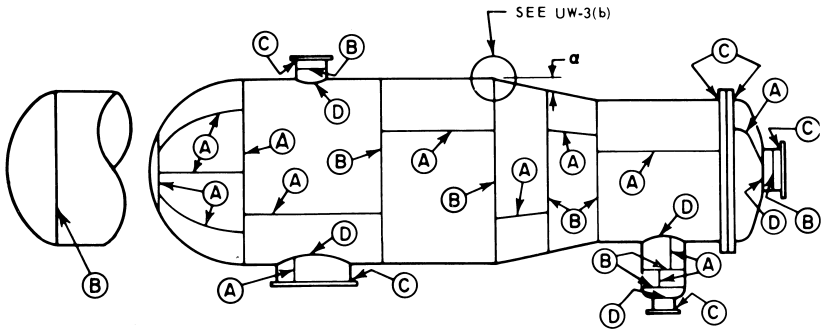


FIG. UW-3 ILLUSTRATION OF WELDED JOINT LOCATIONS TYPICAL OF CATEGORIES A, B, C, AND D

(2) Category B. Circumferential welded joints within the main shell, communicating chambers,[2] nozzles, or transitions in diameter including joints between the transition and a cylinder at either the large or small end; circumferential welded joints connecting formed heads other than hemispherical to main shells, to transitions in diameter, to nozzles, or to communicating chambers.[2]

(3) Category C. Welded joints connecting flanges, Van Stone laps, tubesheets, or flat heads to main shell, to formed heads, to transitions in diameter, to nozzles, or to communicating chambers[2]any welded joint connecting one side plate[3]to another side plate of a flat-sided vessel.

(4) Category D. Welded joints connecting communicating chambers[2]or nozzles to main shells, to spheres, to transitions in diameter, to heads, or to flat-sided vessels, and those joints connecting nozzles to communicating chambers[2](for nozzles at the small end of a transition in diameter, see Category B).

(b) When butt welded joints are required elsewhere in this Division for Category B, an angle joint connecting a transition in diameter to a cylinder shall be considered as meeting this requirement provided the angle α (see Fig. UW-3) does not exceed 30 deg. All requirements pertaining to the butt welded joint shall apply to the angle joint.

MATERIALS

UW-5 GENERAL

(a) Pressure Parts. Materials used in the construction of welded pressure vessels shall comply with the requirements for materials given in UG-4 through UG-15, and shall be proven of weldable quality. Satisfactory qualification of the welding procedure under Section IX is considered as proof.

(b) Nonpressure Parts. Materials used for nonpressure parts which are welded to the pressure vessel shall be proven of weldable quality as described below.

(1) For material identified in accordance with UG-10, UG-11, UG-15, or UG-93, satisfactory qualification of the welding procedure under Section IX is considered as proof of weldable quality.

(2) For materials not identifiable in accordance with UG-10, UG-11, UG-15, or UG-93, but identifiable as to nominal chemical analysis and mechanical properties, S-Number under Section IX, QW/QB-422, or to a material specification not permitted in this Division, satisfactory qualification of the welding procedure under Section IX is considered as proof of weldable quality. For materials identified by S-Numbers, the provisions of Section IX, QW/QB-422 may be followed for welding procedure qualification. The welding procedure need only be qualified once for a given nominal chemical analysis and mechanical properties or material specification not permitted in this Division.

(3) Material which cannot be identified may be proved to be of weldable quality by preparing a butt-joint test coupon from each piece of nonidentified material to be used. Guided bend test specimens made from the test coupon shall pass the tests specified in QW-451 of Section IX.

(c) Two materials of different specifications may be joined by welding provided the requirements of Section IX, QW-250, are met.

(d) Materials joined by the electroslag and electrogas welding processes shall be limited to ferritic steels and the following austenitic steels which are welded to produce a ferrite containing weld metal: SA-240 Types 304, 304L, 316, and 316L; SA-182 F304, F304L, F316,

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and F316L; SA-351 CF3, CF3A, CF3M, CF8, CF8A, and CF8M.

(e) Materials joined by the inertia and continuous drive friction welding processes shall be limited to materials assigned P-Numbers in Section IX and shall not include rimmed or semikilled steel.

DESIGN

UW-8 GENERAL

The rules in the following paragraphs apply specifically to the design of pressure vessels and vessel parts that are fabricated by welding and shall be used in conjunction with the general requirements for *Design* in Subsection A, and with the specific requirements for *Design* in Subsection C that pertain to the class of material used.

UW-9 DESIGN OF WELDED JOINTS

(a) Permissible Types. The types of welded joints permitted in arc and gas welding processes are listed in Table UW-12, together with the limiting plate thickness permitted for each type. Butt type joints only are permitted with pressure welding processes [see UW-27(b)].

(b) Welding Grooves. The dimensions and shape of the edges to be joined shall be such as to permit complete fusion and complete joint penetration. Qualification of the welding procedure, as required in UW-28, is acceptable as proof that the welding groove is satisfactory.

(c) Tapered Transitions. A tapered transition having a length not less than *three* times the offset between the adjacent surfaces of abutting sections, as shown in Fig. UW-9, shall be provided at joints between sections that differ in thickness by more than one-fourth of the thickness of the thinner section, or by more than $\frac{1}{8}$ in. (3.2 mm), whichever is less. The transition may be formed by any process that will provide a uniform taper. When the transition is formed by removing material from the thicker section, the minimum thickness of that section, after the material is removed, shall not be less than that required by UG-23(c). When the transition is formed by adding additional weld metal beyond what would otherwise be the edge of the weld, such additional weld metal buildup shall be subject to the requirements of UW-42. The butt weld may be partly or entirely in the tapered section or adjacent to it. This paragraph also applies when there is a reduction in thickness within a spherical shell or cylindrical shell course and to a taper at a Category A joint within a formed head. Provisions for tapers at circumferential, butt welded joints connecting formed heads to main shells are contained in UW-13.

(d) Except when the longitudinal joints are radiographed 4 in. each side of each circumferential welded intersection, vessels made up of two or more courses shall have the centers of the welded longitudinal joints of adjacent courses staggered or separated by a distance of at least five times the thickness of the thicker plate.

(e) Lap Joints. For lapped joints, the surface overlap shall be not less than four times the thickness of the inner plate except as otherwise provided for heads in UW-13.

(f) Welded Joints Subject to Bending Stresses. Except where specific details are permitted in other paragraphs, fillet welds shall be added where necessary to reduce stress concentration. Corner joints, with fillet welds only, shall not be used unless the plates forming the corner are properly supported independently of such welds. (See UW-18.)

(g) Minimum Weld Sizes. Sizing of fillet and partial penetration welds shall take into consideration the loading conditions in UG-22 but shall not be less than the minimum sizes specified elsewhere in this Division.

UW-10 POSTWELD HEAT TREATMENT

Pressure vessels and pressure vessel parts shall be postweld heat treated as prescribed in UW-40 when postweld heat treatment is required in the applicable part of Subsection C.

UW-11 RADIOGRAPHIC AND ULTRASONIC EXAMINATION

(a) Full Radiography. The following welded joints shall be examined radiographically for their full length in the manner prescribed in UW-51:

(1) all butt welds in the shell and heads of vessels used to contain lethal substances [see UW-2(a)];

(2) all butt welds in vessels in which the nominal thickness [see (g) below] at the welded joint exceeds $1\frac{1}{2}$ in. (38 mm), or exceeds the lesser thicknesses prescribed in UCS-57, UNF-57, UHA-33, UCL-35, or UCL-36 for the materials covered therein, or as otherwise prescribed in UHT-57, ULW-51, ULW-52(d), ULW-54, or ULT-57; however, except as required by UHT-57(a), Categories B and C butt welds in nozzles and communicating chambers that neither exceed NPS

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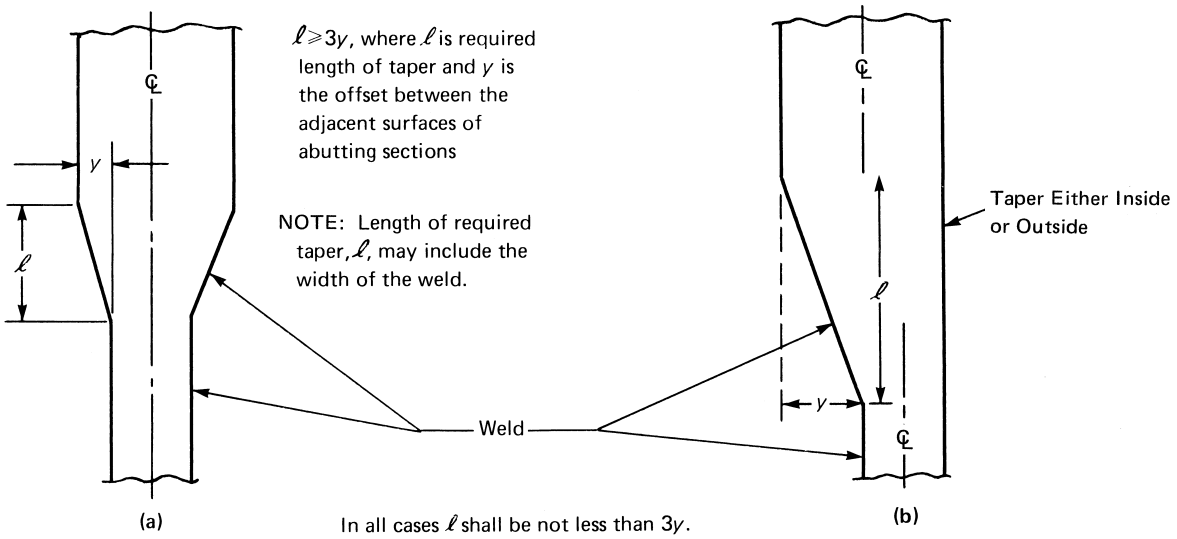


FIG. UW-9 BUTT WELDING OF PLATES OF UNEQUAL THICKNESS

10 nor $1\frac{1}{8}$ in. (29 mm) wall thickness do not require any radiographic examination;

(3) all butt welds in the shell and heads of unfired steam boilers having design pressures exceeding 50 psi (345 kPa) [see UW-2(c)];

(4) all butt welds in nozzles, communicating chambers, etc., attached to vessel sections or heads that are required to be fully radiographed under (1) or (3) above; however, except as required by UHT-57(a), Categories B and C butt welds in nozzles and communicating chambers that neither exceed NPS 10 (DN 250) nor $1\frac{1}{8}$ in. (29 mm) wall thickness do not require any radiographic examination;

(5) all Category A and D butt welds in vessel sections and heads where the design of the joint or part is based on a joint efficiency permitted by UW-12(a), in which case:

(a) Category A and B welds connecting the vessel sections or heads shall be of Type No. (1) or Type No. (2) of Table UW-12;

(b) Category B or C butt welds [but not including those in nozzles or communicating chambers except as required in (2) above] which intersect the Category A butt welds in vessel sections or heads or connect seamless vessel sections or heads shall, as a minimum, meet the requirements for spot radiography in accordance with UW-52. Spot radiographs required by this paragraph shall not be used to satisfy the spot radiography rules as applied to any other weld increment.

(6) all butt welds joined by electrogas welding with any single pass greater than $1\frac{1}{2}$ in. (38 mm) and all butt welds joined by electroslag welding;

(7) ultrasonic examination in accordance with UW-53 may be substituted for radiography for the final closure seam of a pressure vessel if the construction of the vessel does not permit interpretable radiographs in accordance with Code requirements. The absence of suitable radiographic equipment shall not be justification for such substitution.

(8) exemptions from radiographic examination for certain welds in nozzles and communicating chambers as described in (2), (4), and (5) above take precedence over the radiographic requirements of Subsection C of this Division.

(b) Spot Radiography. Except as required in (a)(5)(b) above, butt welded joints made in accordance with Type No. (1) or (2) of Table UW-12 which are not required to be fully radiographed by (a) above, may be examined by spot radiography. Spot radiography shall be in accordance with UW-52. If spot radiography is specified for the entire vessel, radiographic examination is not required of Category B and C butt welds in nozzles and communicating chambers that exceed neither NPS 10 nor $1\frac{1}{8}$ in. (29 mm) wall thickness.

NOTE: This requirement specifies spot radiography for butt welds of Type No. (1) or No. (2) that are used in a vessel, but does not preclude the use of fillet and/or corner welds permitted by other

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paragraphs, such as for nozzle and manhole attachments, welded stays, flat heads, etc., which need not be spot radiographed.

(c) No Radiography. Except as required in (a) above, no radiographic examination of welded joints is required when the vessel or vessel part is designed for external pressure only, or when the joint design complies with UW-12(c).

(d) Electrogas welds in ferritic materials with any single pass greater that $1\frac{1}{2}$ in. (38 mm) and electroslag welds in ferritic materials shall be ultrasonically examined throughout their entire length in accordance with the requirements of Appendix 12. This ultrasonic examination shall be done following the grain refining (austenitizing) heat treatment or postweld heat treatment.

(e) In addition to the requirements in (a) and (b) above, all welds made by the electron beam process shall be ultrasonically examined for their entire length in accordance with the requirements of Appendix 12.

(f) When radiography is required for a welded joint in accordance with (a) and (b) above, and the weld is made by the inertia and continuous drive friction welding processes, the welded joints shall also be ultrasonically examined for their entire length in accordance with Appendix 12.

(g) For radiographic and ultrasonic examination of butt welds, the definition of nominal thickness at the welded joint under consideration shall be the nominal thickness of the thinner of the two parts joined. Nominal thickness is defined in 3-2.

UW-12 JOINT EFFICIENCIES

Table UW-12 gives the joint efficiencies E to be used in the formulas of this Division for joints completed by an arc or gas welding process. Except as required by UW-11(a)(5), a joint efficiency depends only on the type of joint and on the degree of examination of the joint and does not depend on the degree of examination of any other joint. The User or his designated agent [see U-2(a)] shall establish the type of joint and the degree of examination when the rules of this Division do not mandate specific requirements. Rules for determining the applicability of the efficiencies are found in the various paragraphs covering design formulas [for example, see UG-24(a) and UG-27]. For further guidance, see Appendix L.

(a) A value of E not greater than that given in column (a) of Table UW-12 shall be used in the design calculations for fully radiographed butt joints [see UW-11(a)], except that when the requirements of UW-11(a)(5) are not met, a value of E not greater than that given in column (b) of Table UW-12 shall be used.

(b) A value of E not greater than that given in column (b) of Table UW-12 shall be used in the design calculations for spot radiographed butt welded joints [see UW-11(b)].

(c) A value of E not greater than that given in column (c) of Table UW-12 shall be used in the design calculations for welded joints that are neither fully radiographed nor spot radiographed [see UW-11(c)].

(d) Seamless vessel sections or heads shall be considered equivalent to welded parts of the same geometry in which all Category A welds are Type No. 1. For calculations involving circumferential stress in seamless vessel sections or for thickness of seamless heads, $E = 1.0$ when the spot radiography requirements of UW-11(a)(5)(b) are met. $E = 0.85$ when the spot radiography requirements of UW-11(a)(5)(b) are not met, or when the Category A or B welds connecting seamless vessel sections or heads are Type No. 3, 4, 5, or 6 of Table UW-12.

(e) Welded pipe or tubing shall be treated in the same manner as seamless, but with allowable tensile stress taken from the welded product values of the stress tables, and the requirements of UW-12(d) applied.

(f) A value of E not greater than 0.80 may be used in the formulas of this Division for joints completed by any of the pressure welding processes given in UW-27(a), except for electric resistance welding, provided the welding process used is permitted by the rules in the applicable parts of Subsection C for the material being welded. The quality of such welds used in vessels or parts of vessels shall be proved as follows: Test specimens shall be representative of the production welding on each vessel. They may be removed from the shell itself or from a prolongation of the shell including the longitudinal joint, or, in the case of vessels not containing a longitudinal joint, from a test late of the same material and thickness as the vessel and welded in accordance with the same procedure. One reduced-section tension test and two side-bend tests shall be made in accordance with, and shall meet the requirements of QW-150 and QW-160, Section IX.

UW-13 ATTACHMENT DETAILS

(a) Definitions

t_h = nominal thickness of head, in. (mm)

t_p = minimum distance from outside surface of flat head to edge of weld preparation measured as shown in Fig. UW-13.2, in. (mm)

t_s = nominal thickness of shell, in. (mm)

(See UG-27, UG-28, UG-32, UG-34, and other paragraphs for additional definitions.)

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TABLE UW-12
MAXIMUM ALLOWABLE JOINT EFFICIENCIES[1,5] FOR ARC AND GAS WELDED JOINTS

Type No.	Joint Description	Limitations	Joint Category	Degree of Radiographic Examination (a) Full[2]	(b) Spot[3]	(c) None
(1)	Butt joints as attained by double-welding or by other means which will obain the same quality of deposited weld metal on the inside and outside weld surfaces to agree with the requirements of UW-35. Welds using metal backing strips which remain in place are excluded.	None	A, B, C, & D	1.00	0.85	0.70
(2)	Single-welded butt joint with backing strip other than those included under (1)	*(a)* None except as in (b) below	A, B, C, & D	0.90	0.80	0.65
		(b) Circumferential butt joints with one plate offset; see UW-13(b)(4) and Fig. UW-13.1, sketch (k)	A, B, & C	0.90	0.80	0.65
(3)	Single-welded butt joint without use of backing strip	Circumferential butt joints only, not over $\frac{5}{8}$ in. (16 mm) thick and not over 24 in. (610 mm) outside diameter	A, B, & C	NA	NA	0.60
(4)	Double full fillet lap joint	*(a)* Longitudinal joints not over $\frac{3}{8}$ in. (10 mm) thick	A	NA	NA	0.55
		(b) Circumferential joints not over $\frac{5}{8}$ in. (16 mm) thick	B & C[6]	NA	NA	0.55
(5)	Single full fillet lap joints with plug welds conforming to UW-17	*(a)* Circumferential joints[4] for attachment of heads not over 24 in. (610 mm) outside diameter to shells not over $\frac{1}{2}$ in. (13 mm) thick	B	NA	NA	0.50
		(b) Circumferential joints for the attachment to shells of jackets not over $\frac{5}{8}$ in. (16 mm) in nominal thickness where the distance from the center of the plug weld to the edge of the plate is not less than $1\frac{1}{2}$ times the diameter of the hole for the plug.	C	NA	NA	0.50

(continued)

TABLE UW-12
MAXIMUM ALLOWABLE JOINT EFFICIENCIES[1,5] FOR ARC AND GAS WELDED JOINTS (CONT'D)

Type No.	Joint Description	Limitations	Joint Category	Degree of Radiographic Examination		
				(a) Full[2]	(b) Spot[3]	(c) None
(6)	Single full fillet lap joints without plug welds	*(a)* For the attachment of heads convex to pressure to shells not over $\frac{5}{8}$ in. (16 mm) required thickness, only with use of fillet weld on inside of shell; or *(b)* for attachment of heads having pressure on either side, to shells not over 24 in. (610 mm) inside diameter and not over $\frac{1}{4}$ in. (6 mm) required thickness with fillet weld on outside of head flange only	A & B	NA	NA	0.45
			A & B	NA	NA	0.45

NOTES:
(1) The single factor shown for each combination of joint category and degree of radiographic examination replaces both the stress reduction factor and the joint efficiency factor considerations previously used in this Division.
(2) See UW-12(a) and UW-51.
(3) See UW-12(b) and UW-52.
(4) Joints attaching hemispherical heads to shells are excluded.
(5) $E = 1.0$ for butt joints in compression.
(6) For Type No. 4 Category C joint, limitation not applicable for bolted flange connections.

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(b)(1) Ellipsoidal, torispherical, and other types of formed heads, shall be attached to the shell as illustrated in the applicable Fig. UW-13.1 sketches (a), (b), (c), (d), (e), and (k). The construction shown in sketch (f) may also be used for end heads when the thickness of the shell section of the vessel does not exceed $\frac{5}{8}$ in. (16 mm) [see also (c) below]. Limitations relative to the use of these attachments shall be as given in the sketches and related notes and in Table UW-12. Figure UW-13.1 sketches (g), (h), and (j) are examples of attachment methods which are not permissible.

(2) Formed heads, concave or convex to the pressure, shall have a skirt length not less than that shown in Fig. UW-13.1, using the applicable sketch. Heads that are fitted inside or over a shell shall have a driving fit before welding.

(3) A tapered transition having a length not less than three times the offset between the adjacent surfaces of abutting sections as shown in Fig. UW-13.1 sketches (l) and (m) shall be provided at joints between formed heads and shells that differ in thickness by more than one-fourth the thickness of the thinner section or by more than $\frac{1}{8}$ in. (3.2 mm), whichever is less. When a taper is required on any formed head thicker than the shell and intended for butt welded attachment [Fig. UW-13.1 sketches (n) and (o)], the skirt shall be long enough so that the required length of taper does not extend beyond the tangent line. When the transition is formed by removing material from the thicker section, the minimum thickness of that section, after the material is removed, shall not be less than that required by UG-23(c). When the transition is formed by adding additional weld metal beyond what would otherwise be the edge of the weld, such additional weld metal buildup shall be subject to the requirements of UW-42. The center line misalignment between shell and head shall be no greater than one-half the difference between the actual shell and head thickness, as illustrated in Fig. UW-13.1 sketches (l), (m), (n), and (o).

(4) Shells and heads may be attached to shells or heads using a butt weld with one plate offset as shown in Fig. UW-13.1 sketch (k). The weld bead may be deposited on the inside of the vessel only when the weld is accessible for inspection after the vessel is completed. The offset shall be smooth and symmetrical and shall not be machined or otherwise reduced in thickness. There shall be a uniform force fit with the mating section at the root of the weld. Should the offset contain a longitudinal joint the following shall apply.

(a) The longitudinal weld within the area of the offset shall be ground substantially flush with the parent metal prior to the offsetting operation.

(b) The longitudinal weld from the edge of the plate through the offset shall be examined by the magnetic particle method after the offsetting operation. Cracks and cracklike defects are unacceptable and shall be repaired or removed.

(c) As an acceptable alternative to magnetic particle examination or when magnetic particle methods are not feasible because of the nonmagnetic character of the weld deposit, a liquid penetrant method shall be used. Cracks and cracklike defects are unacceptable and shall be repaired or removed.

(c)(1) Intermediate heads, without limit to thickness, of the type shown in Fig. UW-13.1 sketch (f) may be used for all types of vessels provided that the outside diameter of the head skirt is a close fit inside the overlapping ends of the adjacent length of cylinder.

(2) The butt weld and fillet weld shall be designed to take shear based on $1\frac{1}{2}$ times the maximum differential pressure that can exist. The allowable stress value for the butt weld shall be 70% of the stress value for the vessel material and that of the fillet 55%. The area of the butt weld in shear is the width at the root of the weld times the length of weld. The area of the fillet weld is the minimum leg dimension times the length of weld. The fillet weld may be omitted if the construction precludes access to make the weld, and the vessel is in noncorrosive service.

(d) The requirements for the attachment of welded unstayed flat heads to shells are given in UG-34 and in (e) and (f) hereunder.

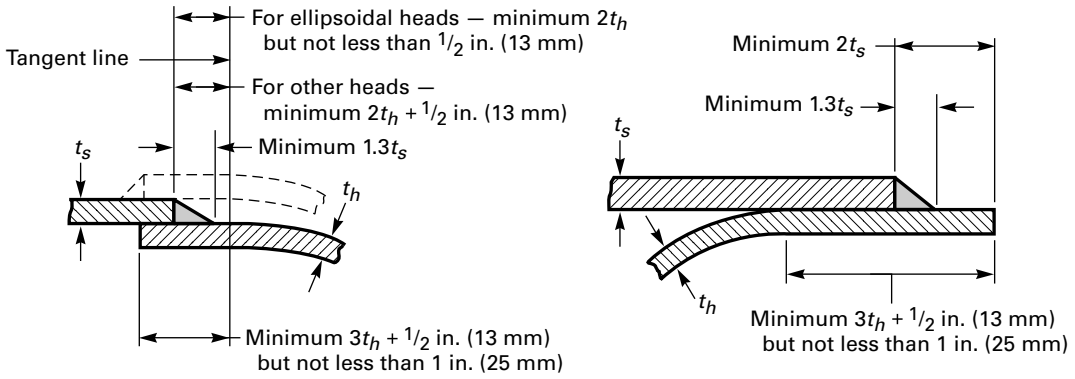
(e) When shells, heads, or other pressure parts are welded to a forged or rolled plate to form a corner joint, as in Fig. UW-13.2, the joint shall meet the following requirements [see also UG-93(d)(3)].

(1) On the cross section through the welded joint, the line of fusion between the weld metal and the forged or rolled plate being attached shall be projected on planes both parallel to and perpendicular to the surface of the plate being attached, in order to determine the dimensions *a* and *b*, respectively (see Fig. UW-13.2).

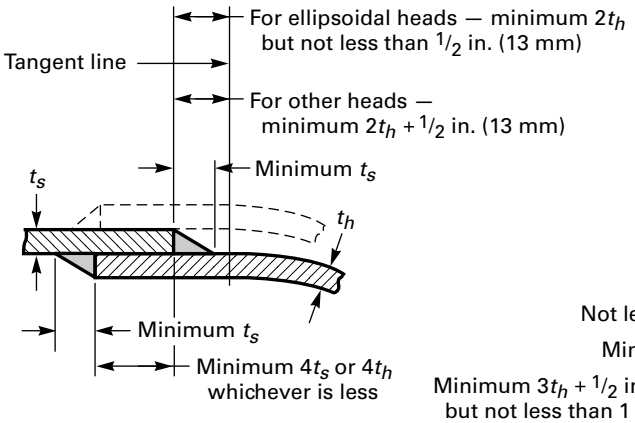
(2) For flange rings of bolted flanged connections, and for flat heads and unsupported tube sheets with a projection having holes for a bolted connection, the sum of *a* and *b* shall be not less than three times the nominal wall thickness of the abutting pressure part.

(3) For supported tubesheets with a projection having holes for a bolted connection, the sum of *a* and *b* shall not be less than two times the nominal wall thickness of the abutting pressure part. A supported tubesheet is defined as one in which not less than 80% of the pressure load on the tubesheet is carried by tubes, stays or braces.

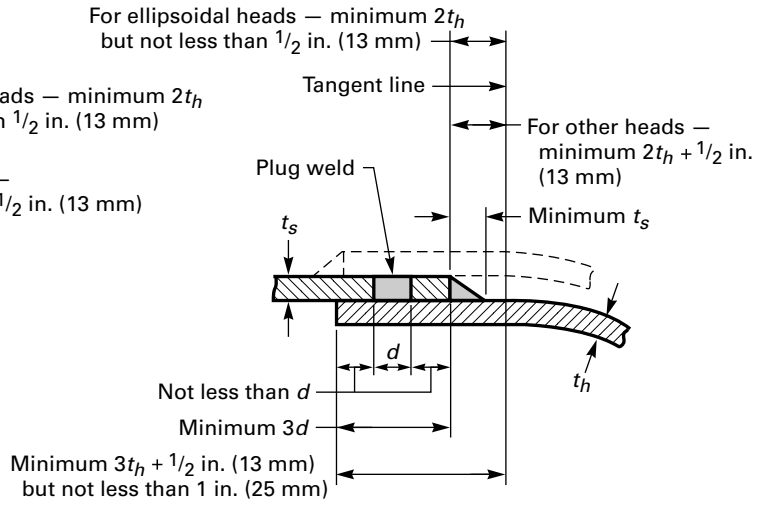
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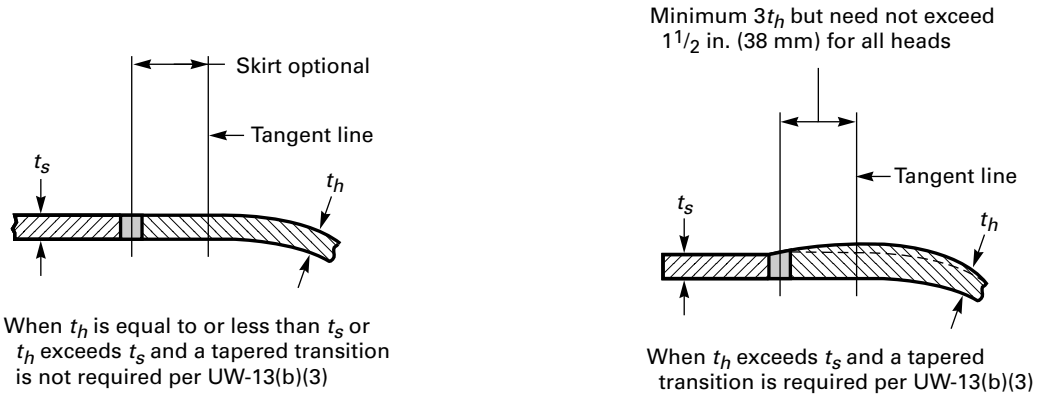
(a) Single Fillet Lap Weld



(b) Double Fillet Lap Weld



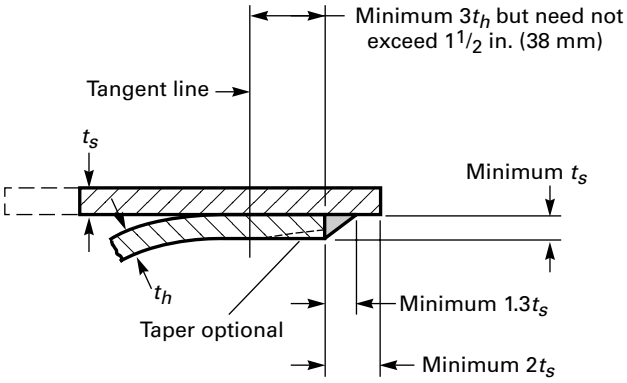
(c) Single Fillet Lap Weld With Plug Welds



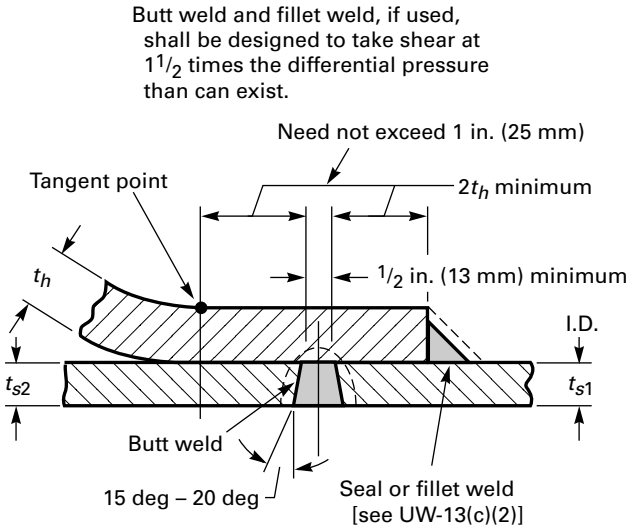
(d) Butt Weld

FIG. UW-13.1 HEADS ATTACHED TO SHELLS
(See Table UW-12 for Limitations)

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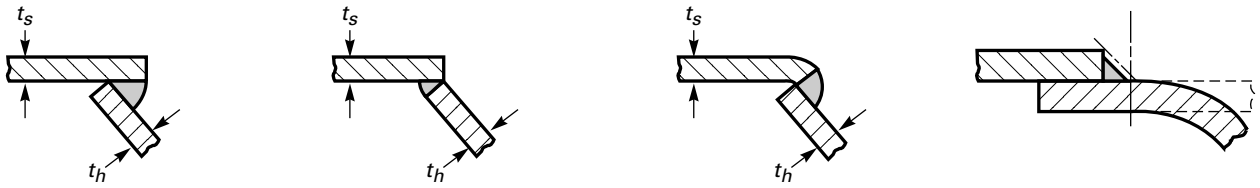


(e) Single Fillet Lap Weld



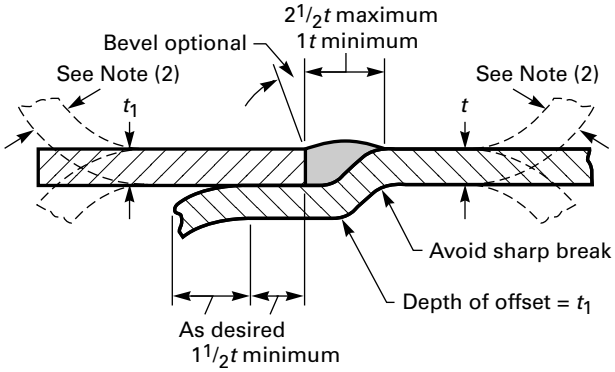
(f) Intermediate Head

GENERAL NOTE: t_{s1} and t_{s2} may be different



(g-1) **(g-2)** **(h)** **(j)**

GENERAL NOTE: Sketches (g-1, (g-2), (h), and (j) are not permissible



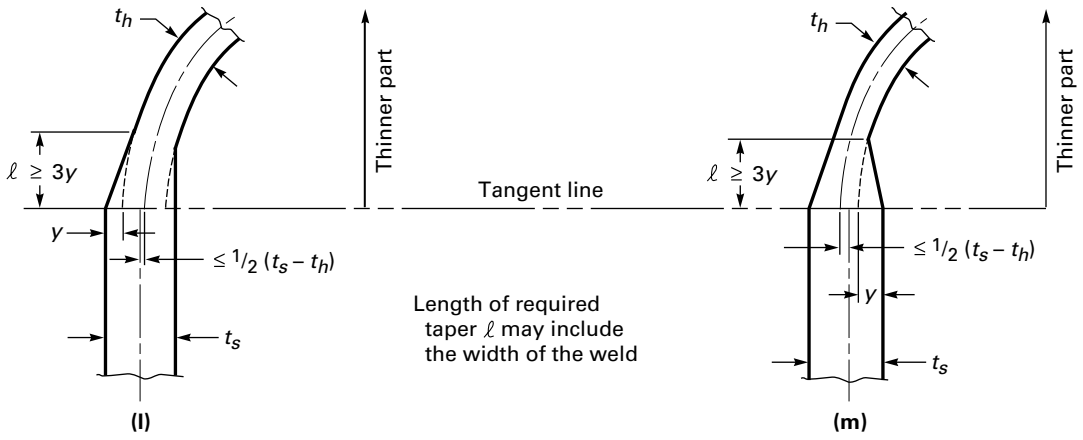
t or $t_1 = {}^5/_8$ maximum [see Note (1)]

(k) Butt Weld With One Plate Edge Offset

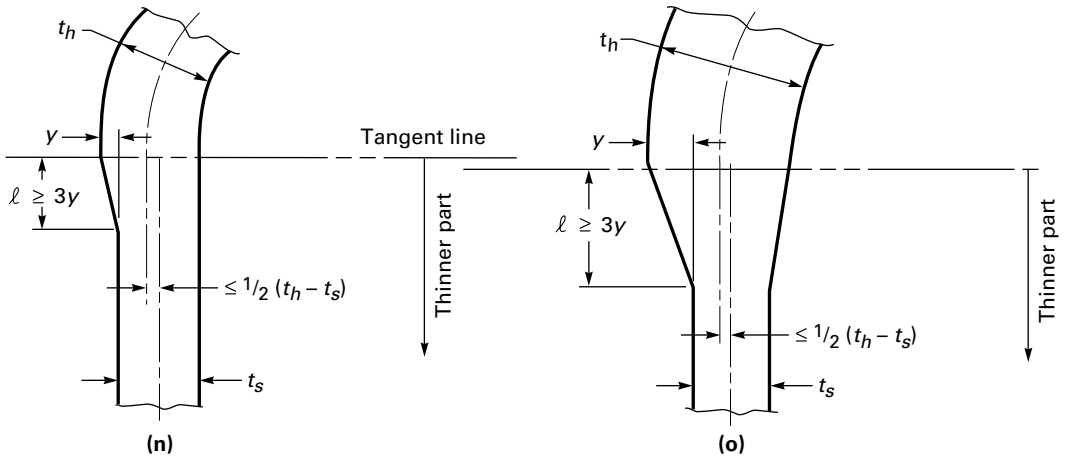
NOTE:
(1) For joints connecting hemispherical heads to shells, the following shall apply:
(a) t or $t_1 = {}^3/_8$ in. (10 mm) maximum
(b) maximum difference in thickness between t or $t_1 = {}^3/_{32}$ in. (2.4 mm);
(c) use of this figure for joints connecting hemispherical heads to shells shall be noted in the "Remarks" part of the Data Report Form.
(2) See UW-13(b)(4) for limitation when weld bead is deposited from inside.

FIG. UW-13.1 HEADS ATTACHED TO SHELLS (CONT'D)
(See Table UW-12 for Limitations)

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In all cases, the projected length of taper ℓ shall be not less than $3y$.
The shell plate center line may be on either side of the head plate center line.

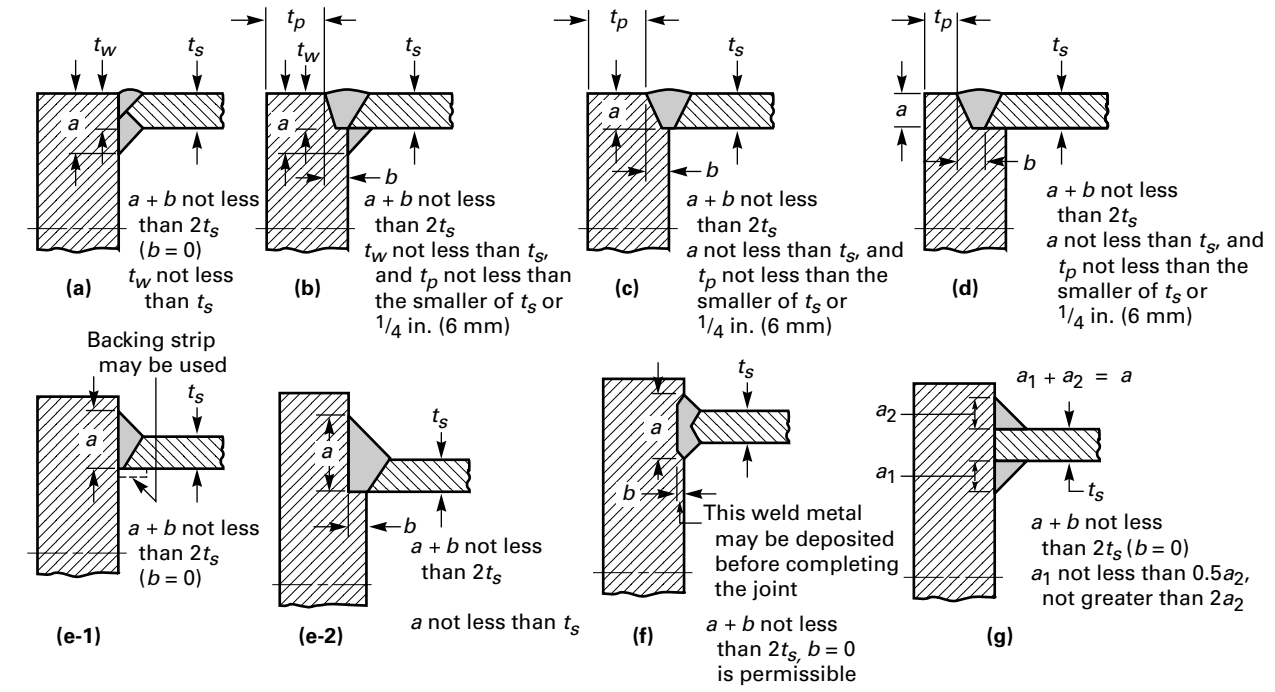


In all cases ℓ shall be not less than $3y$ when t_h exceeds t_s. Minimum length of skirt is $3t_h$ but need not exceed $1\frac{1}{2}$ in. (38 mm) except when necessary to provide required length of taper.
When t_h is equal to or less than $1.25t_s$, length of skirt shall be sufficient for any required taper.

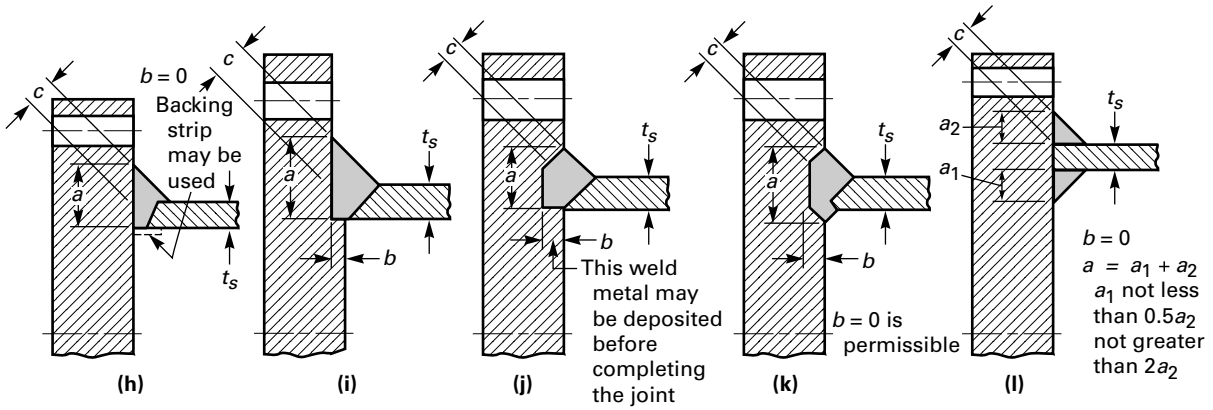
Length of required taper ℓ may include the width of the weld. The shell plate center line may be on either side of the head plate center line.

FIG. UW-13.1 HEADS ATTACHED TO SHELLS (CONT'D)
(See Table UW-12 for Limitations)

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Typical Unstayed Flat Heads, Supported and Unsupported Tubesheets Without a Bolting Flange, and Side Plates of Rectangular Vessels
For unstayed flat heads, see also UG-34



t_s is defined in UG-34(b)
Typical Supported and Unsupported Tubesheets With a Bolting Flange

GENERAL NOTES:
(a) For supported tubesheets: $a + b$ not less than $2t_s$, c not less than $0.7t_s$ or $1.4t_r$, whichever is less.
(b) For unsupported tubesheets: $a + b$ not less than $3t_s$, c not less than t_s or $2t_r$, whichever is less.
(c) t_s and t_r are as defined in UG-34(b).
(d) See UW-13(e) (3) for definition of supported tubesheet.
(e) Dimension b is produced by the weld preparation and shall be verified after fit up and before welding.

01 FIG. UW-13.2 ATTACHMENT OF PRESSURE PARTS TO FLAT PLATES TO FORM A CORNER JOINT

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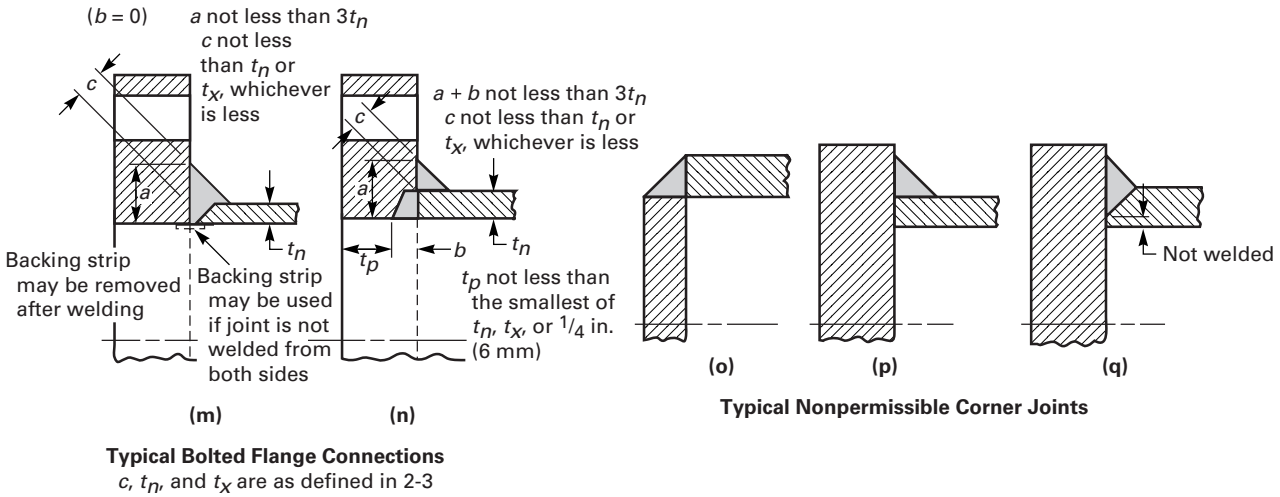


FIG. UW-13.2 ATTACHMENT OF PRESSURE PARTS TO FLAT PLATES TO FORM A CORNER JOINT (CONT'D)

(4) For other components, the sum *a* and *b* shall be not less than two times the nominal wall thickness of the abutting pressure part. Examples of such components are flat heads and supported and unsupported tube sheets without a projection having holes for a bolted connection, and the side plates of a rectangular vessel.

(5) Other dimensions at the joint shall be in accordance with details as shown in Fig. UW-13.2.

(6) Joint details that have a dimension through the joint less than the thickness of the shell, head or other pressure part, or that provide attachment eccentric thereto, are not permissible. See Fig. UW-13.2 sketches (o), (p), and (q).

(f) When used, the hub of a tubesheet or flat head shall have minimum dimensions in accordance with Fig. UW-13.3 and shall meet the following requirements.

(1) When the hub is integrally forged with the tubesheet or flat head, or is machined from a forging, the hub shall have the minimum tensile strength and elongation specified for the material, measured in the direction parallel to the axis of the vessel. Proof of this shall be furnished by a tension test specimen (subsize if necessary) taken in this direction and as close to the hub as practical.[4]

(2) When the hub is machined from plate, the requirements of Appendix 20 shall be met.

(g) In the case of nozzle necks which attach to piping [see U-1(e)(1)(a)] of a lesser wall thickness, a tapered transition from the weld end of the nozzle may be provided to match the piping thickness although that thickness is less than otherwise required by the rules of this Division. This tapered transition shall meet the limitations as shown in Fig. UW-13.4.

UW-14 OPENINGS IN OR ADJACENT TO WELDS 01

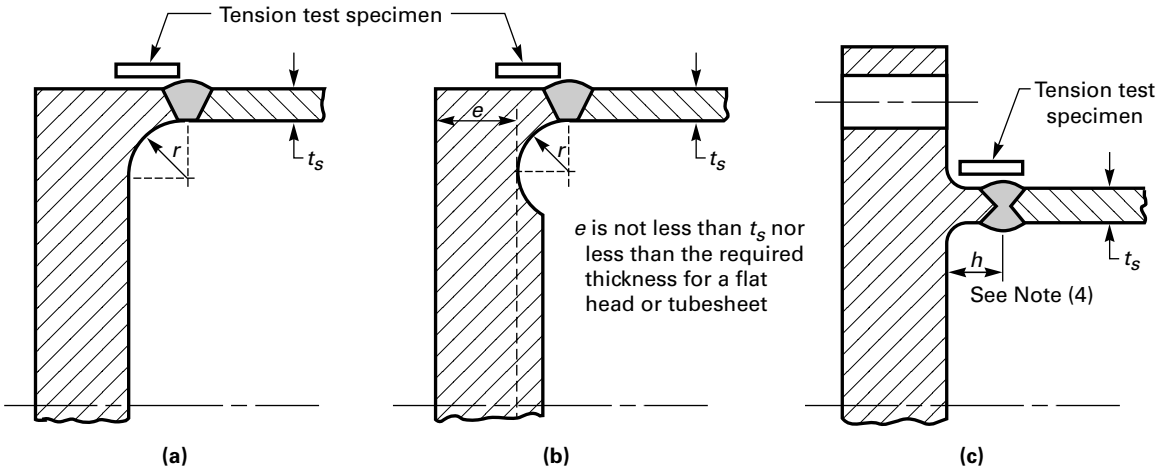
UW-14(a) Any type of opening that meets the requirements for reinforcement given in UG-37 or UG-39 may be located in a welded joint.

UW-14(b) Single openings meeting the requirements given in UG-36(c)(3) may be located in head-to-shell or Category B or C butt welded joints, provided the weld meets the radiographic requirements in UW-51 for a length equal to three times the diameter of the opening with the center of the hole at midlength. Defects that are completely removed in cutting the hole shall not be considered in judging the acceptability of the weld.

UW-14(c) In addition to meeting the radiographic requirements of (b) above, when multiple openings meeting the requirements given in UG-36(c)(3) are in line in a head-to-shell or Category B or C butt welded joint, the requirements of UG-53 shall be met or the openings shall be reinforced in accordance with UG-37 through UG-42.

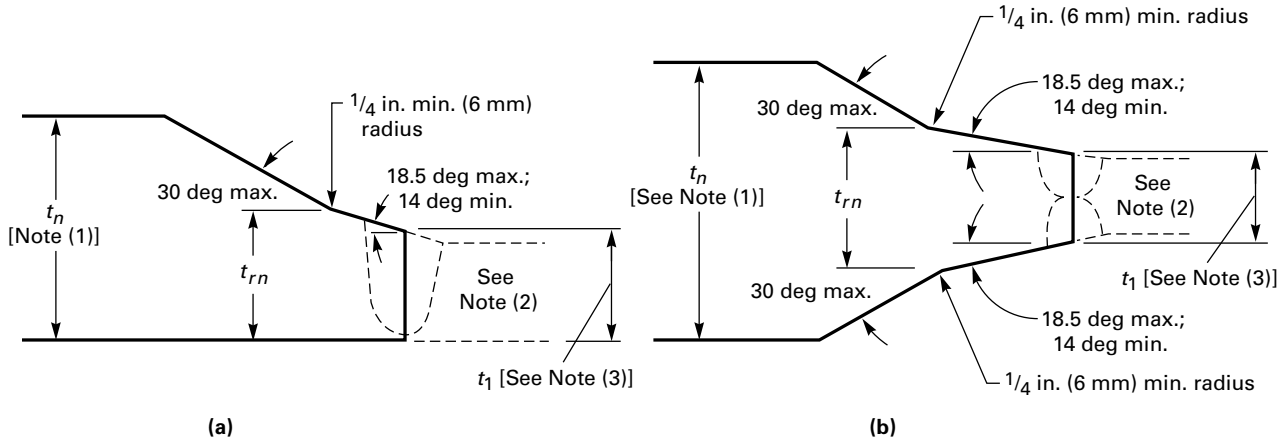
[4] One test specimen may represent a group of forgings provided they are of the same design, are from the same heat of material and are forged in the same manner.

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NOTES:
(1) Refer to Fig. UG-34 sketch (b-2) for dimensional requirements.
(2) Not permissible if machined from rolled plate unless in accordance with Appendix 20. See UW-13(f).
(3) Tension test specimen may be located inside or outside the hub.
(4) h is the greater of $^3/_4$ in. (19 mm) or $1.5t_s$, but need not exceed 2 in.

FIG. UW-13.3 TYPICAL PRESSURE PARTS WITH BUTT WELDED HUBS



NOTES:
(1) As defined in UG-40.
(2) Weld bevel is shown for illustration only.
(3) t_1 is not less than the greater of:
(a) $0.8t_{rn}$ where
t_{rn} = required thickness of seamless nozzle wall
(b) Minimum wall thickness of connecting pipe

FIG. UW-13.4 NOZZLE NECKS ATTACHED TO PIPING OF LESSER WALL THICKNESS

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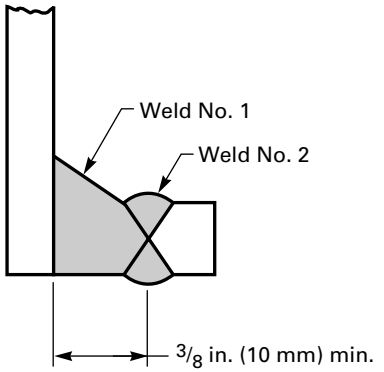


FIG. UW-13.5 FABRICATED LAP JOINT STUB ENDS FOR LETHAL SERVICE

UW-14(d) Except when the adjacent butt weld satisfies the requirement for radiography in (b) above, the edge of openings in solid plate meeting the requirements of UG-36(c)(3) shall not be placed closer than ½ in. (13 mm) from the edge of a Category A, B, or C weld for material 1½ in. (38 mm) thick or less.

UW-15 WELDED CONNECTIONS

(a) Nozzles, other connections, and their reinforcements may be attached to pressure vessels by arc or gas welding. Sufficient welding shall be provided on either side of the line through the center of the opening parallel to the longitudinal axis of the shell to develop the strength of the reinforcing parts as prescribed in UG-41 through shear or tension in the weld, whichever is applicable. The strength of groove welds shall be based on the area subjected to shear or to tension. The strength of fillet welds shall be based on the area subjected to shear (computed on the minimum leg dimension.) The inside diameter of a fillet weld shall be used in figuring its length.

(b) Strength calculations for nozzle attachment welds for pressure loading are not required for the following:

(1) Figure UW-16.1 sketches (a), (b), (c), (d), (e), (f-1), (f-2), (f-3), (f-4), (g), (x-1), (y-1), and (z-1), and all the sketches in Figs. UHT-18.1 and UHT-18.2; see L-7.1 and L-7.7;

(2) openings that are exempt from the reinforcement requirements by UG-36(c)(3).

(3) openings designed in accordance with the rules for ligaments in UG-53.

(c) The allowable stress values for groove and fillet welds in percentages of stress values for the vessel material, which are used with UG-41 calculations, are as follows:

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

NOTE: These values are obtained by combining the following factors: 87½% for combined end and side loading, 80% for shear strength, and the applicable joint efficiency factors.

(d) Reinforcing plates and saddles of nozzles attached to the outside of a vessel shall be provided with at least one telltale hole (maximum size NPS ¼ 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 may be left open or may be plugged when the vessel is in service. If the holes are plugged, the plugging material used shall not be capable of sustaining pressure between the reinforcing plate and the vessel wall.

UW-16 MINIMUM REQUIREMENTS FOR ATTACHMENT WELDS AT OPENINGS 01

(a) General

(1) The terms: nozzles, connections, reinforcements, necks, tubes, fittings, pads, and other similar terms used in this paragraph define essentially the same type construction and form a Category D weld joint between the nozzle (or other term) and the shell, head, etc. as defined in UW-3(a)(4).

(2) The location and minimum size of attachment welds for nozzles and other connections shall conform to the requirements of this paragraph in addition to the strength calculations required in UW-15.

(b) Symbols. The symbols used in this paragraph and in Figs. UW-16.1 and UW-16.2 are defined as follows:

D_o = outside diameter of neck or tube attached by welding on inside of vessel shell only, in. (mm)

G = radial clearance between hole in vessel wall

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and outside diameter of nozzle neck or tube, in. (mm)

Radius = $\frac{1}{8}$ in. (3.2 mm) minimum blend radius

r_1 = minimum inside corner radius, the lesser of $\frac{1}{4}t$ or $\frac{3}{4}$ in. (19 mm)

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

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

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

t_e = thickness of reinforcing plate, as defined in UG-40, in. (mm)

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

t_c = not less than the smaller of $\frac{1}{4}$ in. (6 mm) or $0.7t_{\min}$ (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_1 or t_2 = not less than the smaller of $\frac{1}{4}$ in. (6 mm) or $0.7t_{\min.}$

(c) Necks Attached by a Full Penetration Weld. Necks abutting a vessel wall shall be attached by a full penetration groove weld. See Fig. UW-16.1 sketches (a) and (b) for examples. Necks inserted through the vessel wall may be attached by a full penetration groove weld. See Fig. UW-16.1 sketches (c), (d), and (e). When complete joint penetration cannot be verified by visual inspection or other means permitted in this Division, backing strips or equivalent shall be used with full penetration welds deposited from one side.

If additional reinforcement is required, it shall be provided as integral reinforcement as described in (1) below, or by the addition of separate reinforcement elements (plates) attached by welding as described in (2) below.

(1) Integral reinforcement is that reinforcement provided in the form of extended or thickened necks, thickened shell plates, forging type inserts, or weld buildup which is an integral part of the shell or nozzle wall and, where required, is attached by full penetration welds. See Fig. UW-16.1 sketches (a), (b), (c), (d), (e), (f-1), (f-2), (f-3), (f-4), (g), (x-1), (y-1), and (z-1) for examples of nozzles with integral reinforcement where the F factor in UG-37(b) may be used.

(2) Separate reinforcement elements (plates) may be added to the outside surface of the shell wall, the inside surface of the shell wall, or to both surfaces of the shell wall. When this is done, the nozzle and reinforcement is no longer considered a nozzle with integral reinforcement and the F factor in UG-37(a) shall be $F = 1.0$. Figure UW-16.1 sketches (a-1), (a-2), and (a-3) depict various applications of reinforcement elements added to sketch (a). Any of these applications of reinforcement elements may be used with necks of the types shown in Fig. UW-16.1 sketches (b), (c), (d), and (e) or any other integral reinforcement types listed in (1) above. When a pad is added, the nozzle and reinforcement is no longer considered a nozzle with integral reinforcement. The reinforcement plates shall be attached by welds at the outer edge of the plate, and at the nozzle neck periphery or inner edge of the plate if no nozzle neck is adjacent to the plate. The weld at the outer edge and the weld at the inner edge of the reinforcement plate which does not abut a nozzle neck shall be a fillet weld with a minimum throat dimension of $\frac{1}{2}t_{\min}$. See Fig. UW-16.1 sketch (h) for an example of a fillet weld attachment. The welds attaching the reinforcement plate to a nozzle neck abutting a vessel wall shall be a full penetration weld plus a fillet weld with minimum throat dimension t_w not less than $0.7t_{\min}$.

(d) Neck Attached by Fillet or Partial Penetration Welds.

(1) Necks inserted into or through the vessel wall may be attached by fillet or partial penetration welds, one on each face of the vessel wall. The welds may be any desired combination of fillet, single-bevel, and single-J welds. The dimension of t_1 or t_2 for each weld shall be not less than the smaller of $\frac{1}{4}$ in. (6 mm) or $0.7t_{\min}$, and their sum shall be not less than $1\frac{1}{4}t_{\min}$. See Fig. UW-16.1 sketches (i), (j), (k), and (l).

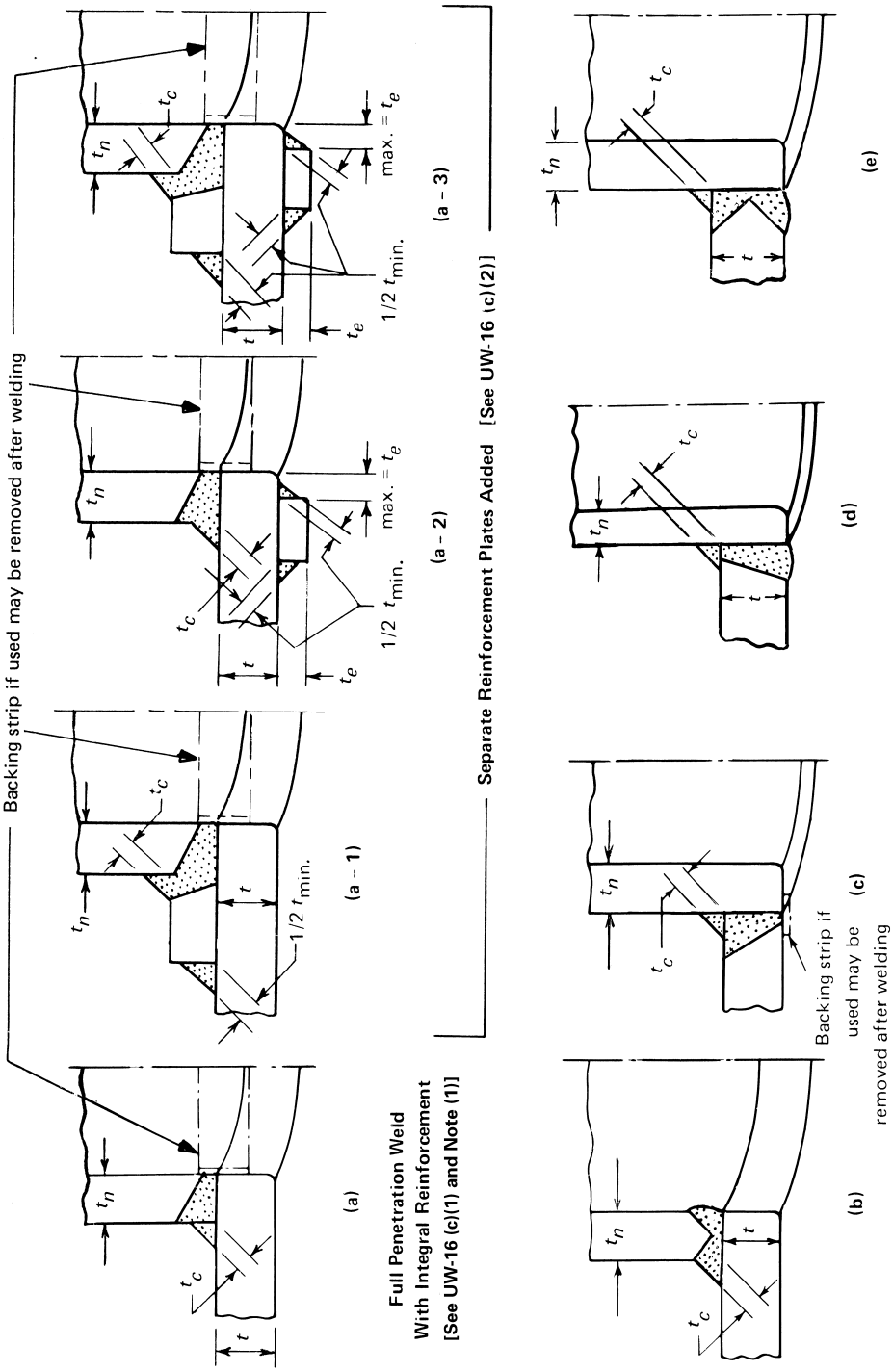
If additional reinforcement is required, it may be provided in the form of extended or thickened necks, thickened shell plates, forgings, and/or separate reinforcement elements (plates) attached by welding. Weld requirements shall be the same as given in (c)(2) above, except as follows. The welds attaching the neck to the vessel wall or to the reinforcement plate shall consist of one of the following:

(a) a single-bevel or single-J weld in the shell plate, and a single-bevel or single-J weld in each reinforcement plate. The dimension t_w of each weld shall be not less than $0.7t_{\min}$. See Fig. UW-16.1 sketches (q) and (r).

(b) a full penetration groove weld in each reinforcement plate, and a fillet, single-bevel, or single-J weld with a weld dimension t_w not less than $0.7t_{\min}$ in the shell plate. See Fig. UW-16.1 sketch (s).

(2) Nozzle necks, flared necks, and studding outlet type flanges may be attached by fillet welds or partial penetration welds between the outside diameter or the

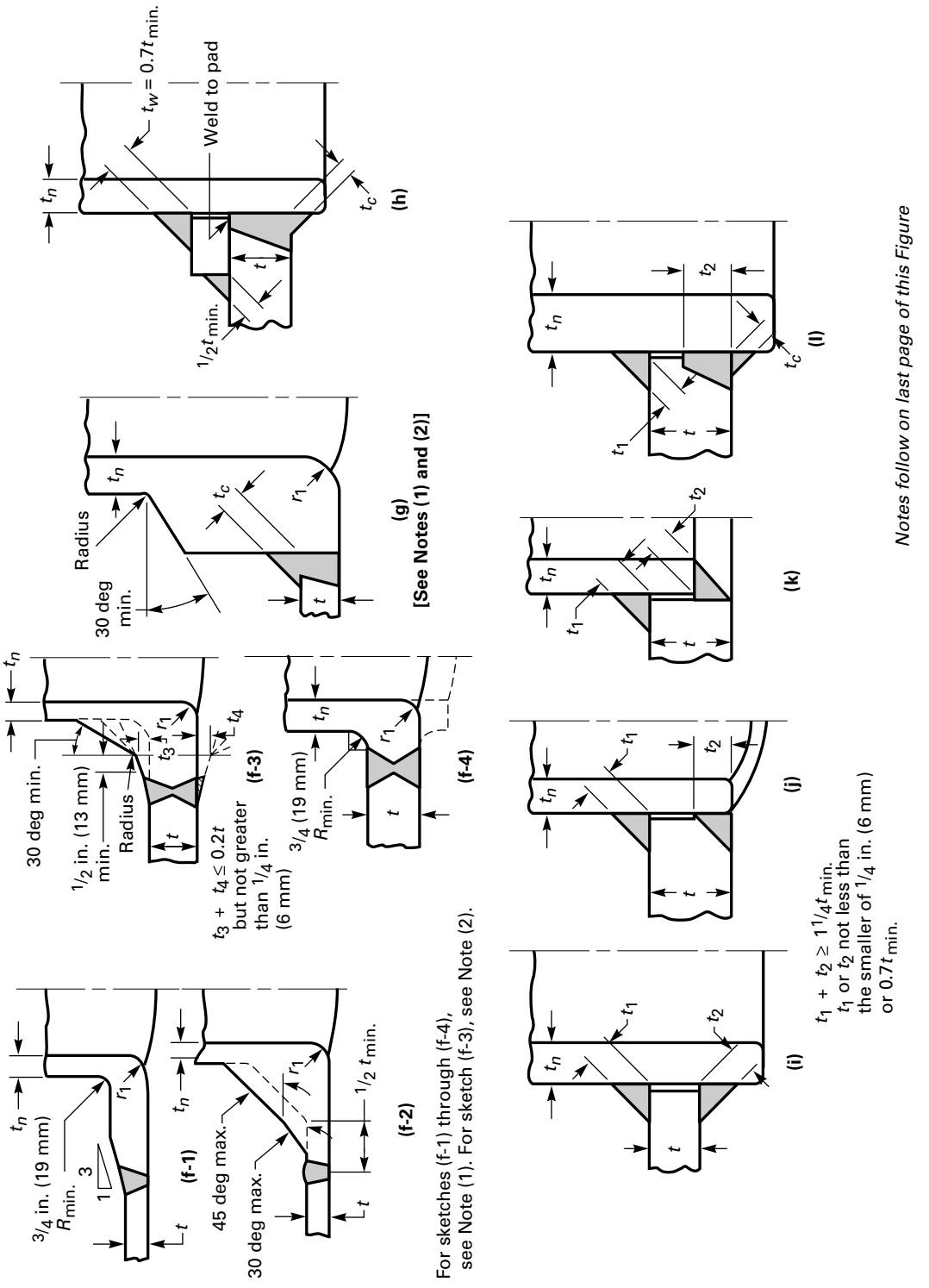
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Notes follow on last page of this Figure

FIG. UW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, HEADS, ETC.

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FIG. UW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, HEADS, ETC. (CONT'D)

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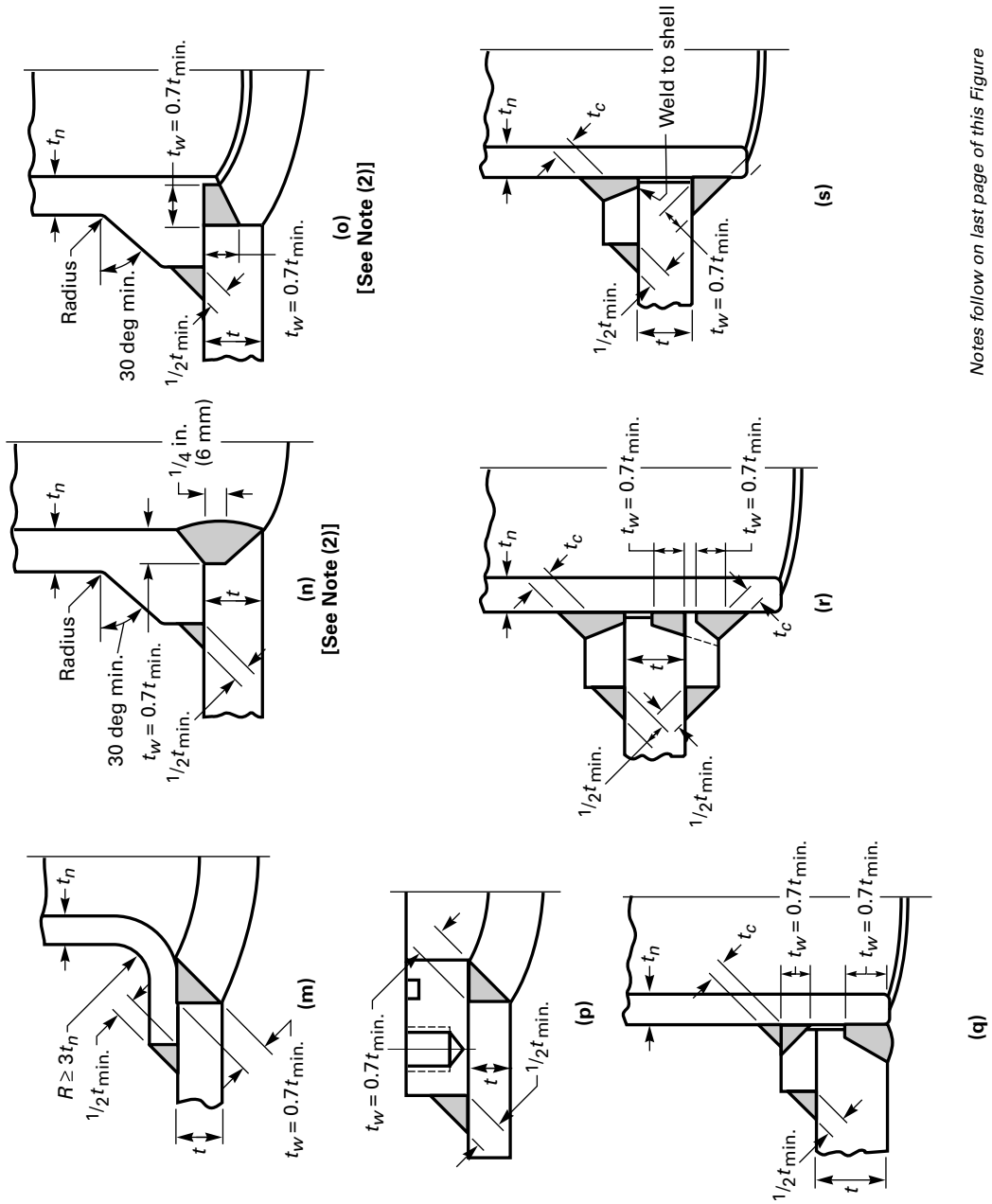


FIG. UW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, HEADS, ETC. (CONT'D)

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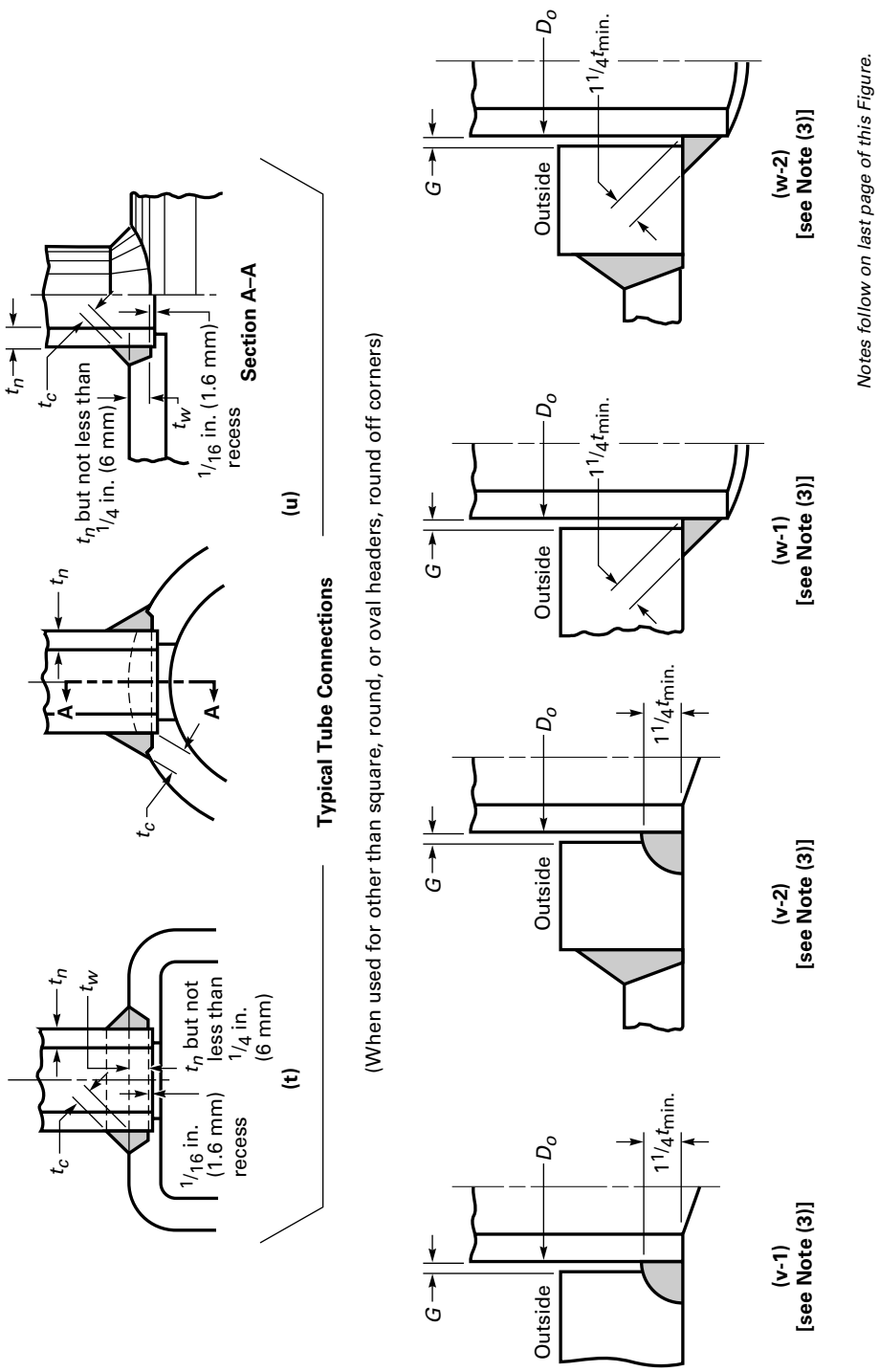
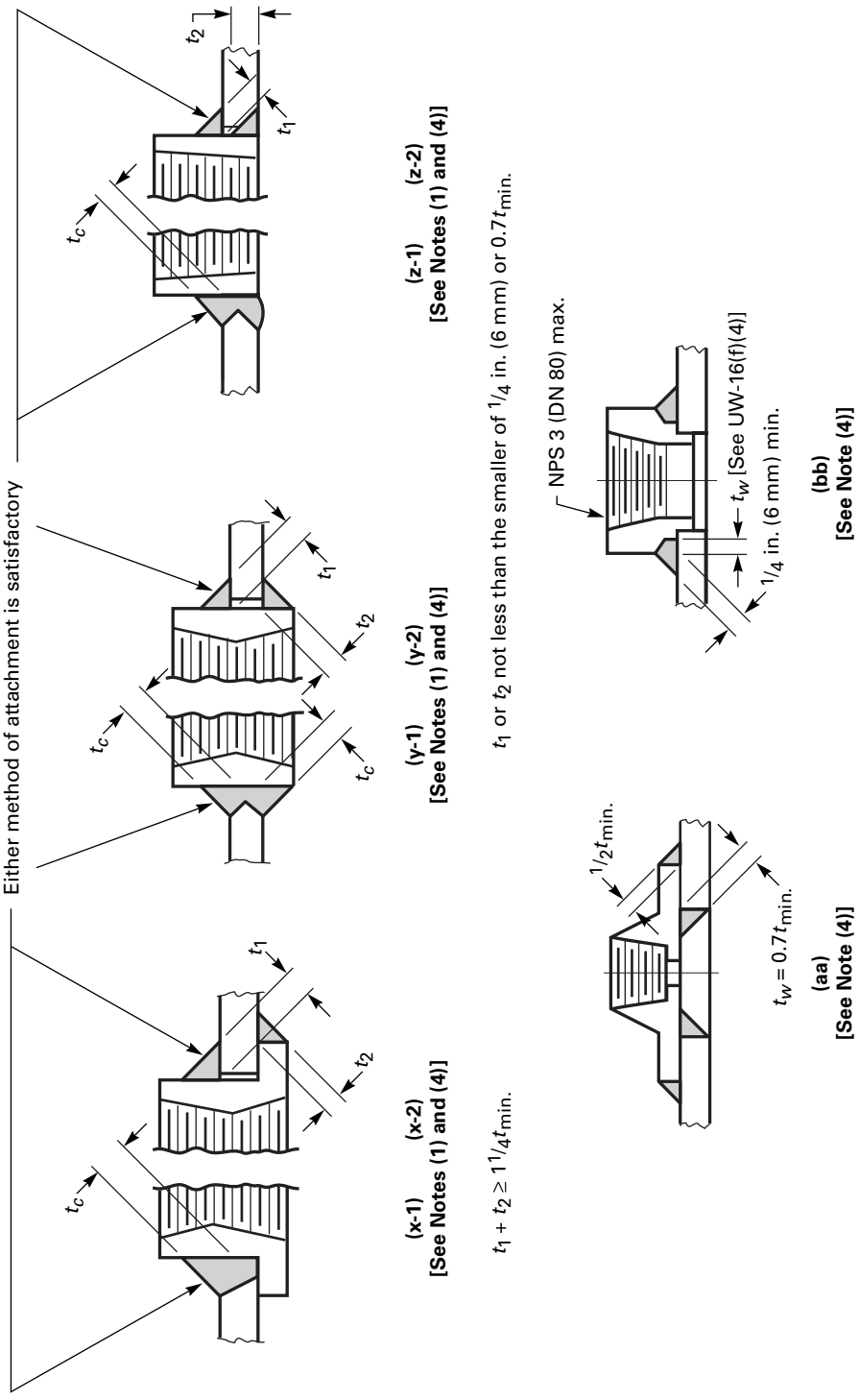


FIG. UW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, HEADS, ETC. (CONT'D)

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NOTES:
(1) Sketches (a), (b), (c), (d), (e), (f-1) through (f-4), (g), (x-1), (y-1), and (z-1) are examples of nozzles with integral reinforcement.
(2) Where the term *Radius* appears, provide a $\frac{1}{8}$ in. (3.2 mm) minimum blend radius.
(3) For sketches (v-1) through (w-2):
  (a) For applications where there are no external loads, $G = \frac{1}{8}$ in. (3.2 mm) max.
  (b) With external loads:
    $G = 0.005$ for $D_o \leq 1$ in. (25 mm); $G = 0.010$ for 1 in. (25 mm) $< D_o \leq 4$ in. (102 mm); $G = 0.015$ for 4 in. (102 mm) $< D_o \leq 6\frac{5}{8}$ in. (168 mm).
(4) For NPS 3 (DN 80) and smaller, see exemptions in UW-16(f)(2).

FIG. UW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, HEADS, ETC. (CONT'D)

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attachment and the outside surface of the shell and at the inside of the opening in the shell. The throat dimension of the outer attachment weld shall not be less than $\frac{1}{2}t_{min}$. The dimension t_w of the weld at the inside of the shell cutout shall not be less than $0.7t_{min}$. See Fig. UW-16.1 sketches (m), (n), (o), and (p).

(e) Necks and Tubes up to and Including NPS 6 (DN 150) Attached From One Side Only. Necks and tubes not exceeding NPS 6 (DN 150) may be attached from one side only on either the outside or inside surface of the vessel.

(1) 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 be not less than t_n nor less than $\frac{1}{4}$ in. See Fig. UW-16.1 sketches (t) and (u).

(2) 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 vessel hole and nozzle outside diameter at the unwelded side shall not exceed tolerances given in Fig. UW-16.1 sketches (v-1), (v-2), (w-1), and (w-2). Such attachments shall satisfy the rules for reinforcement of openings except that no material in the nozzle neck shall be counted as reinforcement.

(f) Fittings: Internally Threaded, Externally Threaded, Socket Welded or Butt Welded. The attachment of fittings shall meet the following requirements.

(1) Except as provided for in (2), (3), (4), (5), and (6) below, fittings shall be attached by a full penetration groove weld or by two fillet or partial penetration welds, one on each face of the vessel wall. The minimum weld dimensions shall be as shown in Fig. UW-16.1 sketches (x), (y), (z), and (aa).

(2) Fittings not exceeding NPS 3 (DN 80) shown on Fig. UW-16.1 sketches (x), (y), (z), (aa), and (bb) may be attached by welds that are exempt from size requirements with the following limitations.

(a) UW-15(a) requirements shall be satisfied for UG-22 loadings.

(b) For partial penetration welds or fillet welds, t_1 or t_2 shall not be less than the smaller of $\frac{3}{32}$ in. (2.4 mm) or $0.7t_{min}$.

(3)(a) Fittings and bolting pads not exceeding NPS 3 (DN 80), as shown in Fig. UW-16.2, may be attached to vessels by a fillet weld deposited from the outside only with the following limitations:

(1) maximum vessel wall thickness of $\frac{3}{8}$ in. (10 mm);

(2) the maximum size of the opening in the vessel is limited to the outside diameter of the attached pipe plus $\frac{3}{4}$ in. (19 mm), but not greater than one-half of the vessel inside diameter;

(3) the attachment weld throat shall be the greater of the following:

(a) the minimum nozzle neck thickness required by UG-45 for the same nominal size connection; or

(b) that necessary to satisfy the requirements of UW-18 for the applicable loadings of UG-22.

(4) the typical fitting dimension t_f as shown in Fig. UW-16.2 sketch (p) shall be sufficient to accommodate a weld leg which will provide a weld throat dimension.

(b) If the opening exceeds the requirements of (f)(3)(a)(2) above or (f)(5)(d) below in any direction, or is greater than one-half the vessel inside diameter, the part of the vessel affected shall be subjected to a proof test as required in UG-36(a)(2), or the opening shall be reinforced in accordance with UG-37 and the nozzle or other connection attached, using a suitable detail in Fig. UW-16.1, if welded.

(4) Fittings not exceeding NPS 3 (DN 80) may be attached by a fillet groove weld from the outside only as shown in Fig. UW-16.1 sketch (bb). The groove weld t_w shall not be less than the thickness of Schedule 160 pipe (ANSI/ASME B36.10).

(5) Flange-type fittings not exceeding NPS 2 (DN 50), with some acceptable types such as those shown in Fig. UW-16.2, may be attached without additional reinforcement other than that in the fitting and its attachment to the vessel wall. The construction satisfies the requirements of this Division without further calculation or proof test as permitted in UG-36(c)(3) provided all of the following conditions are met.

(a) Maximum vessel wall thickness shall not exceed $\frac{3}{8}$ in. (10 mm).

(b) Maximum design pressure shall not exceed 350 psi (2410 kPa).

(c) Minimum fillet leg t_f is $\frac{3}{32}$ in. (2.4 mm).

(d) The finished opening, defined as the hole in the vessel wall, shall not exceed the outside diameter of the nominal pipe size plus $\frac{3}{4}$ in. (19 mm).

(6) Fittings conforming to Fig. UW-16.2 sketch (k) not exceeding NPS 3 may be attached by a single fillet weld on the inside of the vessel only, provided the criteria of Fig. UW-16.1 sketch (w) and UW-16(e)(2) are met.

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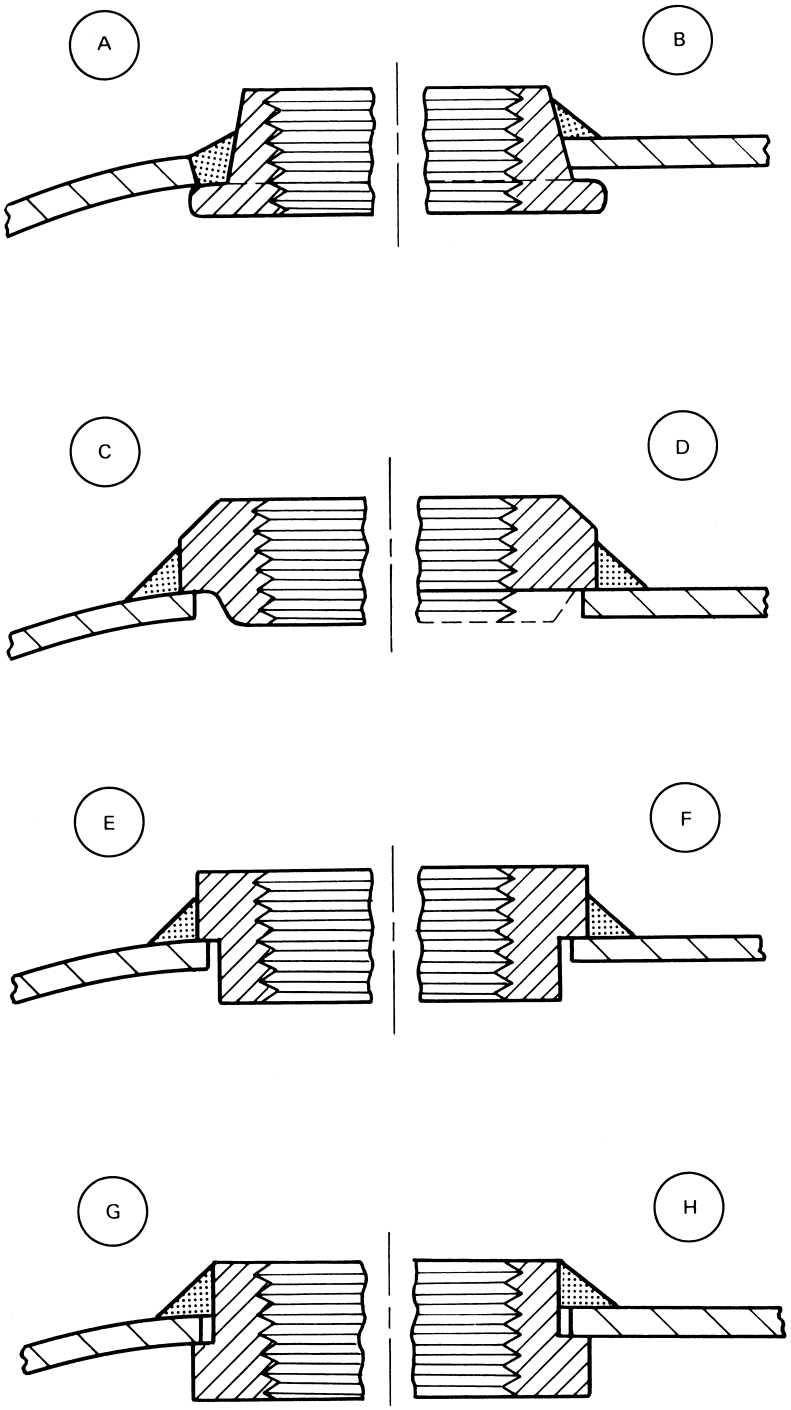


FIG. UW-16.2 SOME ACCEPTABLE TYPES OF SMALL FITTINGS
See UW-16(f)(3)(a) for Limitations

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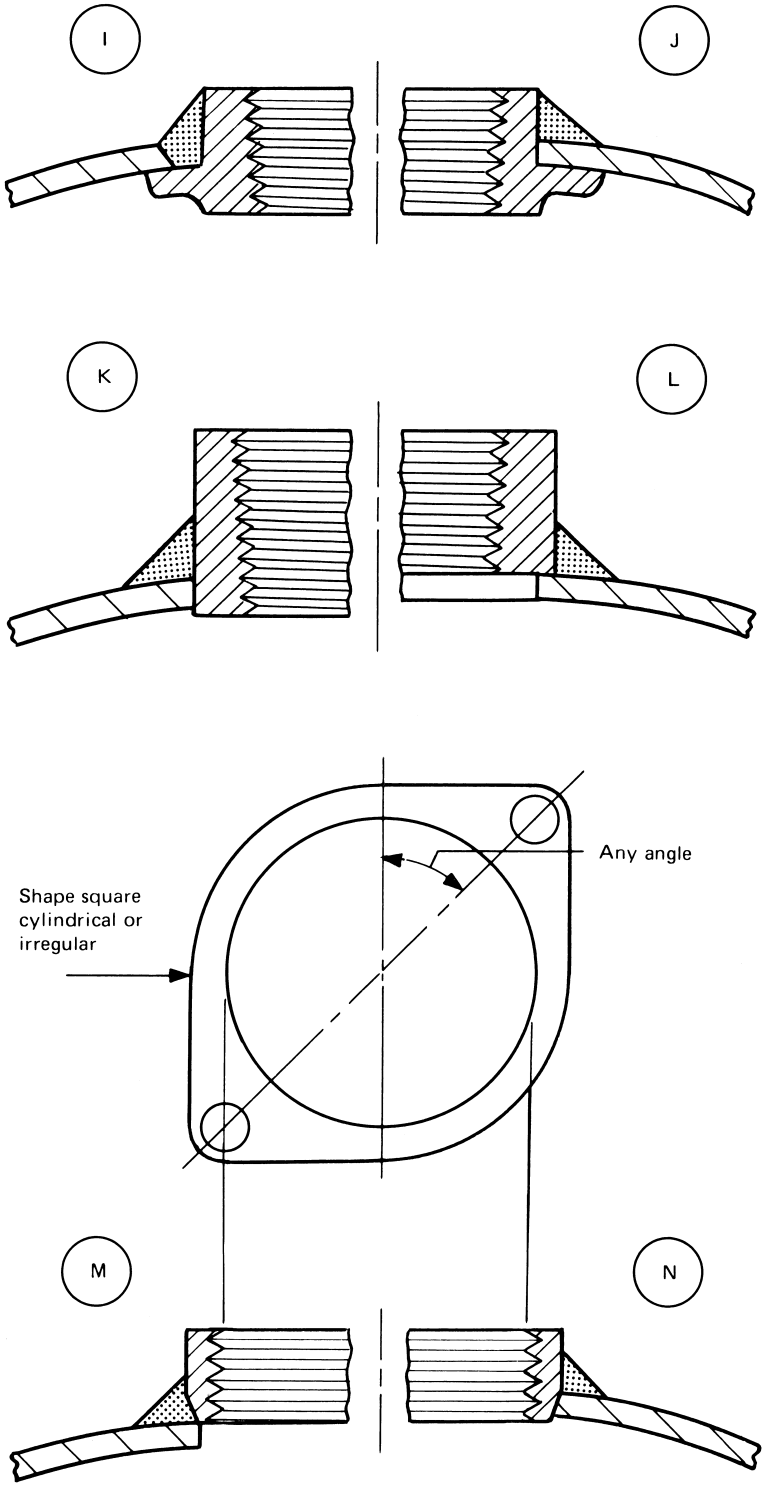


FIG. UW-16.2 SOME ACCEPTABLE TYPES OF SMALL FITTINGS (CONT'D)
See UW-16(f)(3)(a) for Limitations

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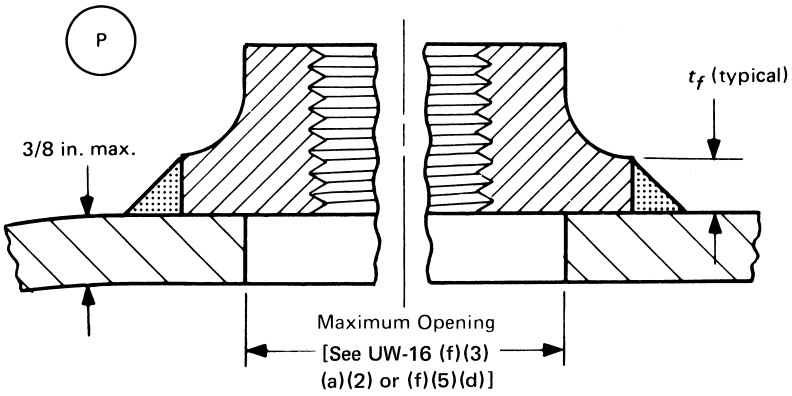


FIG. UW-16.2 SOME ACCEPTABLE TYPES OF SMALL FITTINGS (CONT'D)
See UW-16(f)(3)(a) for Limitations

UW-17 PLUG WELDS

(a) Plug welds may be used in lap joints, in reinforcements around openings and in nonpressure structural attachments. They shall be properly spaced to carry their proportion of the load, but shall not be considered to take more than 30% of the total load to be transmitted.

(b) Plug weld holes shall have a diameter not less than $t + \frac{1}{4}$ in. (6 mm) and not more than $2t + \frac{1}{4}$ in. (6 mm), where t is the thickness in inches of the plate or attached part in which the hole is made.

(c) Plug weld holes shall be completely filled with weld metal when the thickness of the plate, or attached part, in which the weld is made is $\frac{5}{16}$ in. (8 mm) or less; for thicker plates or attached parts the holes shall be filled to a depth of at least half the plate thickness or $\frac{5}{16}$ of the hole diameter, whichever is larger, but in no case less than $\frac{5}{16}$ in. (8 mm).

(d) The allowable working load on a plug weld in either shear or tension shall be computed by the following formula:

for Customary units,

$$P = 0.63S(d - {}^1/_4)^2$$

for SI units,

$$P = 0.63S(d - 6)^2 \quad **$$

where

P = total allowable working load on the plug weld, lb (kN)

d = the bottom diameter of the hole in which the weld is made, in. (mm)

S = maximum allowable stress value for the material in which the weld is made, psi (kPa) (see UG-23)

UW-18 FILLET WELDS

(a) Fillet welds may be employed as strength welds for pressure parts within the limitations given elsewhere in this Division. Particular care shall be taken in the layout of joints in which fillet welds are to be used in order to assure complete fusion at the root of the fillet.

(b) Corner or tee joints may be made with fillet welds provided the plates are properly supported independently of such welds, except that independent supports are not required for joints used for the purposes enumerated in UG-55.

(c) Figures UW-13.1 and UW-13.2 show several construction details that are not permissible.

(d) Unless the sizing basis is given elsewhere in this Division, the allowable load on fillet welds shall equal the product of the weld area (based on minimum leg dimension), the allowable stress value in tension of the material being welded, and a joint efficiency of 55%.

** For some of the terms of the above equation(s), it may be necessary to convert millimeters to meters to obtain a rational result in SI units.

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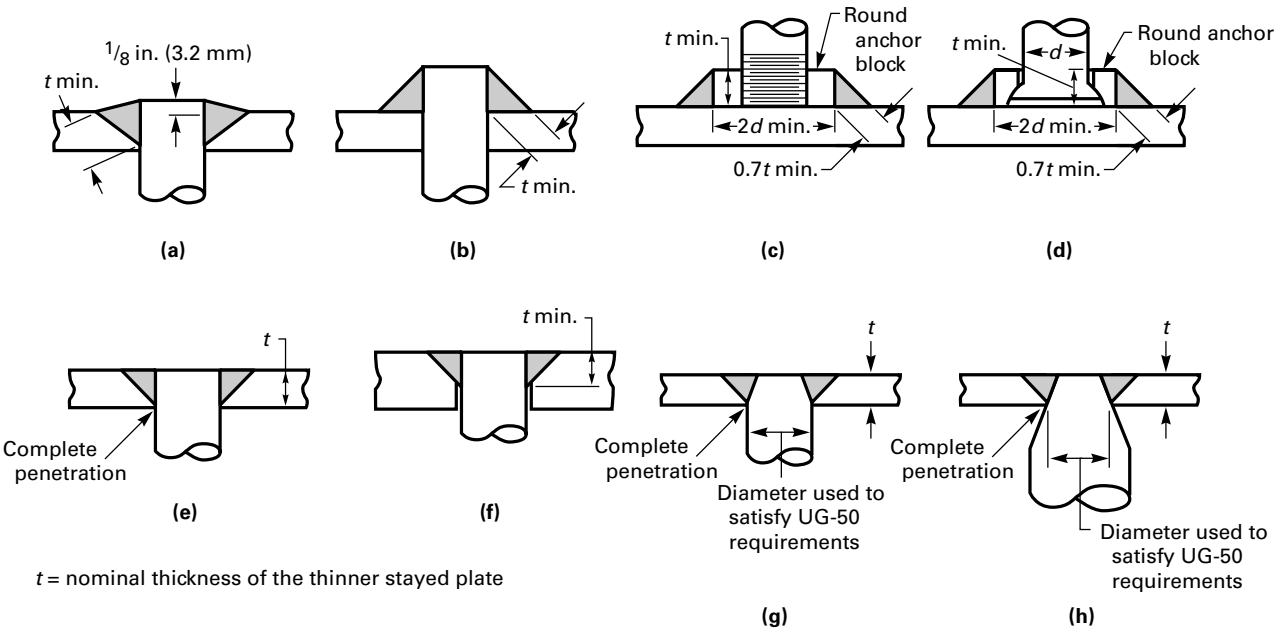


FIG. UW-19.1 TYPICAL FORMS OF WELDED STAYBOLTS

UW-19 WELDED STAYED CONSTRUCTION

(a) Welded-in staybolts shall meet the following requirements:

(1) the arrangement shall substantially conform to one of those illustrated in Fig. UW-19.1;

(2) the required thickness of the plate shall not exceed 1½ in. (38 mm), but if greater than ¾ in. (19 mm), the staybolt pitch shall not exceed 20 in. (508 mm);

(3) the provisions of UG-47 and UG-49 shall be followed; and

(4) the required area of the staybolt shall be determined in accordance with the requirements in UG-50.

(b) Welded stays, substantially as shown in Fig. UW-19.2, may be used to stay jacketed pressure vessels provided:

(1) the pressure does not exceed 300 psi (2070 kPa);

(2) the required thickness of the plate does not exceed ½ in. (13 mm);

(3) the size of the fillet welds is not less than the plate thickness;

(4) the inside welds are properly inspected before the closing plates are attached;

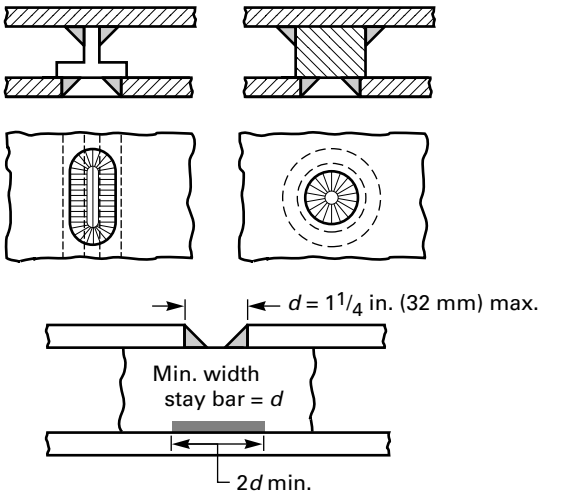


FIG. UW-19.2 USE OF PLUG AND SLOT WELDS FOR STAYING PLATES

(5) the allowable load on the fillet welds is computed in accordance with UW-18(d);

(6) the maximum diameter or width of the hole in the plate does not exceed 1¼ in. (32 mm);

(7) the welders are qualified under the rules of Section IX;

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(8) the maximum spacing of stays is determined by the formula in UG-47(a), using $C = 2.1$ if either plate is not over $^{7}/_{16}$ in. (11 mm) thick, $C = 2.2$ if both plates are over $^{7}/_{16}$ in. (11 mm) thick.

(c) Welded stayed construction, consisting of a dimpled or embossed plate welded to another like plate or to a plain plate may be used, provided:

(1) the welded attachment is made by fillet welds around holes or slots as shown in Fig. UW-19.2 or if the thickness of the plate having the hole or slot is $^{3}/_{16}$ in. (4.8 mm) or less, and the hole is 1 in. (25 mm) or less in diameter, the holes may be completely filled with weld metal. The allowable load on the weld shall equal the product of the thickness of the plate having the hole or slot, the circumference or perimeter of the hole or slot, the allowable stress value in tension of the weaker of the materials being joined and a joint efficiency of 55%;

(2) the maximum allowable working pressure of the dimpled or embossed components is established in accordance with the requirements of UG-101. This proof test may be carried out on a representative panel. If a representative panel is used, it shall be rectangular in shape and at least 5 pitches in each direction, but not less than 24 in. (610 mm) in either direction;

(3) the plain plate, if used, shall meet the requirements for braced and stayed surfaces.

(d) The welds need not be radiographed, nor need they be postweld heat treated unless the vessel or vessel part in which they occur is required to be postweld heat treated.

UW-20 TUBE-TO-TUBESHEET WELDS

UW-20(a) Definitions

UW-20(a)(1) Full Strength Weld. A full strength tube-to-tubesheet weld is one in which the design strength is equal to or greater than the maximum allowable axial tube strength. When the weld in a tube-to-tubesheet joint meets the requirements of (c) below, it is a full strength weld and the joint does not require qualification by shear load testing. Such a weld also provides tube joint leak tightness.

UW-20(a)(2) Partial Strength Weld. A partial strength weld is one in which the design strength is based on the mechanical and thermal axial tube loads (in either direction) that are determined from the actual design conditions. The maximum allowable axial load of this weld may be determined in accordance with (d) below, Appendix A, or UW-18(d). When the weld in a tube-to-tubesheet joint meets the requirements of (d) below, it is a partial strength weld and the joint does not require qualification by shear load testing. Such a weld also provides tube joint leak tightness.

UW-20(a)(3) Seal Weld. A tube-to-tubesheet seal weld is one used to supplement an expanded tube joint to ensure leak tightness. Its size has not been determined based on axial tube loading.

UW-20(b) Symbols. The symbols used in this paragraph and in Fig. UW-20 are defined as follows:

a_c = length of the combined weld legs measured parallel to the longitudinal axis of the tube at its outside diameter, in. (mm)

a_f = fillet weld leg, in. (mm)

a_g = groove weld leg, in. (mm)

a_r = minimum required length of the weld leg(s) under consideration, in. (mm)

d_o = tube outside diameter, in. (mm)

F_d = design strength, but not greater than F_t, lb (kN)

f_d = ratio of the design strength to the tube strength
= 1.0 for full strength welds
= F_d/F_t for partial strength welds

F_f = fillet weld strength, but not greater than F_t, lb (kN)
= $0.55\pi a_f(d_o + 0.67a_f)S_w$

f_f = ratio of the fillet weld strength to the design strength
= $1 - F_g/(f_dF_t)$

F_g = groove weld strength, but not greater than F_t, lb (kN)
= $0.85\pi a_g(d_o + 0.67a_g)S_w$

F_t = tube strength, lb (kN)
= $\pi t(d_o - t)S_a$

f_w = weld strength factor
= S_a/S_w

$L_{max.}$ = maximum allowable axial load in either direction on the tube-to-tubesheet joint, lb (kN)

t = nominal tube thickness, in. (mm)

S = allowable stress value as given in the applicable part of Section II, Part D, psi (kPa)

S_a = allowable stress in tube, psi (kPa) (see S, above). For a welded tube, use the allowable stress for an equivalent seamless tube.

S_t = allowable stress of the material to which the tube is welded, psi (kPa) (see S, above)

S_w = allowable stress in weld, psi (kPa) (lesser of S_a or S_t, above)

UW-20(c) Full strength welds shown in Fig. UW-20 shall conform to the following requirements.

UW-20(c)(1) The size of a full strength weld shall be determined in accordance with (e) below.

UW-20(c)(2) The maximum allowable axial load in either direction on a tube-to-tubesheet joint with a full strength weld shall be determined as follows.

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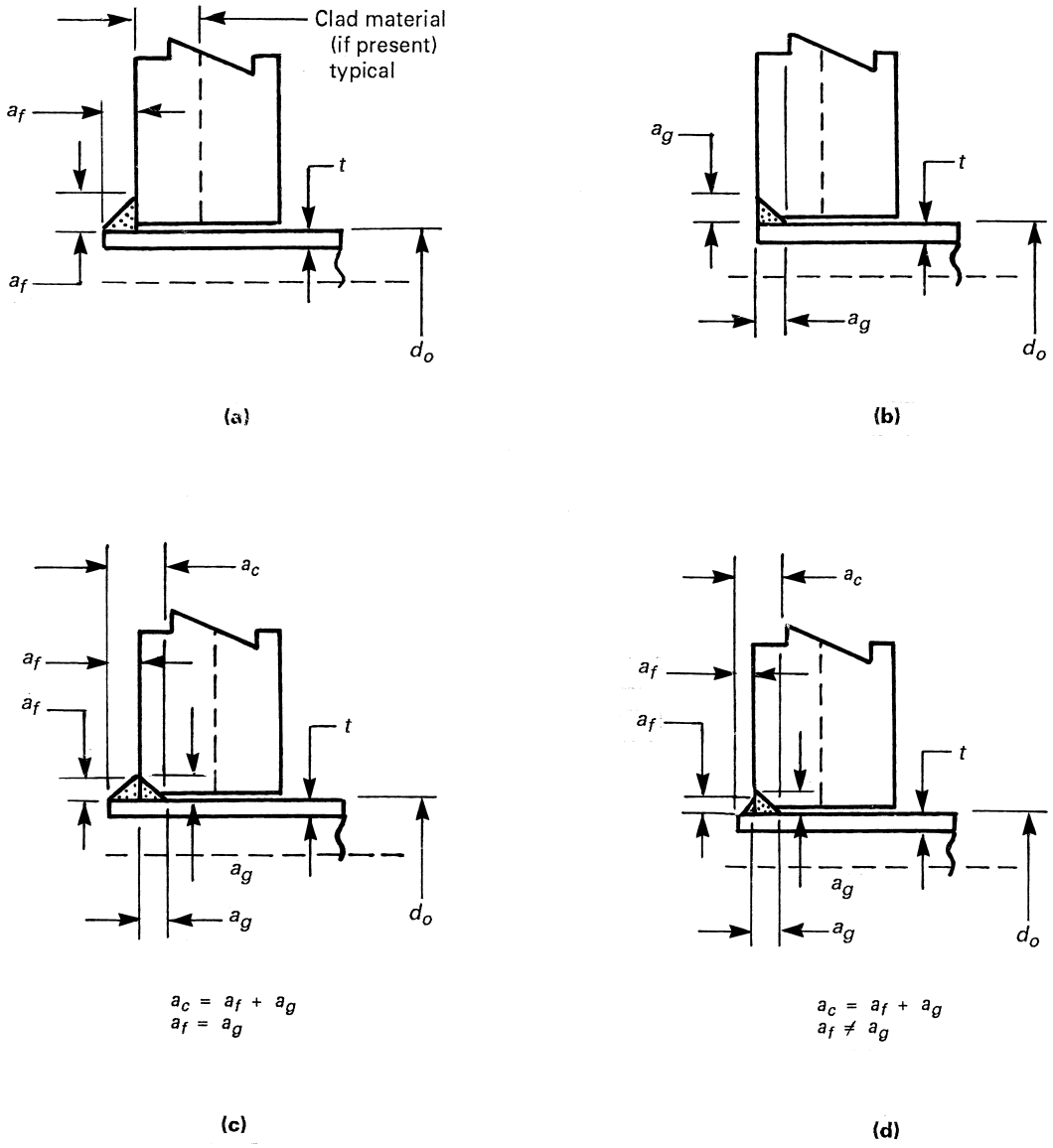


FIG. UW-20 SOME ACCEPTABLE TYPES OF TUBE-TO-TUBESHEET WELDS

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(a) For loads due to pressure-induced axial forces, $L_{max.} = F_t$.

(b) For loads due to thermally-induced or pressure plus thermally-induced axial forces:

(1) $L_{max.} = F_t$ for welded only tube-to-tubesheet joints, where the thickness through the weld throat is less than the nominal tube thickness *t;*

(2) $L_{max.} = 2F_t$ for all other welded tube-to-tubesheet joints.

UW-20(d) Partial strength welds shown in Fig. UW-20 shall conform to the following requirements.

UW-20(d)(1) The size of a partial strength weld shall be determined in accordance with (e) below.

UW-20(d)(2) The maximum allowable axial load in either direction on a tube-to-tubesheet joint with a partial strength weld shall be determined as follows.

(a) For loads due to pressure-induced axial forces, $L_{max.} = F_f + F_g$, but not greater than F_t.

(b) For loads due to thermally-induced or pressure plus thermally-induced axial forces:

(1) $L_{max.} = F_f + F_g$, but not greater than F_t, for welded only tube-to-tubesheet joints, where the thickness through the weld throat is less than the nominal tube thickness *t;*

(2) $L_{max.} = 2(F_f + F_g)$, but not greater than $2F_t$, for all other welded tube-to-tubesheet joints.

UW-20(e) The size of tube-to-tubesheet strength welds shown in Fig. UW-20 shall conform to the following requirements.

UW-20(e)(1) For fillet welds shown in sketch (a),

$$a_r = \sqrt{(0.75d_o)^2 + 2.73t(d_o - t)f_w f_d} - 0.75d_o$$

(a) For full strength welds, a_f shall not be less than the greater of a_r or *t.*

(b) For partial strength welds, a_f shall not be less than a_r.

UW-20(e)(2) For groove welds shown in sketch (b),

$$a_r = \sqrt{(0.75d_o)^2 + 1.76t(d_o - t)f_w f_d} - 0.75d_o$$

(a) For full strength welds, a_g shall not be less than the greater of a_r or *t.*

(b) For partial strength welds, a_g shall not be less than a_r.

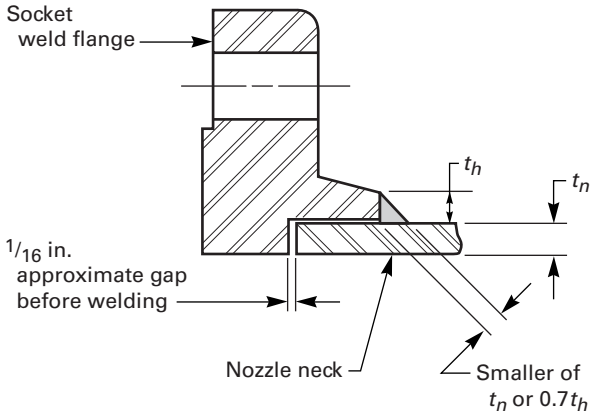


FIG. UW-21 WELDS OF SOCKET WELD FLANGES TO NOZZLE NECKS 01

UW-20(e)(3) For combined groove and fillet welds shown in sketch (c), where a_f is equal to a_g,

$$a_r = 2\left[\sqrt{(0.75d_o)^2 + 1.07t(d_o - t)f_w f_d} - 0.75d_o\right]$$

(a) For full strength welds, a_c shall not be less than the greater of a_r or *t.*

(b) For partial strength welds, a_c shall not be less than a_r.

Calculate a_f and a_g: $a_f = a_c/2$ and $a_g = a_c/2$.

UW-20(e)(4) For combined groove and fillet welds shown in sketch (d), where a_f is not equal to a_g, a_r shall be determined as follows: Choose a_g. Calculate a_r:

$$a_r = \sqrt{(0.75d_o)^2 + 2.73t(d_o - t)f_w f_d f_f} - 0.75d_o$$

(a) For full strength welds, a_c shall not be less than the greater of $(a_r + a_g)$ or *t.*

(b) For partial strength welds, a_c shall not be less than $a_r + a_g$.

Calculate a_f: $a_f = a_c - a_g$.

UW-21 FLANGE TO NOZZLE NECK WELDS 01

UW-21(a) ASME B16.5 socket weld flanges shall be welded to a nozzle neck using an external fillet weld. The minimum fillet weld throat dimension shall be the lesser of the nozzle wall thickness or 0.7 times the hub thickness of the socket weld flange. See Fig. UW-21.

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UW-21(b) ASME B16.5 slip-on flanges shall be welded to a nozzle neck using an internal and an external fillet weld. The minimum fillet weld throat dimension shall equal 0.7 times the nozzle wall. See Fig. 2-4 sketch (3).

FABRICATION

01 UW-26 GENERAL

(a) The rules in the following paragraphs apply specifically to the fabrication of pressure vessels and vessel parts that are fabricated by welding and shall be used in conjunction with the general requirements for *Fabrication* in Subsection A, and with the specific requirements for *Fabrication* in Subsection C that pertain to the class of material used.

(b) Each Manufacturer or parts Manufacturer shall be responsible for the quality of the welding done by his organization and shall conduct tests not only of the welding procedure to determine its suitability to ensure welds which will meet the required tests, but also of the welders and welding operators to determine their ability to apply the procedure properly.

(c) No production welding shall be undertaken until after the welding procedures which are to be used have been qualified. Only welders and welding operators who are qualified in accordance with Section IX shall be used in production.

(d) Welders[5] not in the employ of the Manufacturer (Certificate of Authorization Holders) may be used to fabricate pressure vessels constructed in accordance with this Division, provided all the following conditions are met.

(1) All Code construction shall be the responsibility of the Manufacturer.

(2) All welding shall be performed in accordance with the Manufacturer's welding procedure specifications in accordance with the requirements of Section IX.

(3) All welders shall be qualified by the Manufacturer in accordance with the requirements of Section IX.

(4) The Manufacturer's Quality Control System shall include as a minimum:

(a) a requirement for complete and exclusive administrative and technical supervision of all welders by the Manufacturer;

(b) evidence of the Manufacturer's authority to assign and remove welders at his discretion without involvement of any other organization;

(c) a requirement for Assignment of Welder Identification symbols;

(d) evidence that this program has been accepted by the Manufacturer's Authorized Inspection Agency which provides the inspection service.

(5) The Manufacturer shall be responsible for Code compliance of the vessel or part, including Code Symbol stamping and providing Data Report Forms properly executed and countersigned by the Inspector.

UW-27 WELDING PROCESSES

(a) The welding processes that may be used in the construction of vessels under this Part of this Division are restricted as follows:

(1) arc welding processes: atomic hydrogen, electrogas, gas metal arc, gas tungsten arc, plasma arc, shielded metal arc, stud, and submerged arc;

(2) other than arc welding processes: electron beam, flash, electroslag, explosive,[6] induction, inertia and continuous drive friction, laser beam, oxyfuel gas, resistance, and thermit.

(b) Other than pressure inherent to the welding processes, no mechanical pressure or blows shall be applied except as permitted for peening in UW-39.

(c) Definitions are given in Section IX which include variations of these processes.

(d) Arc stud welding and resistance stud welding may be used only for non-pressure-bearing attachments, having a load or non-load-carrying function, except for material listed in Table UHT-23 provided that, in the case of ferrous materials, the heat treatment requirements of UCS-56 are complied with and the requirements of UW-28(b) and UW-29(a) are met prior to start of production welding. Studs shall be limited to 1 in. (25 mm) diameter maximum for round studs and an equivalent cross-sectional area for studs with other shapes.

(e) The electroslag welding process may be used for butt welds only in ferritic steels and austenitic stainless steels of types listed in UW-5(d), provided the requirements of UW-11(a)(6) and UW-11(d) are satisfied.

(f) The electrogas welding process may be used for butt welds only in ferritic steels and austenitic stainless steels of types listed in UW-5(d), provided the require-

[5] *Welder* includes brazer, welding and brazing operator.

[6] *explosive welding* — a solid state welding process wherein coalescence is produced by the application of pressure by means of an explosion.

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ments of UW-11(a)(6) are satisfied. When a single pass is greater than $1\frac{1}{2}$ in. (38 mm) in ferritic materials, the joint shall be given a grain refining (austenitizing) heat treatment.

01 UW-28 QUALIFICATION OF WELDING PROCEDURE

(a) Each procedure of welding that is to be followed in construction shall be recorded in detail by the manufacturer.

(b) The procedure 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.

(c) The procedure 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 meet the following requirements.

(1) When the welding process is manual, machine, or semiautomatic, procedure qualification is required in accordance with Section IX.

(2) When the welding is any automatic welding process performed in accordance with a Welding Procedure Specification (in compliance with Section IX as far as applicable), procedure qualification testing is not required.

(d) Welding of all test coupons shall be conducted by the Manufacturer. Testing of all test coupons shall be the responsibility of the Manufacturer. Alternatively, AWS Standard Welding Procedure Specifications that have been accepted by Section IX may be used provided they meet all other requirements of this Division. Qualification of a welding procedure by one Manufacturer shall not qualify that procedure for any other Manufacturer except as provided in QW-201 of Section IX.

UW-29 TESTS OF WELDERS AND WELDING OPERATORS

(a) The welders and welding operators used in welding pressure parts and in joining load-carrying nonpressure parts (attachments) to pressure parts shall be qualified in accordance with Section IX.

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

(2) When stud welding is used to attach load-carrying studs, a production stud weld test of each welder or welding operator shall be performed on a separate test plate or tube prior to the start of welding on each work shift. This weld test shall consist of five studs, welded and tested by the bend or torque stud weld testing procedure described in Section IX.

(b) The welders and 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 comply with the following.

(1) When the welding process is manual, machine, or semiautomatic, qualification in accordance with Section IX is required.

(2) When welding is done by any automatic welding process, performance qualification testing is not required.

(3) When stud welding is used, a production stud weld test, appropriate to the end use application requirements, shall be specified by the Manufacturer and carried out on a separate test plate or tube at the start of each shift.

(c) Each welder and welding operator shall be assigned an identifying number, letter, or symbol by the manufacturer which shall be used to identify the work of that welder or welding operator in accordance with UW-37(f).

(d) The Manufacturer shall maintain a record of the welders and welding operators showing the date and result of tests and the identification mark assigned to each. These records shall be certified to by the Manufacturer and be accessible to the Inspector.

(e) Welding of all test coupons shall be conducted by the Manufacturer. Testing of all test coupons shall be the responsibility of the Manufacturer. A performance qualification test conducted by one Manufacturer shall not qualify a welder or welding operator to do work for any other Manufacturer except as provided in QW-300 of Section IX.

UW-30 LOWEST PERMISSIBLE TEMPERATURES FOR WELDING

It is recommended that no welding of any kind be done when the temperature of the base metal is lower than 0°F (−18°C). At temperatures between 32°F (0°C) and 0°F (−18°C), the surface of all areas within 3 in. (76 mm) of the point where a weld is to be started should be heated to a temperature at least warm to the hand [estimated to be above 60°F (16°C)] before welding is started. It is recommended also that no

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welding be done when surfaces are wet or covered with ice, when snow is falling on the surfaces to be welded, or during periods of high wind, unless the welders or welding operators and the work are properly protected.

UW-31 CUTTING, FITTING, AND ALIGNMENT

(a) When plates are shaped by oxygen or arc cutting, the edges to be welded shall be uniform and smooth and shall be freed of all loose scale and slag accumulations before welding (see UG-76 and UCS-5).

(b) Plates that are being welded shall be fitted, aligned, and retained in position during the welding operation.

(c) Bars, jacks, clamps, tack welds, or other appropriate means may be used to hold the edges of parts in alignment. 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.

Provided that the work is done under the provisions of U-2(b), it is not necessary that a subcontractor making such tack welds for a vessel or parts manufacturer be a holder of a Code Certificate of Authorization. The requirements of UW-26(d) do not apply to such tack welds.

(d) The edges of butt joints shall be held during welding so that the tolerances of UW-33 are not exceeded in the completed joint. When fitted girth joints have deviations exceeding the permitted tolerances, the head or shell ring, whichever is out-of-true, shall be reformed until the errors are within the limits specified. Where fillet welds are used, the lapped plates shall fit closely and be kept in contact during welding.

(e) 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.

UW-32 CLEANING OF SURFACES TO BE WELDED

UW-32(a) The surfaces to be welded shall be clean and free of scale, rust, oil, grease, slag, detrimental oxides, and other deleterious foreign material. The method and extent of cleaning should be determined based on the material to be welded and the contaminants to be removed. When weld metal is to be deposited over a previously welded surface, all slag shall be removed by a roughing tool, chisel, chipping hammer, or other suitable means so as to prevent inclusion of impurities in the weld metal.

UW-32(b) Cast surfaces to be welded shall be machined, chipped, or ground to remove foundry scale and to expose sound metal.

UW-32(c) The requirements in (a) and (b) above are not intended to apply to any process of welding by which proper fusion and penetration are otherwise obtained and by which the weld remains free from defects.

UW-33 ALIGNMENT TOLERANCE

(a) Alignment of sections at edges to be butt welded shall be such that the maximum offset is not greater than the applicable amount for the welded joint category (see UW-3) under consideration, as listed in Table UW-33. The section thickness t is the nominal thickness of the thinner section at the joint.

(b) Any offset within the allowable tolerance provided above shall be faired at a three to one 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. Such additional weld metal buildup shall be subject to the requirements of UW-42.

UW-34 SPIN-HOLES

Spin-holes are permitted at the center of heads to facilitate forming. Spin-holes not greater in diameter than $2\frac{3}{8}$ in. may be closed with a full-penetration weld using either a welded plug or weld metal. The weld and plug shall be no thinner than the head material adjacent to the spin-hole.

The finished weld shall be examined[7] and shall meet the acceptance requirements of Appendix 6 or Appendix

[7] Examination shall be by magnetic particle or liquid penetrant methods when the material is ferromagnetic, or by the liquid penetrant method when the material is nonmagnetic.

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TABLE UW-33

Customary Units

Section Thickness, in.	Joint Categories A	Joint Categories B, C, & D
Up to 1/2, incl.	1/4t	1/4t
Over 1/2 to 3/4, incl.	1/8 in.	1/4t
Over 3/4 to 1 1/2, incl.	1/8 in.	3/16 in.
Over 1 1/2 to 2, incl.	1/8 in.	1/8t
Over 2	Lesser of 1/16t or 3/8 in.	Lesser of 1/8t or 3/4 in.

SI Units

Section Thickness, mm	Joint Categories A	Joint Categories B, C, & D
Up to 13, incl.	1/4t	1/4t
Over 13 to 19, incl.	3.2 mm	1/4t
Over 19 to 38, incl.	3.2 mm	4.8 mm
Over 38 to 51, incl.	3.2 mm	1/8t
Over 51	Lesser of 1/16t or 10 m m	Lesser of 1/8t or 19 mm

8 of this Division. Radiographic examination, if required by UW-11(a), and additional inspections, if required by the material specification, shall be performed.

This weld is a butt weld, but it is not categorized. It shall not be considered in establishing the joint efficiency of any part of the head or of the head-to-shell weld.

UW-35 FINISHED LONGITUDINAL AND CIRCUMFERENTIAL JOINTS

(a) Butt welded joints shall have complete penetration and full fusion. As-welded surfaces are permitted; however, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, and abrupt ridges and valleys 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 a radiographic film, the film shall be compared to the actual weld surface for determination of acceptability.

(b) A reduction in thickness due to the welding process is acceptable provided all of the following conditions are met.

(1) The reduction in thickness shall not reduce the material of the adjoining surfaces below the minimum required thickness at any point.

(2) The reduction in thickness shall not exceed 1/32 in. (0.8 mm) or 10% of the nominal thickness of the adjoining surface, whichever is less.[8]

(c) When a single-welded butt joint is made by using a backing strip which is left in place [Type No. (2) of Table UW-12], the requirement for reinforcement applies only to the side opposite the backing strip.

(d) To assure that the weld grooves are completely filled so that the surface of the weld metal at any point does not fall below the surface of the adjoining base materials,[9] 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:

Customary Units

Material Nominal Thickness, in.	Maximum Reinforcement, in. Category B & C Butt Welds	Maximum Reinforcement, in. Other Welds
Less than 3/32	3/32	1/32
3/32 to 3/16, incl.	1/8	1/16
Over 3/16 to 1/2, incl.	5/32	3/32
Over 1/2 to 1, incl.	3/16	3/32
Over 1 to 2, incl.	1/4	1/8
Over 2 to 3, incl.	1/4	5/32
Over 3 to 4, incl.	1/4	7/32
Over 4 to 5, incl.	1/4	1/4
Over 5	5/16	5/16

SI Units

Material Nominal Thickness, mm	Maximum Reinforcement, mm. Category B & C Butt Welds	Maximum Reinforcement, mm. Other Welds
Less than 2.4	2.4	0.8
2.4 to 4.8, incl.	3.2	1.6
Over 4.8 to 13, incl.	4.0	2.4
Over 13 to 25, incl.	4.8	2.4
Over 25 to 51, incl.	5	3.2
Over 51 to 76, incl.	6	4
Over 76 to 102, incl.	6	6
Over 102 to 127, incl.	6	6
Over 127	8	8

[8] It is not the intent of this paragraph to require measurement of reductions in thickness due to the welding process. If a disagreement between the Manufacturer and the Inspector exists as to the acceptability of any reduction in thickness, the depth shall be verified by actual measurement.

[9] Concavity due to the welding process on the root side of a single welded circumferential butt weld is permitted when the resulting thickness of the weld is at least equal to the thickness of the thinner member of the two sections being joined and the contour of the concavity is smooth.

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UW-36 FILLET WELDS

In making fillet welds, the weld metal shall be deposited in such a way that adequate penetration into the base metal at the root of the weld is secured. The reduction of the thickness of the base metal due to the welding process at the edges of the fillet weld shall meet the same requirements as for butt welds [see UW-35(b)].

01 UW-37 MISCELLANEOUS WELDING REQUIREMENTS

(a) The reverse side of double-welded joints shall be prepared by chipping, grinding, or melting out, so as to secure sound metal at the base of weld metal first deposited, before applying weld metal from the reverse side.

(b) The requirements in (a) above are not intended to apply to any process of welding by which proper fusion and penetration are otherwise obtained and by which the base of the weld remains free from defects.

(c) If the welding is stopped for any reason, extra care shall be taken in restarting to get the required penetration and fusion. For submerged arc welding, chipping out a groove in the crater is recommended.

(d) Where single-welded joints are used, particular care shall be taken in aligning and separating the components to be joined so that there will be complete penetration and fusion at the bottom of the joint for its full length.

(e) In welding plug welds, a fillet around the bottom of the hole shall be deposited first.

(f) Welder and Welding Operator Identification

(1) Each welder and welding operator shall stamp the identifying number, letter, or symbol assigned by the Manufacturer, on or adjacent to and at intervals of not more than 3 ft (0.9 m) along the welds which he makes in steel plates $\frac{1}{4}$ in. (6 mm) and over in thickness and in nonferrous plates $\frac{1}{2}$ in. (13 mm) and over in thickness; or a record shall be kept by the Manufacturer of welders and welding operators employed on each joint which shall be available to the Inspector. For identifying welds on vessels in which the wall thickness is less than $\frac{1}{4}$ in. (6 mm) for steel material and less than $\frac{1}{2}$ in. (13 mm) for nonferrous material, suitable stencil or other surface markings shall be used; or a record shall be kept by the Manufacturer of welders and welding operators employed on each joint which shall be available to the Inspector; or a stamp may be used provided the vessel part is not deformed and the following additional requirements are met:

(a) for ferrous materials:

(1) the materials shall be limited to P-No. 1 Gr. Nos. 1 and 2;

(2) the minimum nominal plate thickness shall be 0.1875 in. (4.8 mm), or the minimum nominal pipe wall thickness shall be 0.154 in. (3.9 mm);

(3) the minimum design metal temperature shall be no colder than −20°F (−29°C);

(b) for nonferrous materials:

(1) the materials shall be limited to aluminum as follows: SB-209 Alloys 3003, 5083, 5454, and 6061; SB-241 Alloys 3003, 5083, 5086, 5454, 6061, and 6063; and SB-247 Alloys 3003, 5083, and 6061;

(2) the minimum nominal plate thickness shall be 0.249 in. (6.32 mm), or the minimum nominal pipe thickness shall be 0.133 in. (3.37 mm).

(2) When a multiple number of permanent nonpressure part load bearing attachment welds, nonload bearing welds such as stud welds, or special welds such as tube-to-tubesheet welds are made on a vessel, 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 that will identify the welders or welding operators that made such welds on each vessel so that the Inspector can verify that the welders or welding operators were all properly qualified;

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

(3) Permanent identification of welders or welding operators making tack welds that become part of the final pressure weld is not required provided the Manufacturer's Quality Control System includes a procedure to permit the Inspector to verify that such tack welds were made by qualified welders or welding operators.

(g) The welded joint between two members joined by the inertia and continuous drive friction welding processes shall be a 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 within ±10%. The flash shall be removed to sound metal.

(h) Capacitor discharge welding may be used for welding temporary attachments and permanent nonstructural attachments without postweld heat treatment, provided the following requirements are met.

(1) A welding procedure specification shall be prepared in accordance with Section IX, insofar as possible describing the capacitor discharge equipment,

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the combination of materials to be joined, and the technique of application. Qualification of the welding procedure is not required.

(2) The energy output shall be limited to 125 W-sec.

UW-38 REPAIR OF WELD DEFECTS

Defects, such as cracks, pinholes, and incomplete fusion, detected visually or by the hydrostatic or pneumatic test or by the examinations prescribed in UW-11 shall be removed by mechanical means or by thermal gouging processes, after which the joint shall be rewelded [see UW-40(e)].

UW-39 PEENING

(a) Weld metal and heat affected zones may be peened by manual, electric, or pneumatic means when it is deemed necessary or helpful to control distortion, to relieve residual stresses, or to improve the quality of the weld. Peening shall not be used on the initial (root) layer of weld metal nor on the final (face) layer unless the weld is subsequently postweld heat treated. In no case, however, is peening to be performed in lieu of any postweld heat treatment required by these rules.

(b) Controlled shot peening and other similar methods which are intended only to enhance surface properties of the vessel or vessel parts shall be performed after any nondestructive examinations and pressure tests required by these rules.

UW-40 PROCEDURES FOR POSTWELD HEAT TREATMENT

(a) The operation of postweld heat treatment shall be performed in accordance with the requirements given in the applicable Part in Subsection C using one of the following procedures. In the procedures that follow, the soak band is defined as the volume of metal required to meet or exceed the minimum PWHT temperatures listed in Table UCS-56. As a minimum, the soak band shall contain the weld, heat affected zone, and a portion of base metal adjacent to the weld being heat treated. The minimum width of this volume is the widest width of weld plus 1t or 2 in. (51 mm), whichever is less, on each side or end of the weld. The term t is the nominal thickness as defined in (f) below.

(1) heating the vessel as a whole in an enclosed furnace. This procedure is preferable and should be used whenever practicable.

(2) heating the vessel in more than one heat in a furnace, provided the overlap of the heated sections of the vessel is at least 5 ft (1.5 m). When this procedure is used, the portion outside of the furnace shall be shielded so that the temperature gradient is not harmful. The cross section where the vessel projects from the furnace shall not intersect a nozzle or other structural discontinuity.

(3) heating of shell sections and/or portions of vessels to postweld heat treat longitudinal joints or complicated welded details before joining to make the completed vessel. When the vessel is required to be postweld heat treated, and it is not practicable to postweld heat treat the completed vessel as a whole or in two or more heats as provided in (2) above, any circumferential joints not previously postweld heat treated may be thereafter locally postweld heat treated by heating such joints by any appropriate means that will assure the required uniformity. For such local heating, the soak band shall extend around the full circumference. The portion outside the soak band shall be protected so that the temperature gradient is not harmful. This procedure may also be used to postweld heat treat portions of new vessels after repairs.

(4) heating the vessel internally by any appropriate means and with adequate indicating and recording temperature devices to aid in the control and maintenance of a uniform distribution of temperature in the vessel wall. Previous to this operation, the vessel should be fully enclosed with insulating material, or the permanent insulation may be installed provided it is suitable for the required temperature. In this procedure the internal pressure should be kept as low as practicable, but shall not exceed 50% of the maximum allowable working pressure at the highest metal temperature expected during the postweld heat treatment period.

(5) heating a circumferential band containing nozzles or other welded attachments that require postweld heat treatment in such a manner that the entire band shall be brought up uniformly to the required temperature and held for the specified time. Except as modified in this paragraph below, the soak band shall extend around the entire vessel, and shall include the nozzle or welded attachment. The circumferential soak band width may be varied away from the nozzle or attachment weld requiring PWHT, provided the required soak band around the nozzle or attachment weld is heated to the required temperature and held for the required time. As an alternative to varying the soak band width, the

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temperature within the circumferential band away from the nozzle or attachment may be varied and need not reach the required temperature, provided the required soak band around the nozzle or attachment weld is heated to the required temperature, held for the required time, and the temperature gradient is not harmful throughout the heating and cooling cycle. The portion of the vessel outside of the circumferential soak band shall be protected so that the temperature gradient is not harmful. This procedure may also be used to postweld heat treat portions of vessels after repairs.

(6) heating the circumferential joints of pipe or tubing by any appropriate means using a soak band that extends around the entire circumference. The portion outside the soak band shall be protected so that the temperature gradient is not harmful. The proximity to the shell increases thermal restraint, and the designer should provide adequate length to permit heat treatment without harmful gradients at the nozzle attachment or heat a full circumferential band around the shell, including the nozzle.

(7) heating a local area around nozzles or welded attachments in the larger radius sections of a double curvature head or a spherical shell or head in such a manner that the area is brought up uniformly to the required temperature and held for the specified time. The soak band shall include the nozzle or welded attachment. The soak band shall include a circle that extends beyond the edges of the attachment weld in all directions by a minimum of t or 2 in. (51 mm), whichever is less. The portion of the vessel outside of the soak band shall be protected so that the temperature gradient is not harmful.

(8) heating of other configurations. Local area heating of other configurations not addressed in (a)(1) through (a)(7) above is permitted, provided that other measures (based upon sufficiently similar, documented experience or evaluation) are taken that consider the effect of thermal gradients, all significant structural discontinuities (such as nozzles, attachments, head to shell junctures), and any mechanical loads which may be present during PWHT. The portion of the vessel or component outside the soak band shall be protected so that the temperature gradient is not harmful.

(b) The temperatures and rates of heating and cooling to be used in postweld heat treatment of vessels constructed of materials for which postweld heat treatment may be required are given in UCS-56, UHT-56, UNF-56, and UHA-32.

(c) The minimum temperature for postweld heat treatment given in Tables UCS-56, UHT-56, and UHA-32 and in UNF-56, shall be the minimum temperature of the plate material of the shell or head of any vessel. Where more than one pressure vessel or pressure vessel part are postweld heat treated in one furnace charge, thermocouples shall be placed on vessels at the bottom, center, and top of the charge, or in other zones of possible temperature variation so that the temperature indicated shall be true temperature for all vessels or parts in those zones.[10]

(d) When pressure parts of two different P-Number Groups are joined by welding, the postweld heat treatment shall be that specified according to either UCS-56 or UHA-32, for the material requiring the higher postweld heat treatment temperature.

(e) Postweld heat treatment, when required, shall be done before the hydrostatic test and after any welded repairs except as permitted by UCS-56(f). A preliminary hydrostatic test to reveal leaks prior to postweld heat treatment is permissible.

(f) The term nominal thickness as used in Tables UCS-56, UCS-56.1, UHA-32 and UHT-56, is the thickness of the welded joint as defined below. For pressure vessels or parts of pressure vessels being postweld heat treated in a furnace charge, it is the greatest weld thickness in any vessel or vessel part which has not previously been postweld heat treated.

(1) When the welded joint connects parts of the same thickness, using a full penetration buttweld, the nominal thickness is the total depth of the weld exclusive of any permitted weld reinforcement.

(2) For groove welds, the nominal thickness is the depth of the groove.

(3) For fillet welds, the nominal thickness is the throat dimension. If a fillet weld is used in conjunction with a groove weld, the nominal thickness is the depth of the groove or the throat dimension, whichever is greater.

(4) For stud welds, the nominal thickness shall be the diameter of the stud.

(5) When a welded joint connects parts of unequal thicknesses, the nominal thickness shall be the following:

(a) the thinner of two adjacent butt-welded parts including head to shell connections;

(b) the thickness of the shell or the fillet weld, whichever is greater, in connections to intermediate heads of the type shown in Fig. UW-13.1 sketch (f);

(c) the thickness of the shell in connections to tubesheets, flat heads, covers, flanges, or similar constructions;

[10] Furnace gas temperature measurement alone is not considered sufficiently accurate.

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(d) in Figs. UW-16.1 and UW-16.2, the thickness of the weld across the nozzle neck or shell or head or reinforcing pad or attachment fillet weld, whichever is the greater;

(e) the thickness of the nozzle neck at the joint in nozzle neck to flange connections;

(f) the thickness of the weld at the point of attachment when a nonpressure part is welded to a pressure part;

(g) the thickness of the weld in tube-to-tubesheet connections.

The thickness of the head, shell, nozzle neck, or other parts as used above shall be the wall thickness of the part at the welded joint under consideration. For plate material, the thickness as shown on the Material Test Report or material Certificate of Compliance before forming may be used, at the Manufacturer's option, in lieu of measuring the wall thickness at the welded joint.

(6) For repairs, the nominal thickness is the depth of the repair weld.

UW-41 SECTIONING OF WELDED JOINTS

Welded joints may be examined by sectioning when agreed to by user and Manufacturer, but this examination shall not be considered a substitute for spot radiographic examination. This type of examination has no effect on the joint factors in Table UW-12. The method of closing the hole by welding is subject to acceptance by the Inspector. Some acceptable methods are given in Appendix K.

UW-42 SURFACE WELD METAL BUILDUP

Construction in which deposits of weld metal are applied to the surface of base metal for the purpose of:

(a) restoring the thickness of the base metal for strength consideration; or

(b) modifying the configuration of weld joints in order to provide the tapered transition requirements of UW-9(c) and UW-33(b) shall be performed in accordance with the following rules.

(1) A butt welding procedure qualification in accordance with provisions of Section IX must be performed for the thickness of weld metal deposited, prior to production welding.

(2) All weld metal buildup must be examined over the full surface of the deposit by either magnetic particle examination to the requirements of Appendix 6, or by liquid penetrant examination to the requirements of Appendix 8.

When such surface weld metal buildup is used in welded joints which require full or spot radiographic examination, the weld metal buildup shall be included in the examination.

INSPECTION AND TESTS

UW-46 GENERAL

The rules in the following paragraphs apply specifically to the inspection and testing of pressure vessels and vessel parts that are fabricated by welding and shall be used in conjunction with the general requirements for *Inspection and Tests* in Subsection A, and with the specific requirements for *Inspection and Tests* in Subsection C that pertain to the class of material used. [For tests on reinforcing plates, see UW-15(d).]

UW-47 CHECK OF WELDING PROCEDURE

The Inspector shall assure himself that the welding procedure employed in the construction of a vessel has been qualified under the provisions of Section IX. The Manufacturer shall submit evidence to the Inspector that the requirements have been met.

UW-48 CHECK OF WELDER AND WELDING OPERATOR QUALIFICATIONS

(a) The Manufacturer shall certify that the welding on a vessel has been done only by welders and welding operators who have been qualified under the requirements of Section IX and the Inspector shall assure himself that only qualified welders and welding operators have been used.

(b) The Manufacturer shall make available to the Inspector a certified copy of the record of the qualification tests of each welder and welding operator. The Inspector shall have the right at any time to call for and witness tests of the welding procedure or of the ability of any welder and welding operator.

UW-49 CHECK OF POSTWELD HEAT TREATMENT PRACTICE

The Inspector shall satisfy himself that all postweld heat treatment has been correctly performed and that the temperature readings conform to the requirements.

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UW-50 NONDESTRUCTIVE EXAMINATION OF WELDS ON PNEUMATICALLY TESTED VESSELS

On welded pressure vessels to be pneumatically tested in accordance with UG-100, the full length of the following welds shall be examined[7] for the purpose of detecting cracks:

(a) all welds around openings;

(b) all attachment welds, including welds attaching nonpressure parts to pressure parts, having a throat thickness greater than $\frac{1}{4}$ in. (6 mm).

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UW-51 RADIOGRAPHIC AND RADIOSCOPIC EXAMINATION OF WELDED JOINTS

(a) All welded joints to be radiographed shall be examined in accordance with Article 2 of Section V except as specified below.

(1) A complete set of radiographs and records, as described in T-291 and T-292 of Article 2 of Section V, for each vessel or vessel part shall be retained by the Manufacturer until the Manufacturer's Data Report has been signed by the Inspector.

(2) The Manufacturer shall certify that personnel performing and evaluating radiographic examinations required by this Division have been qualified and certified in accordance with their employer's written practice. SNT-TC-1A[11] 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),[11] or CP-189[11] 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 Appendix 10].

(3) A written radiographic examination procedure is not required. Demonstration of density and penetrameter image requirements on production or technique radiographs shall be considered satisfactory evidence of compliance with Article 2 of Section V.

(4) The requirements of T-285 of Article 2 of Section V are to be used only as a guide. Final acceptance of radiographs shall be based on the ability to see the prescribed penetrameter image and the specified hole or the designated wire of a wire penetrameter.

(b) Indications shown on the radiographs of welds and characterized as imperfections are unacceptable under the following conditions and shall be repaired as provided in UW-38, and the repair radiographed to UW-51 or, at the option of the Manufacturer, ultrasonically examined in accordance with the method described in Appendix 12 and the standards specified in this paragraph, provided the defect has been confirmed by the ultrasonic examination to the satisfaction of the Authorized Inspector prior to making the repair. For material thicknesses in excess of 1 in. (25 mm), the concurrence of the user shall be obtained. This ultrasonic examination shall be noted under remarks on the Manufacturer's Data Report Form:

(1) any indication characterized as a crack or zone of incomplete fusion or penetration;

(2) any other elongated indication on the radiograph which has 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 = the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t.

(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;

(4) rounded indications in excess of that specified by the acceptance standards given in Appendix 4.

(c) All welded joints to be examined by Real Time Radioscopic Examination shall be examined in accordance with Appendix II of Article 2 of Section V as specified below.

(1) A complete set of records, as described in II-292, shall be evaluated by the Manufacturer prior to being presented to the Inspector. Imperfections listed in UW-51(b)(1), (2), (3), and (4) are unacceptable and shall be repaired as provided in UW-38 and the repair reexamined by either film or Real Time Radioscopic Examination. Records shall be retained by the Manufacturer until the Data Report has been signed by the Inspector.

[11] Recommended Practice No. SNT-TC-1A, Personnel Qualification and Certification in Nondestructive Testing, ACCP, ASNT Central Certification Program, and CP-189 are published by the American Society for Nondestructive Testing, Inc., 1711 Arlingate Plaza, Caller #28518, Columbus, Ohio 43228-0518.

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(2) Provisions for training, experience, qualification, and certification of personnel responsible for equipment setup, calibration, operation, and evaluation of examination data shall be described in the Manufacturer's Quality Control System [see Appendix 10].

(3) The use of Real Time Radioscopic Examination shall be noted under remarks on the Manufacturer's Data Report.

UW-52 SPOT EXAMINATION OF WELDED JOINTS

NOTE: Spot radiographing of a welded joint is recognized as an effective inspection tool. The spot radiography rules are also considered to be an aid to quality control. Spot radiographs made directly after a welder or an operator has completed a unit of weld proves that the work is or is not being done in accordance with a satisfactory procedure. If the work is unsatisfactory, corrective steps can then be taken to improve the welding in the subsequent units, which unquestionably will improve the weld quality.

Spot radiography in accordance with these rules will not ensure a fabrication product of predetermined quality level throughout. It must be realized that an accepted vessel under these spot radiography rules may still contain defects which might be disclosed on further examination. If all radiographically disclosed weld defects must be eliminated from a vessel, then 100% radiography must be employed.

(a) Butt welded joints which are to be spot radiographed shall be examined locally as provided herein.

(b) Minimum Extent of Spot Radiographic Examination

(1) One spot shall be examined on each vessel for each 50 ft (15.2 m) increment of weld or fraction thereof for which a joint efficiency from column (b) of Table UW-12 is selected. However, for identical vessels, each with less than 50 ft (15.2 m) of weld for which a joint efficiency from column (b) of Table UW-12 is selected, 50 ft (15.2 m) increments of weld may be represented by one spot examination.

(2) For each increment of weld to be examined, a sufficient number of spot radiographs shall be taken to examine the welding of each welder or welding operator. Under conditions where two or more welders or welding operators make weld layers in a joint, or on the two sides of a double-welded butt joint, one spot may represent the work of all welders or welding operators.

(3) Each spot examination shall be made as soon as practicable after completion of the increment of weld to be examined. The location of the spot shall be chosen by the Inspector after completion of the increment of welding to be examined, except that when the Inspector has been notified in advance and cannot be present or otherwise make the selection, the fabricator may exercise his own judgment in selecting the spots.

(4) Radiographs required at specific locations to satisfy the rules of other paragraphs, such as UW-9(d), UW-11(a)(5)(b), and UW-14(b), shall not be used to satisfy the requirements for spot radiography.

(c) Standards for Spot Radiographic Examination. Spot examination by radiography shall be made in accordance with the technique prescribed in UW-51(a). The minimum length of spot radiograph shall be 6 in. Spot radiographs may be retained or be discarded by the Manufacturer after acceptance of the vessel by the Inspector. The acceptability of welds examined by spot radiography shall be judged by the following standards.

(1) Welds in which indications are characterized as cracks or zones of incomplete fusion or penetration shall be unacceptable.

(2) Welds in which indications are characterized as slag inclusions or cavities shall be unacceptable if the length of any such indication is greater than $\frac{2}{3}t$ where t is the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t. If several indications within the above limitations exist in line, the welds shall be judged acceptable if the sum of the longest dimensions of all such indications is not more than t in a length of $6t$ (or proportionately for radiographs shorter than $6t$) and if the longest indications considered are separated by at least $3L$ of acceptable weld metal where L is the length of the longest indication. The maximum length of acceptable indications shall be $\frac{3}{4}$ in. (19 mm). Any such indications shorter than $\frac{1}{4}$ in. (6 mm) shall be acceptable for any plate thickness.

(3) Rounded indications are not a factor in the acceptability of welds not required to be fully radiographed.

(d) Evaluation and Retests

(1) When a spot, radiographed as required in (b)(1) or (b)(2) above, is acceptable in accordance with (c)(1) and (c)(2) above, the entire weld increment represented by this radiograph is acceptable.

(2) When a spot, radiographed as required in (b)(1) or (b)(2) above, has been examined and the radiograph discloses welding which does not comply with the minimum quality requirements of (c)(1) or (c)(2) above, two additional spots shall be radiographically examined in the same weld increment at locations away from the original spot. The locations of these additional spots shall be determined by the Inspector

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or fabricator as provided for the original spot examination in (b)(3) above.

(a) If the two additional spots examined show welding which meets the minimum quality requirements of (c)(1) and (c)(2) above, the entire weld increment represented by the three radiographs is acceptable provided the defects disclosed by the first of the three radiographs are removed and the area repaired by welding. The weld repaired area shall be radiographically examined in accordance with the foregoing requirements of UW-52.

(b) If either of the two additional spots examined shows welding which does not comply with the minimum quality requirements of (c)(1) or (c)(2) above, the entire increment of weld represented shall be rejected. The entire rejected weld shall be removed and the joint shall be rewelded or, at the fabricator's option, the entire increment of weld represented shall be completely radiographed and only defects need be corrected.

(c) Repair welding shall be performed using a qualified procedure and in a manner acceptable to the Inspector. The rewelded joint, or the weld repaired areas, shall be spot radiographically examined at one location in accordance with the foregoing requirements of UW-52.

UW-53 TECHNIQUE FOR ULTRASONIC EXAMINATION OF WELDED JOINTS

Ultrasonic examination of welded joints when required or permitted by other paragraphs of this Division shall be performed in accordance with Appendix 12 and shall be evaluated to the acceptance standards specified in Appendix 12. The written examination procedure shall be available to the Inspector and shall be proven by actual demonstration to the satisfaction of the Inspector to be capable of detecting and locating imperfections described in this Division.

MARKING AND REPORTS

UW-60 GENERAL

The provisions for marking and reports, UG-115 through UG-120, shall apply without supplement to welded pressure vessels.

PRESSURE RELIEF DEVICES

UW-65 GENERAL

The provisions for pressure relief devices, UG-125 through UG-136, shall apply without supplement to welded pressure vessels.

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