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PART ULW
REQUIREMENTS FOR PRESSURE VESSELS FABRICATED BY LAYERED CONSTRUCTION

INTRODUCTION

The rules in Section VIII, Divisions 1 and 2 to cover the construction of layered vessels have been developed to parallel each other as far as can be done within the parameters of each Division. The design criteria may influence the selection of the Division. There are several manufacturing techniques used to fabricate layered vessels, and these rules have been developed to cover most techniques used today for which there is extensive documented construction and operational data. Some acceptable layered shell types are shown in Fig. ULW-2.1. Some acceptable layered head types are shown in Fig. ULW-2.2.

ULW-1 SCOPE

The rules in Part ULW are applicable to pressure vessels or parts thereof fabricated by layered construction as defined in 3-2 and ULW-2. These rules shall be used in conjunction with the requirements of Subsections A, B, and C, except for directly fired vessels described in UW-2(d) in Subsection B and except for Parts UCI and UCD in Subsection C, or except as otherwise required in this Part. The requirements for vessels that are to contain lethal substances, UW-2(a), apply only to the inner shell and the inner heads. Brazing of layered parts is not permitted except for the inner shell, inner head, and special solid wall fittings. The Manufacturer's Quality Control System as required by U-2(h) and Appendix 10 shall include the construction procedure that will outline the sequence and method of application of layers and measurement of layer gaps.

ULW-2 NOMENCLATURE

The following terms are used in Part ULW relative to layered vessels.

(a) Layered Vessel. A vessel having a shell and/or heads made up of two or more separate layers;

(b) Inner Shell. The inner cylinder which forms the pressure tight membrane;

(c) Inner Head. The inner head which forms the pressure tight membrane;

(d) Shell Layer. Layers may be cylinders formed from plate, sheet, or forging, or the equivalent formed by coiling, or by helically wound interlocking strips. (This does not include wire winding.)

(e) Head Layer. Any one of the head layers of a layered vessel except the inner head;

(f) Overwraps. Layers added to the basic shell or head thickness for the purpose of building up the thickness of a layered vessel for reinforcing shell or head openings, or making a transition to thicker sections of the layered vessel;

(g) Dummy Layer. A layer used as a filler between the inner shell (or inner head) and other layers, and not considered as part of the required total thickness.

MATERIAL

ULW-5 GENERAL

Material used for pressure parts shall conform to one of the specifications permitted in the applicable Parts of Subsections A, B, and C, except for 5%, 8%, and 9% nickel steel materials which are permitted only for inner shells and inner heads. For helically wound interlocking strip vessels where the mechanical properties of the material are enhanced by heat treatment during the fabrication process, the test specimens shall be taken from prolongations of the strip material after winding and after heat treatment. See Appendix 29.

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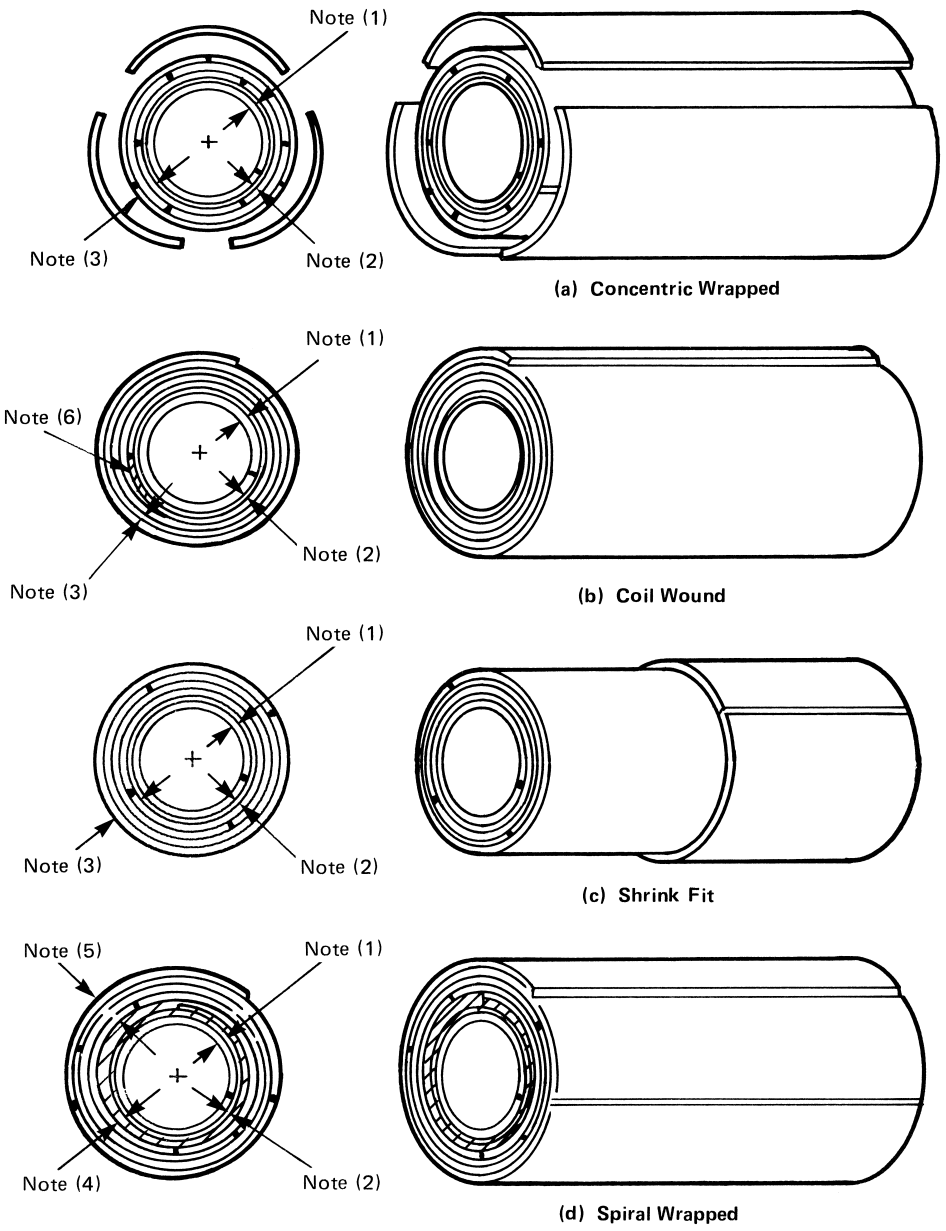
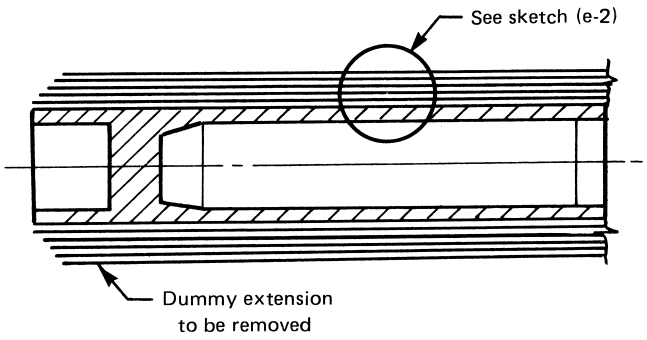


FIG. ULW-2.1 SOME ACCEPTABLE LAYERED SHELL TYPES

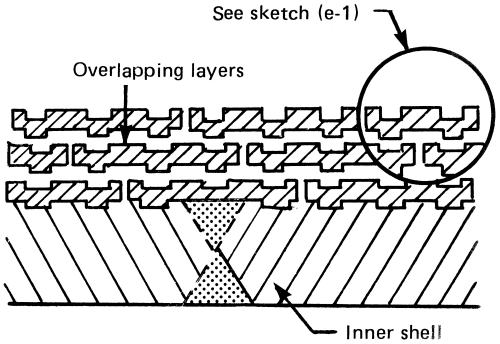
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(e) Helically Wound Interlocking Strip



(e-1) Detail of Individual Strip



(e-2)

NOTES:
(1) Inner shell
(2) Dummy layer (if used)
(3) Layers
(4) Shell layer (tapered)
(5) Balance of layers
(6) Gap

FIG. ULW-2.1 SOME ACCEPTABLE LAYERED SHELL TYPES (CONT'D)

DESIGN

ULW-16 GENERAL

(a) The design of layered pressure vessels shall conform to the design requirements given in UG-16 through UG-46 except that:

(1) reinforcement of openings is required as illustrated in Fig. ULW-18.1;

(2) in calculating the requirements for vacuum per UG-28, only the inner shell or inner head thickness shall be used;

(3) layered shells under axial compression shall be calculated using UG-23, and utilizing the total shell thickness.

(b) The inner shell or inner head material which has a lower allowable design stress than the layer materials may only be included as credit for part of the total wall thickness if S_1 is not less than $0.50S_L$ by considering its effective thickness to be

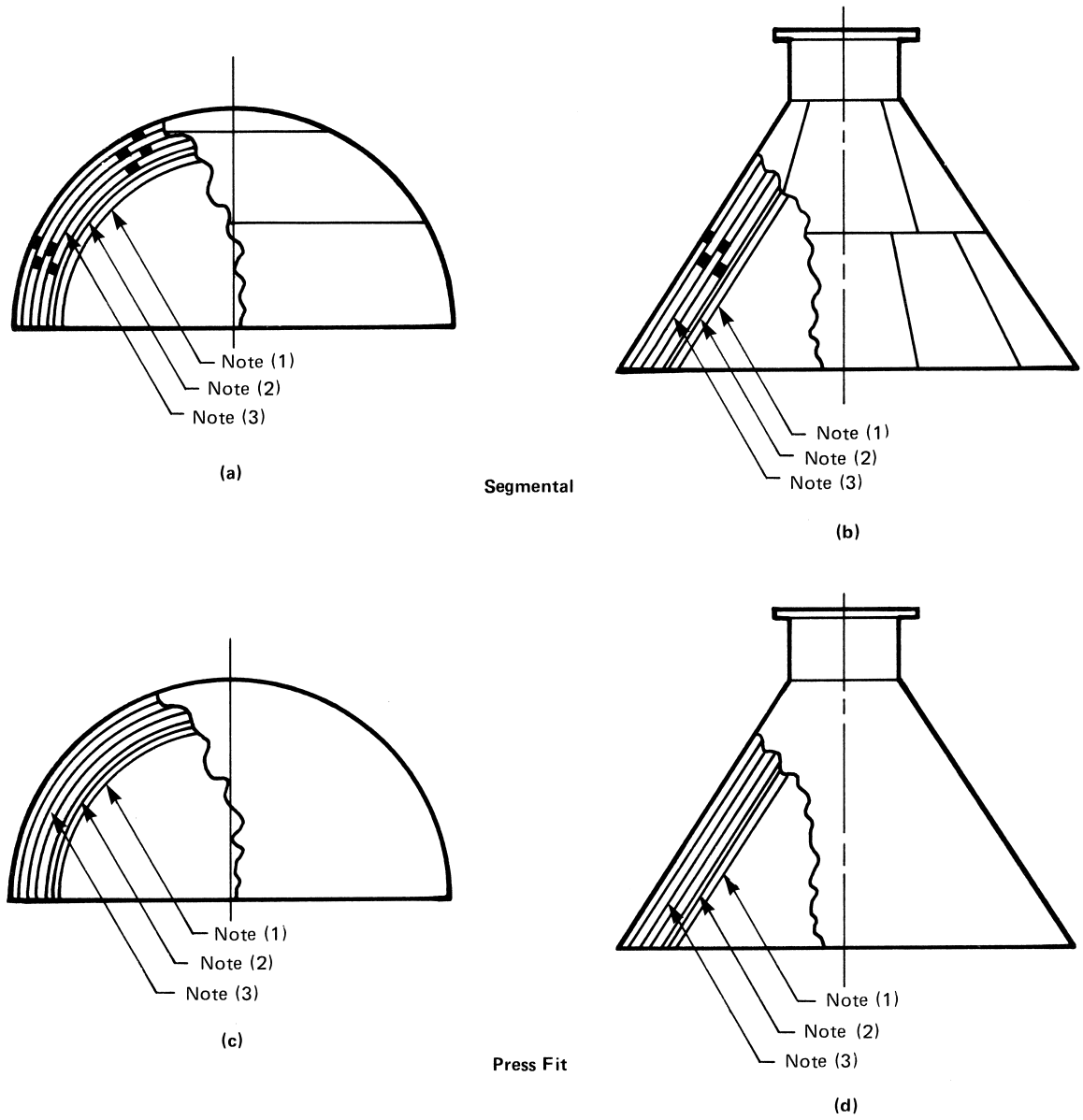
$$t_{\text{eff}} = t_{\text{act}} \frac{S_1}{S_L}$$

where

t_{eff} = effective thickness of inner shell or inner head, in. (mm)

t_{act} = nominal thickness of inner shell or inner head, in. (mm)

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NOTES:
(1) Inner head
(2) Dummy layer (if used)
(3) Head layers

FIG. ULW-2.2 SOME ACCEPTABLE LAYERED HEAD TYPES

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S_1 = design stress of inner shell or inner head, psi (kPa)

S_L = design stress of layers, psi (kPa)

(c) Layers in which the maximum allowable stress value of the materials is within 20% of the other layers may be used by prorating the maximum allowable stress of the layers in the thickness formula, provided the materials are compatible in modulus of elasticity and coefficient of thermal expansion.

(d) The minimum thickness of any layer shall not be less than $\frac{1}{8}$ in. (3.2 mm).

(e) Torispherical layered heads are not permitted.

ULW-17 DESIGN OF WELDED JOINTS

(a) Category A and B joints of inner shells and inner heads of layered sections shall be as follows.

(1) Category A joints shall be Type No. (1) of Table UW-12.

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

(b) Category A joints of layered sections shall be as follows.

(1) Category A joints of layers over $\frac{7}{8}$ in. (3.2 mm). in thickness shall be Type No. (1) of Table UW-12.

(2) Category A joints of layers $\frac{7}{8}$ in. (22 mm) or less in thickness shall be of Type No. (1) or (2) of Table UW-12, except the final outside weld joint of spiral wrapped layered shells may be a single lap weld.

(3) Welds joining the ends of helically wound interlocking strips shall be of Type No. (1) of Table UW-12 and shall comply with the requirements of ULW-52(e).

(c) Category B joints of layered shell sections to layered shell sections, or layered shell sections to solid shell sections, shall be of Type (1) or (2) of Table UW-12.

(1) Category B joints of layered sections to layered sections of unequal thickness shall have transitions as shown in Fig. ULW-17.1 sketch (a) or (b).

(2) Category B joints of layered sections to solid sections of unequal thickness shall have transitions as shown in Fig. ULW-17.1 sketch (c), (d), (e), or (f).

(3) Category B joints of layered sections to layered sections of equal thickness shall be as shown in Fig. ULW-17.6 sketch (b), (c), (f), or (g).

(4) Category B joints of layered sections to solid sections of equal thickness shall be as shown in Fig. ULW-17.6 sketch (a) or (e).

(d) Category A joints of solid hemispherical heads to layered shell sections shall be of Type (1) or (2) of Table UW-12.

(1) Transitions shall be as shown in Fig. ULW-17.2 sketch (a), (b-1), (b-2), or (b-3) when the hemispherical head thickness is less than the thickness of the layered shell section and the transition is made in the layered shell section.

(2) Transitions shall be as shown in Fig. ULW-17.2 sketches (c), (d-1), or (e) when the hemispherical head thickness is greater than the thickness of the layered shell section and transition is made in the layered shell section.

(3) Transition shall be as shown in Fig. ULW-17.2 sketch (f) when the hemispherical head thickness is less than the thickness of the layered shell section and the transition is made in the hemispherical head section.

(e) Category B joints of solid elliptical, torispherical, or conical heads to layered shell sections shall be of Type (1) or (2) of Table UW-12. Transitions shall be as shown in Fig. ULW-17.2 sketch (c), (d-1), (d-2), (e), or (f).

(f) Category C joints of solid flat heads and tubesheets to layered shell sections shall be of Type (1) or (2) of Table UW-12 as indicated in Fig. ULW-17.3. Transitions, if applicable, shall be used as shown in Fig. ULW-17.1 sketch (c), (d), (e), or (f).

(g) Category C joints attaching solid flanges to layered shell sections and layered flanges to layered shell sections shall be of Type (1) or (2) of Table UW-12 as indicated in Fig. ULW-17.4.

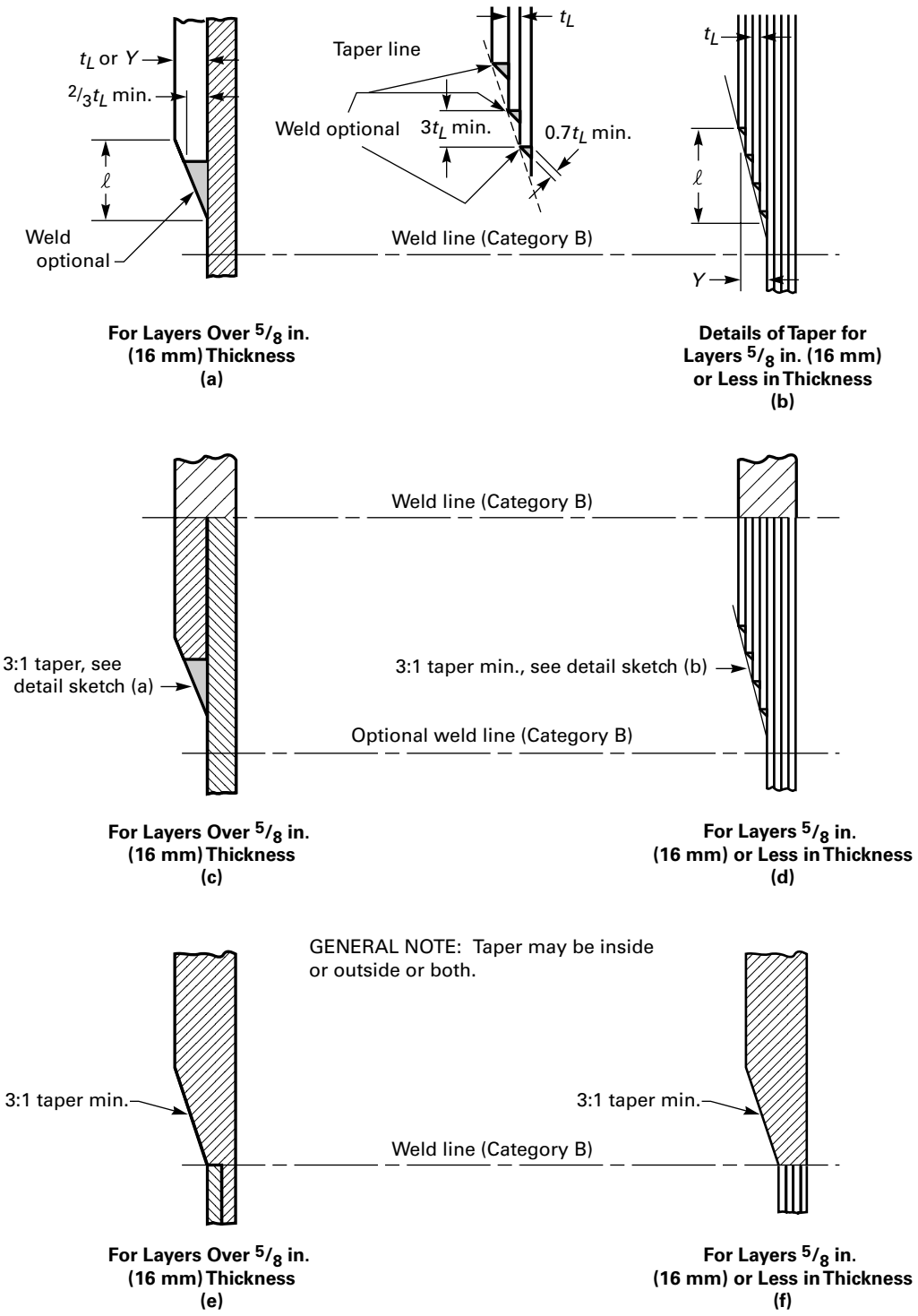
(h) Category A joints of layered hemispherical heads to layered shell sections shall be of Type (1) or (2) of Table UW-12 with a transition as shown in Fig. ULW-17.5 sketch (a-1) or (a-2).

(i) Category B joints of layered conical heads to layered shell sections shall be of Type (1) or (2) of Table UW-12 with transitions as shown in Fig. ULW-17.5 sketch (b-1).

(j) Category B joints of layered shells to layered shell sections or layered shell sections to solid heads or shells may be butt joints as shown in Fig. ULW-17.6 sketches (c), (d), and (e), or step welds as shown in Fig. ULW-17.6 sketches (a), (b), (f), and (g).

(k) Category D joints of solid nozzles, manholes, and other connections to layered shell or layered head sections shall be full penetration welds as shown in Fig. ULW-18.1 except as permitted in sketch (i), (j), (k), or (l). Category D joints between layered nozzles and shells or heads are not permitted.

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GENERAL NOTE: $\ell \geq 3Y$, where ℓ is required length of taper and Y is the offset. t_L is the thickness of one layer. The length of required taper may include the width of the weld. The transition may be on either or both sides.

01 FIG. ULW-17.1 TRANSITIONS OF LAYERED SHELL SECTIONS

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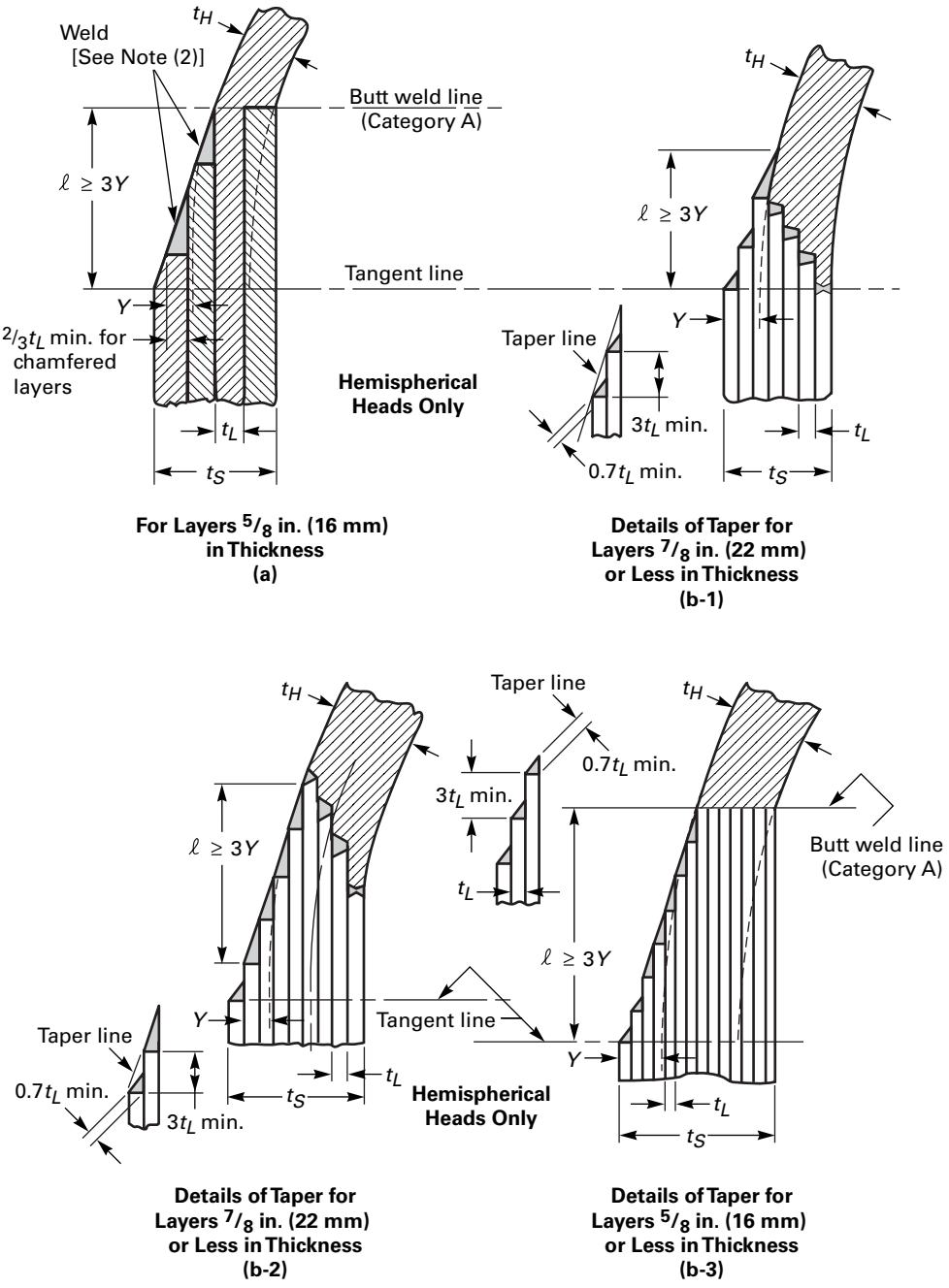
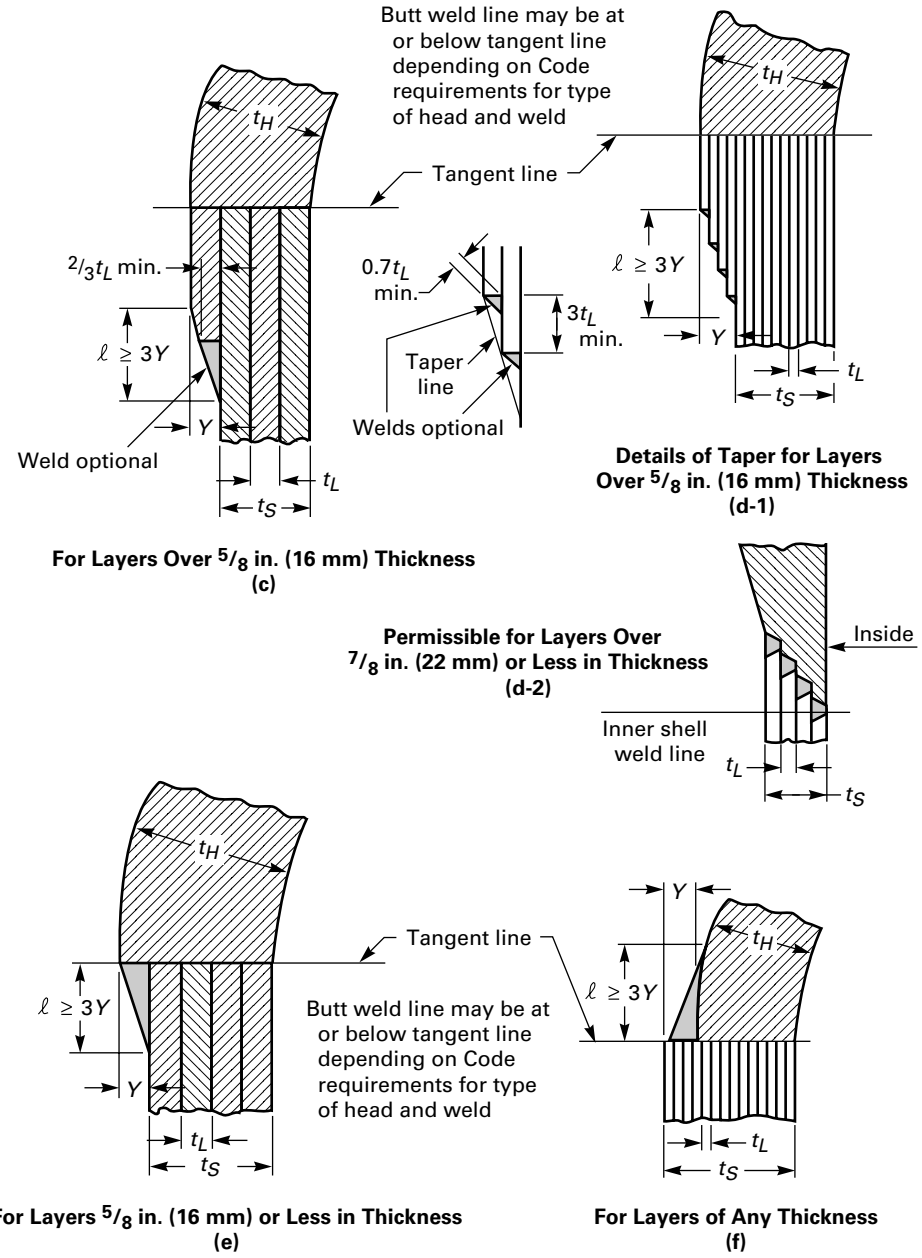


FIG. ULW-17.2 SOME ACCEPTABLE SOLID HEAD ATTACHMENTS TO LAYERED SHELL SECTIONS **01**

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For Layers Over $5/8$ in. (16 mm) Thickness (c)

Details of Taper for Layers Over $5/8$ in. (16 mm) Thickness (d-1)

Permissible for Layers Over $7/8$ in. (22 mm) or Less in Thickness (d-2)

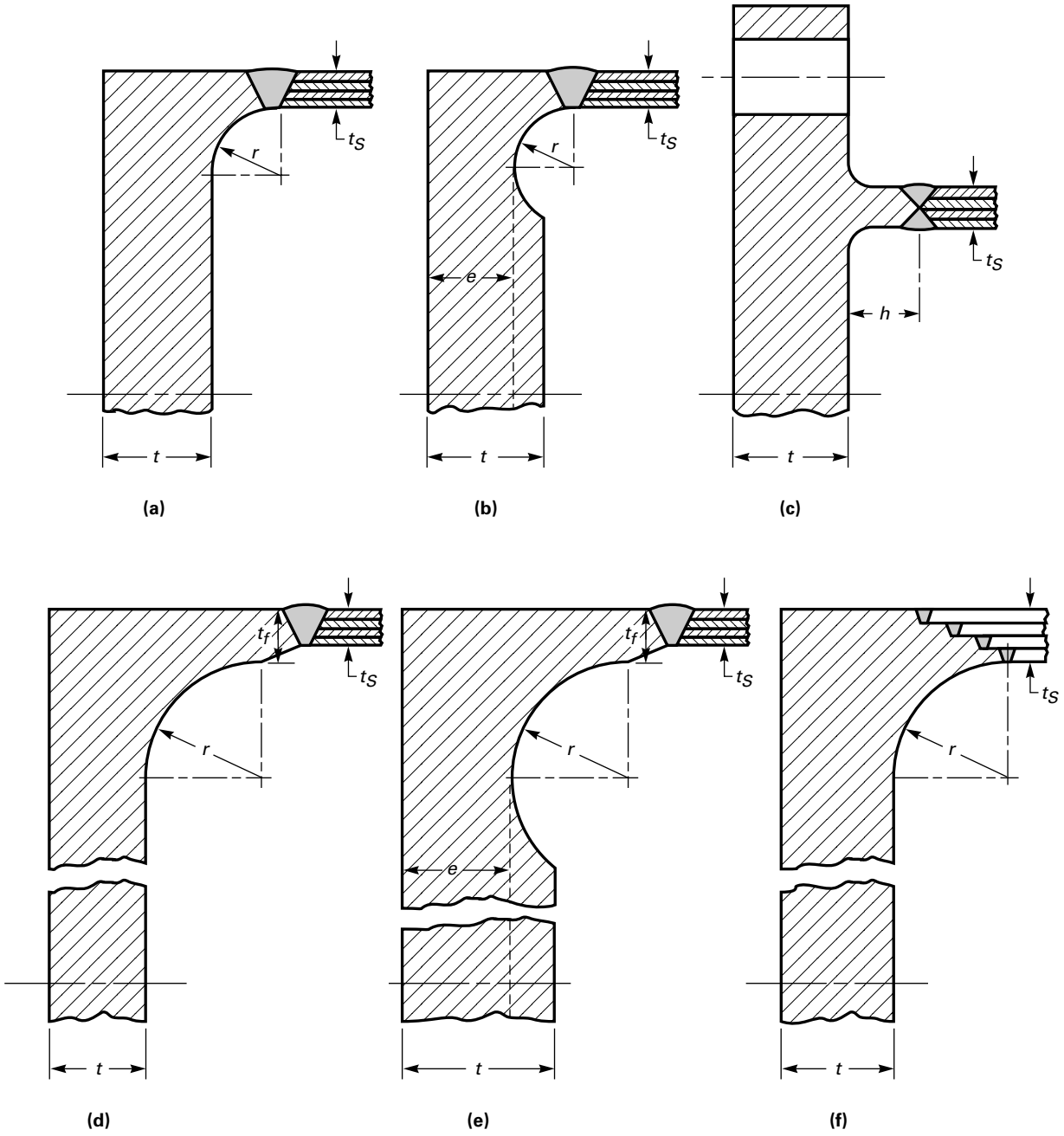
For Layers $5/8$ in. (16 mm) or Less in Thickness (e)

For Layers of Any Thickness (f)

NOTES:
(1) t_H = thickness of head at joint, in. (mm)
t_L = thicknes of one layer, in. (mm)
t_S = thickness of layered shell, in. (mm)
Y = offset, in. (mm)
(2) Actual thickness shall not be less than theoretical head thickness.
(3) In sketch (e), Y shall not be larger than t_L. In sketch (f), Y shall not be larger than $1/2 t_S$. In all cases ℓ shall not be less than 3 times Y. The shell center line may be on either side of the head center line by a maximum of $1/2(t_S - t_H)$. The length of required taper may include the width of the weld.

01 FIG. ULW-17.2 SOME ACCEPTABLE SOLID HEAD ATTACHMENTS TO LAYERED SHELL SECTIONS (CONT'D)

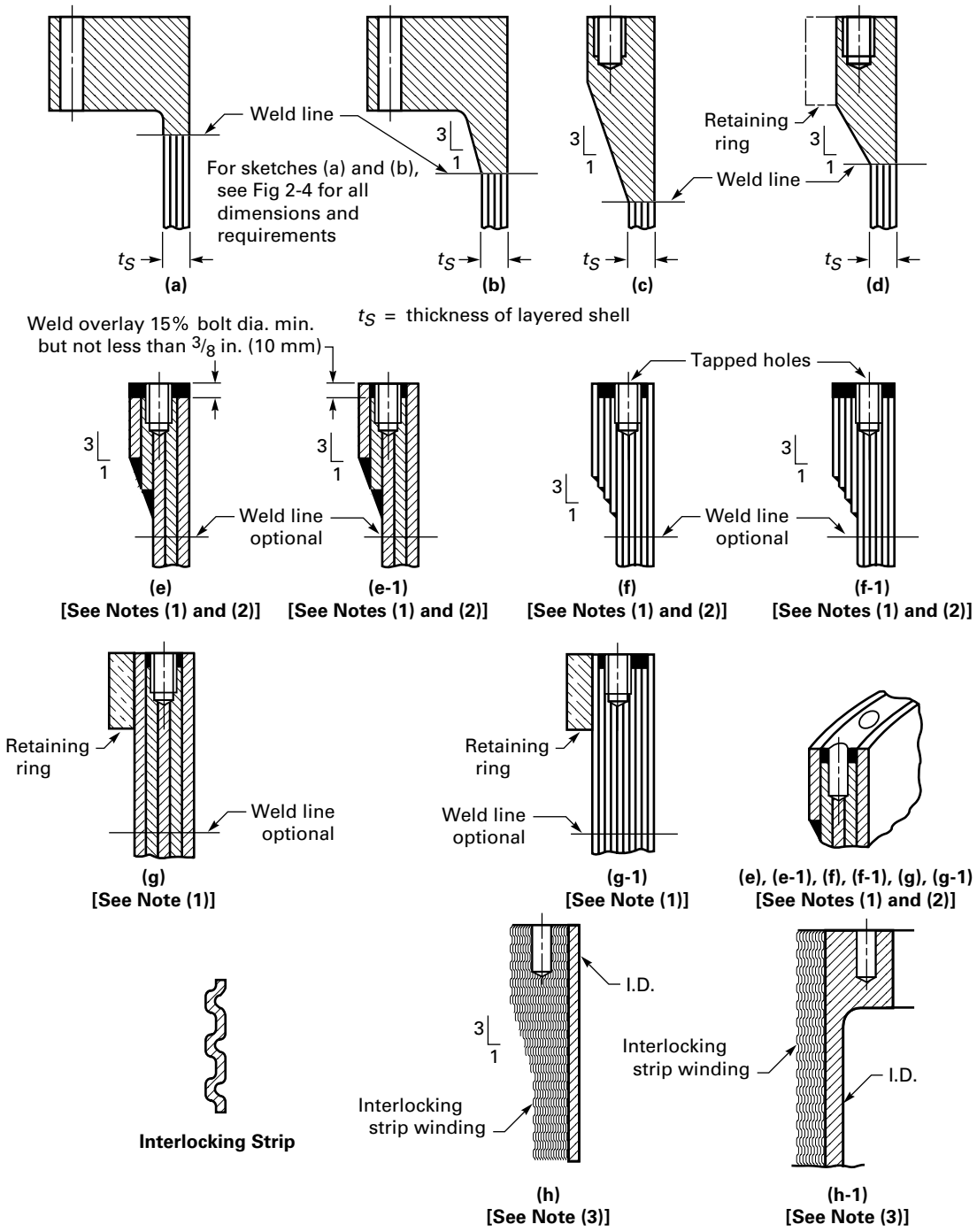
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NOTE:
t_s = thickness of layered shell [see ULW-17 (f)], in. (mm)
t = thickness of flat head or tubesheet [see UG-34], in. (mm)
For all other dimensions, see Fig. UW-13.3.

FIG. ULW-17.3 SOME ACCEPTABLE FLAT HEADS AND TUBESHEETS WITH HUBS JOINING LAYERED SHELL SECTIONS

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NOTES

(1) The following limitations apply to sketches (e), (e-1), (f), (f-1), (g), (g-1):
(a) the weld overlay shall tie the overlay, the overwraps, and layers together; and
(b) the bolt circle shall not exceed the outside diameter of the shell.

(2) For sketches (e), (e-1), (f), and (f-1), the angle of transition and size of fillet welds are optional. The bolt circle diameter shall be less than the outside diameter of the layered shell.

(3) For sketches (h) and (h-1), the bolt circle shall not exceed the outside diameter of the shell.

01 FIG. ULW-17.4 SOME ACCEPTABLE FLANGES FOR LAYERED SHELLS

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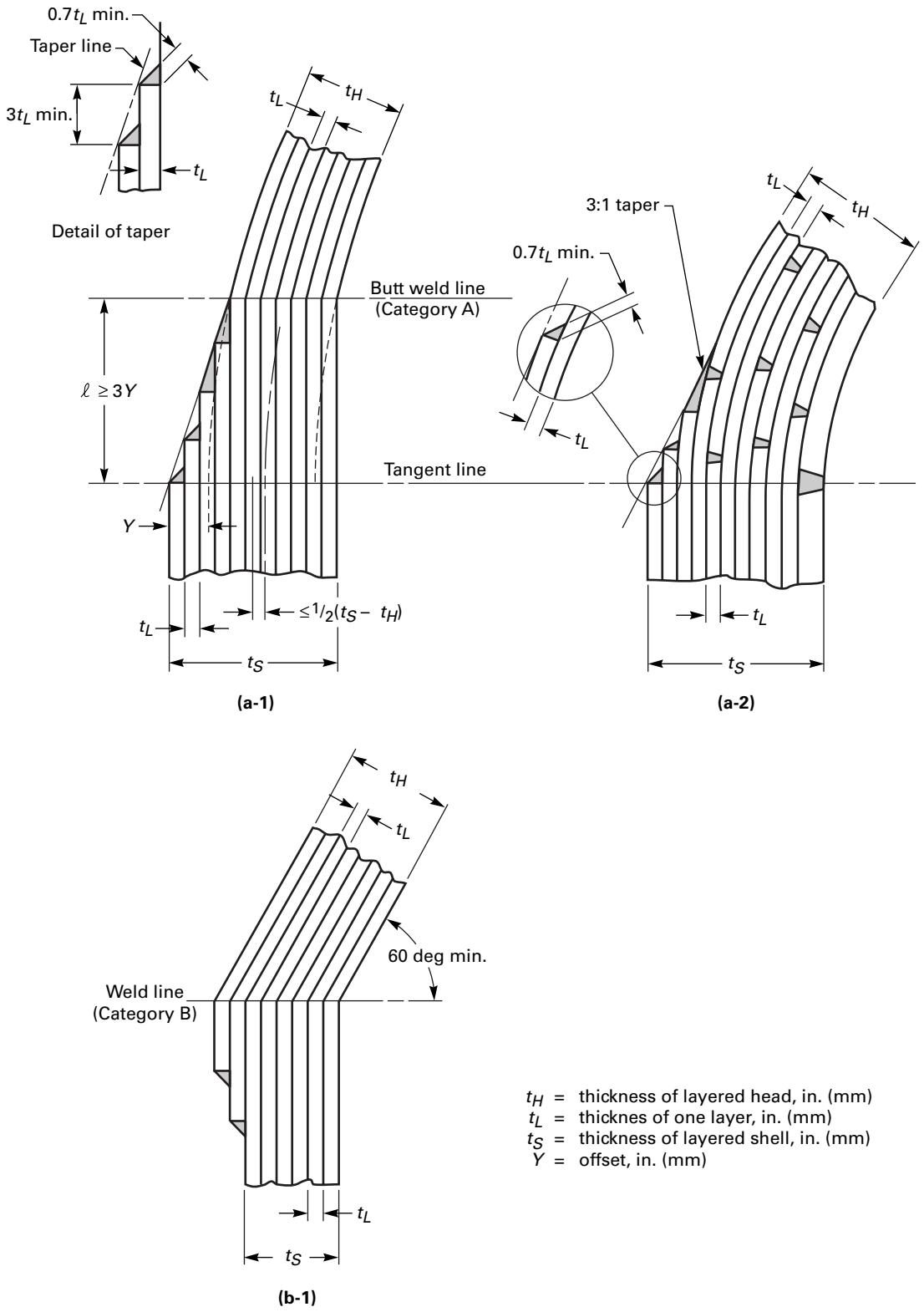


FIG. ULW-17.5 SOME ACCEPTABLE LAYERED HEAD ATTACHMENTS TO LAYERED SHELLS

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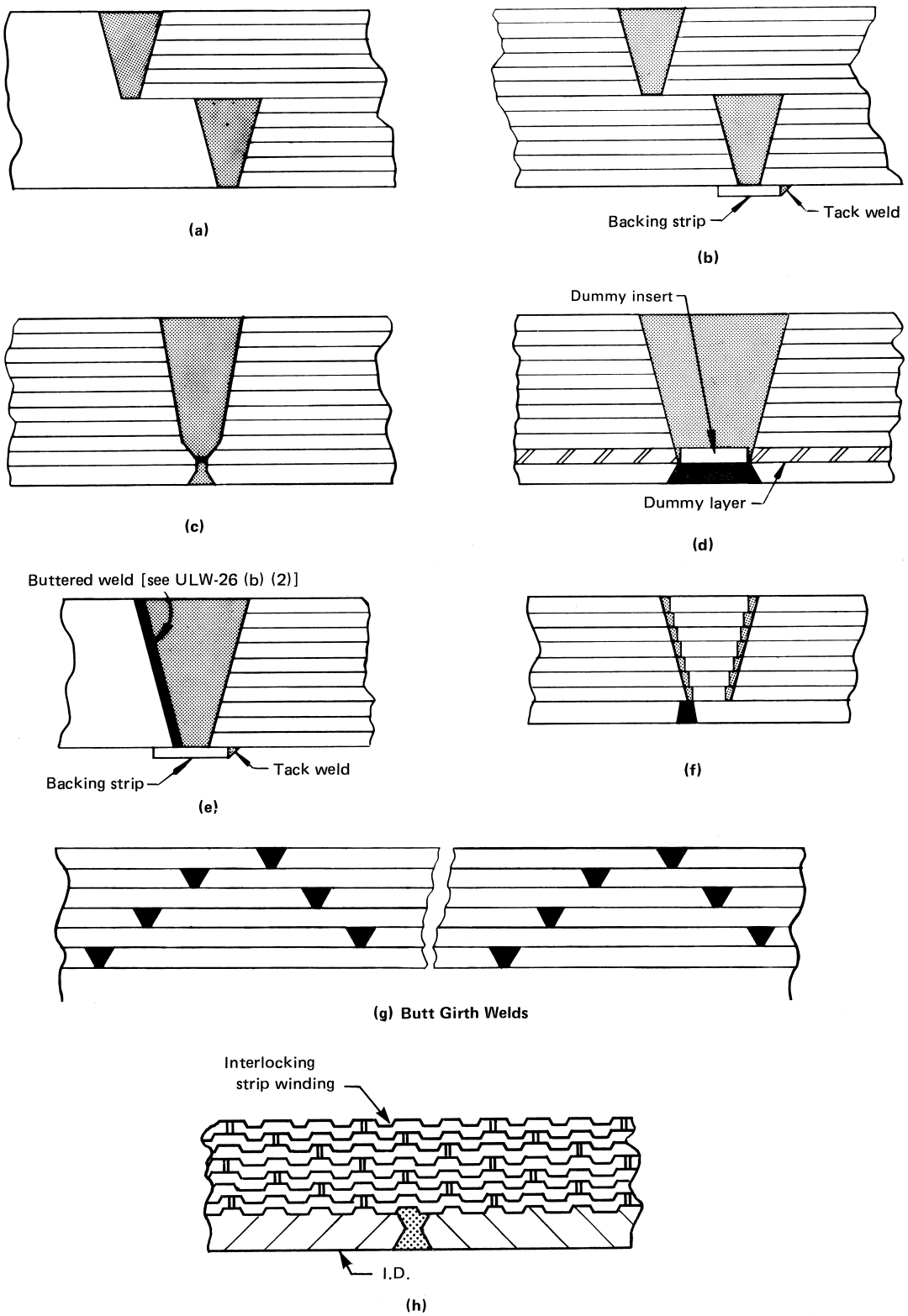


FIG. ULW-17.6 SOME ACCEPTABLE WELDED JOINTS OF LAYERED-TO-LAYERED AND LAYERED-TO-SOLID SECTIONS

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(l) When layers of Category A joints as shown in Fig. ULW-17.2 sketches (a), (b-1), (b-2), and (b-3) and Fig. ULW-17.5 sketches (a-1) and (a-2) are welded with fillet welds having a taper less than 3:1, the longitudinal load resisted by the weld shall not exceed the allowable load as defined in UW-18(d). No resistance due to friction shall be used in determining the longitudinal load at the welds. The longitudinal load resisted by the weld shall consider the load transferred from the remaining outer layers.

ULW-18 NOZZLE ATTACHMENTS AND OPENING REINFORCEMENT

(a) All openings, except as provided in (b) below, shall meet the requirements for reinforcing per UG-36 through UG-46. All reinforcements required for openings shall be integral with the nozzle or provided in the layered section or both. Additional layers may be included for required reinforcement. Some acceptable nozzle geometries and attachments are shown in Fig. ULW-18.1. Openings are not permitted in the shell sections of helically wound interlocking strip construction.

(b) Openings, NPS 2 (DN 50) and smaller, need not be reinforced when installed in layered construction, but shall be welded on the inside as shown in Fig. ULW-18.1 sketch (j). The nozzle nominal wall thickness shall not be less than Schedule 80 pipe as fabricated, in addition to meeting the requirements of UG-45.

(c) Openings up to and including 6 in. (152 mm) nominal pipe size may be constructed as shown in Fig. ULW-18.1 sketches (k) and (l). Such partial penetration weld attachments may only be used for instrumentation openings, inspection openings, etc., on which there are no external mechanical loadings provided the following requirements are met.

(1) The requirements for reinforcing specified in (a) above apply except that the diameter of the finished openings in the wall shall be d' as specified in Fig. ULW-18.1 sketches (k) and (l), and the thickness t_r is the required thickness of the layered shells computed by the design requirements.

(2) Additional reinforcement, attached to the inside surface of the inner shell, may be included after the corrosion allowance is deducted from all exposed surfaces. The attachment welds shall comply with UW-15, UW-16, and Fig. ULW-18.1 sketch (k) or (l).

(3) Metal in the nozzle neck available for reinforcement shall be limited by the boundaries specified in UG-40(c), except that the inner layer shall be considered the shell.

(d) Openings greater than NPS 2 may be constructed as shown in Fig. ULW-18.1 sketch (i). The requirements for reinforcing specified in (a) above apply except that:

(1) the diameter of the finished openings in the wall shall be d' as specified in Fig. ULW-18.1 sketch (i); and the thickness t_r is the required thickness of the layered shells computed by the design requirements;

(2) additional reinforcement may be included in the solid hub section as shown in Fig. ULW-18.1 sketch (i);

(3) metal in the nozzle neck available for reinforcement shall be limited by the boundaries specified in UG-40(c), except that the inner layer shall be considered the shell.

(e) The bolt circle in a layered flange shall not exceed the outside diameter of the shell. Weld overlay as shown in Fig. ULW-17.4 sketches (e), (e-1), (f), (f-1), (g), and (g-1) shall be provided to tie the overwraps and layers together.

ULW-20 WELDED JOINT EFFICIENCY

When the nondestructive examinations outlined in ULW-50 through ULW-57 have been complied with, the weld joint efficiency for design purposes shall be 100%.

ULW-22 ATTACHMENTS

Attachments to a single layer of a layered vessel shall be given consideration in meeting the requirements of UG-22. Outside layers are especially critical when support lugs, skirts, or jacket closures are welded to them. Only the thickness of the layer to which the attachment is welded shall be considered in calculating the stress near the attachment, except where provisions are made to transfer the load to other layers. For some acceptable supports, see Fig. ULW-22. Jacketed closures shall be designed in accordance with Appendix 9 except that:

(1) partial jackets as shown in Fig. 9-7 are not permitted on layered sections;

(2) provisions shall be made for extending layer vents through the jacket (see ULW-76).

ULW-26 POSTWELD HEAT TREATMENT

(a) When required, pressure parts shall be postweld heat treated in accordance with the rules prescribed in UCS-56, UG-85, UW-10, UW-40, and UHT-56; however, layered vessels or layered vessel sections need

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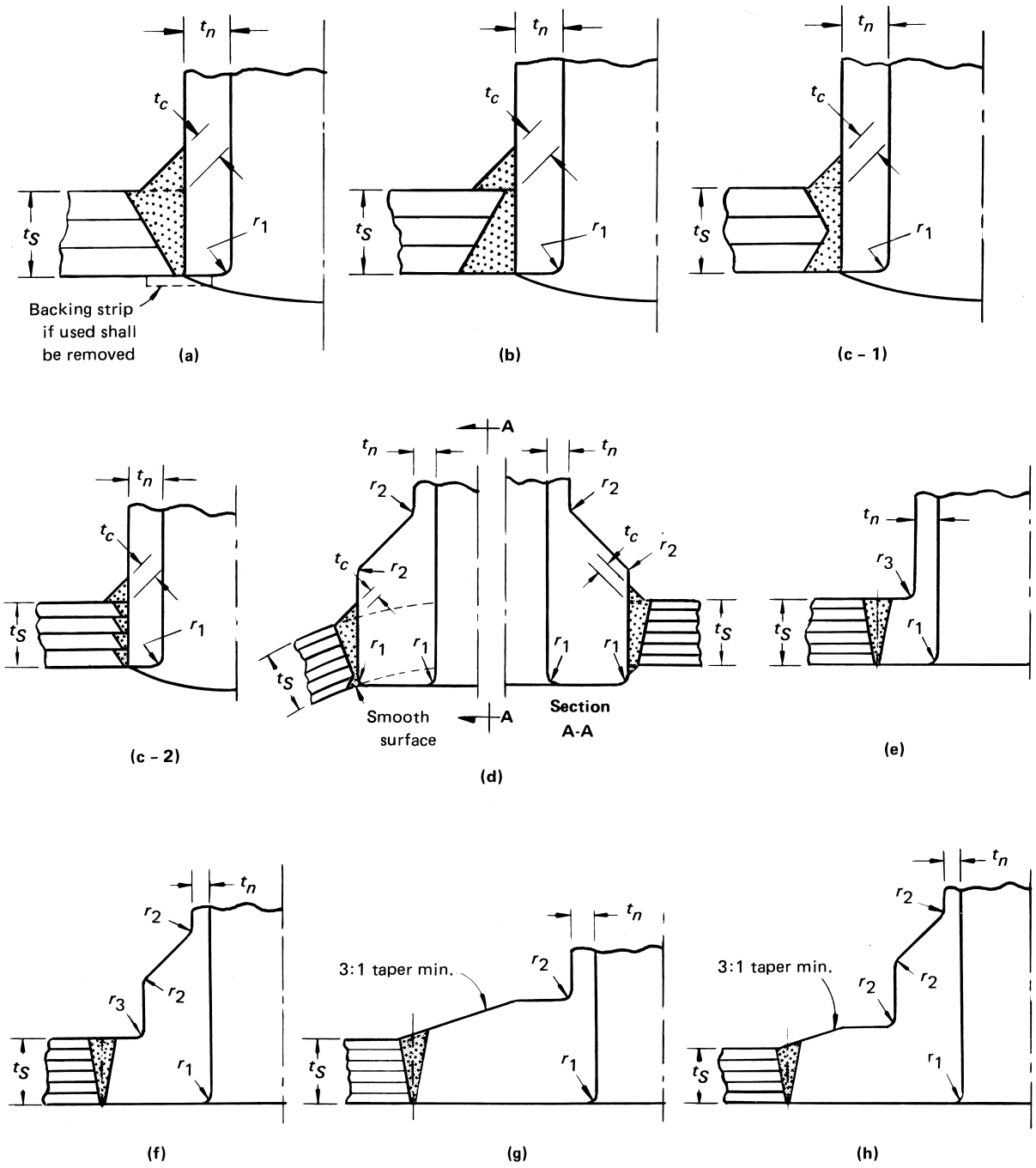
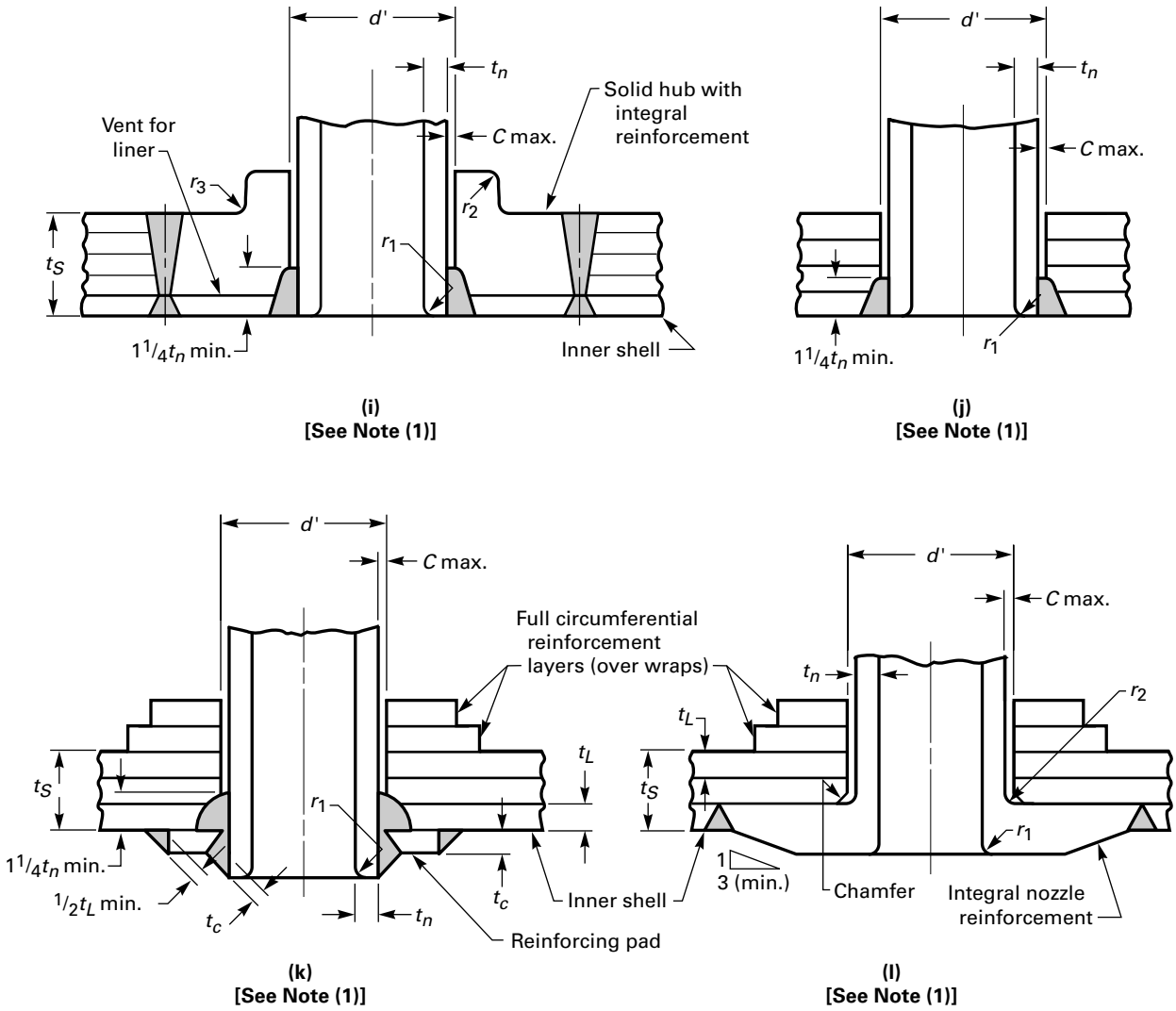


FIG. ULW-18.1 SOME ACCEPTABLE NOZZLE ATTACHMENTS IN LAYERED SHELL SECTIONS

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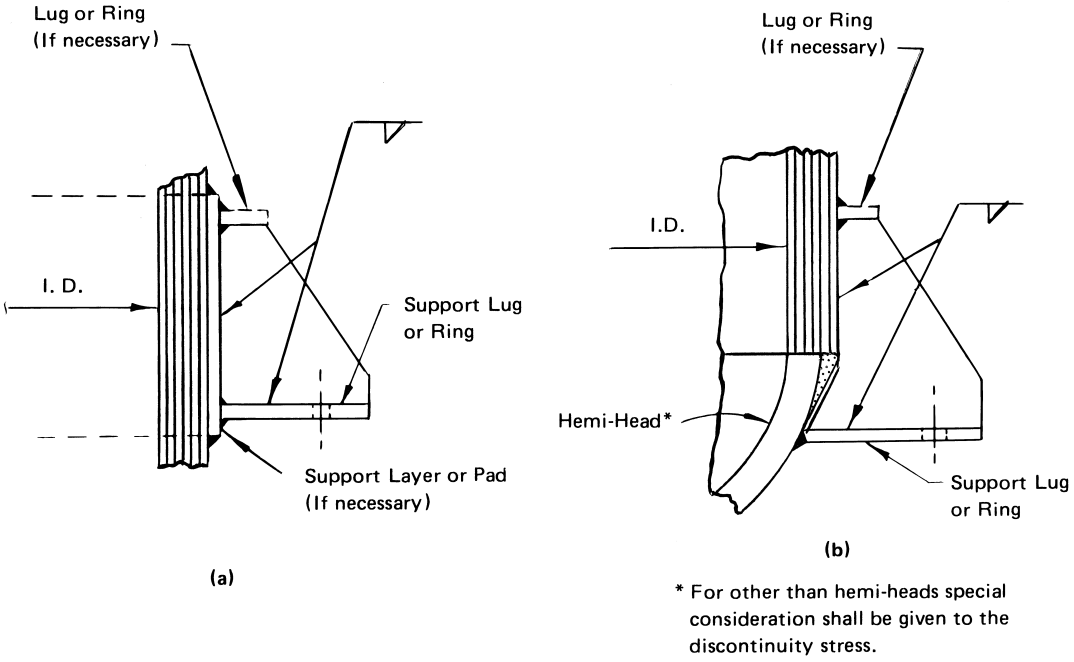


C max. = $\frac{1}{8}$ in (3.2 mm) radial clearance between nozzle neck and vessel opening
d' = finished opening in the wall (refer fo ULW-18 for max. permissible diameter)
r_1 min. = $\frac{1}{4}$ t_n or $\frac{3}{4}$ in. (19 mm) whichever is less
r_2 = $\frac{1}{4}$ in. (6 mm) minimum
r_3 min. = r_1 minimum
t_c = not less than $\frac{1}{4}$ in. (6 mm) or 0.7 of the smaller of $\frac{3}{4}$ in. (19 mm) or t_n
t_L = thickness of one layer, in. (mm)
t min. = the smaller of $\frac{3}{4}$ in. (19 mm) or t_n
t_n = nominal thickness of nozzle wall, in. (mm)
t_S = thickness of layered shell, in. (mm)

NOTE:
(1) Provide means, other than by seal welding, to prevent entry of external foreign matter into the annulus between the layers and the nozzle neck O.D. for sketches (i), (j), (k), (l).

FIG. ULW-18.1 SOME ACCEPTABLE NOZZLE ATTACHMENTS IN LAYERED SHELL SECTIONS (CONT'D) **01**

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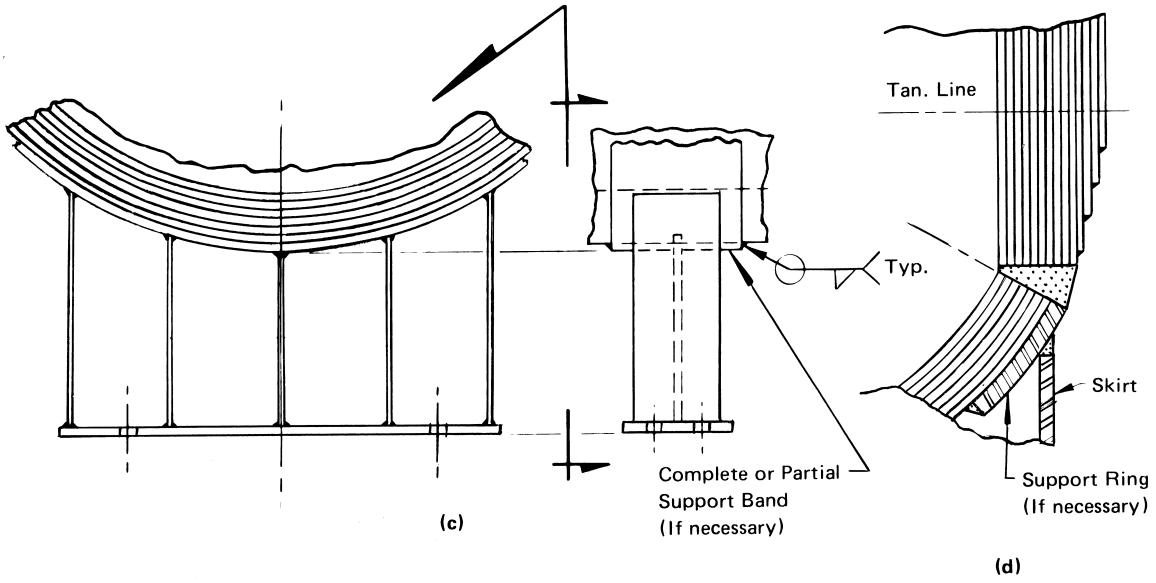


FIG. ULW-22 SOME ACCEPTABLE SUPPORTS FOR LAYERED VESSELS

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not be postweld heat treated provided the requirements of (b) below are met.

(b) Unless required by UW-2, layered vessels or layered vessel sections need not be postweld heat treated when welded joints connect a layered section to a layered section, or a layered section to a solid wall, provided all of the following conditions are met.

(1) The thickness referred to in UCS-56 and UHT-56 is the thickness of one layer. Should more than one thickness of layer be used, the thickness of the thickest layer shall govern.

(2) The finished joint preparation of a solid section which is required to be postweld heat treated under the provisions of UCS-56 or UHT-56, shall be provided with a buttered[1] layer of at least $\frac{1}{8}$ in. (3.2 mm) thick welding material not requiring postweld heat treatment. Solid sections of P-No. 1 materials need not have this buttered layer. Postweld heat treatment of the buttered solid section shall then be performed prior to attaching to the layered sections. Postweld heat treatment following attachment to the layered section is not required unless the layered section is required to be postweld heat treated.

(3) Multipass welding is used and the weld layer thickness is limited to $\frac{3}{8}$ in. (10 mm) maximum. When materials listed in Part UHT are used, the last pass shall be given a temper bead welding technique[2] treatment except for 5%, 8%, and 9% nickel steels.

(4) For lethal service [UW-2(a)], see ULW-1 Scope.

WELDING

ULW-31 WELDED JOINTS

The design of welded joints of layered vessels shall be in accordance with ULW-17. Welded joints of Table UW-12, Type Nos. (3), (4), (5), and (6) are not permitted in layered vessels, except as provided for in ULW-17(b)(2).

ULW-32 WELDING PROCEDURE QUALIFICATION

Welding procedure qualifications shall be in accordance with Section IX except as modified herein.

(a) The minimum and maximum thicknesses qualified by procedure qualification test plates shall be as shown in Table QW-451 of Section IX except that:

(1) for the longitudinal joints of the layer section of the shell, the qualification shall be based upon the thickness of the thickest individual layer, exclusive of the inner shell or inner head;

(2) for circumferential joint procedure qualification, the thickness of the layered test plate need not exceed 3 in. (76 mm), shall consist of at least 2 layers, but shall not be less than 2 in. (51 mm) in thickness;

(3) for circumferential weld joints made individually for single layers and spaced at least one layer thickness apart, the procedure qualification for the longitudinal joint applies.

(b) The longitudinal weld joint of the inner shell or inner head and the longitudinal weld joint of layer shell or layer head shall be qualified separately except if of the same P-Number material. The weld gap of the longitudinal layer weld joint shall be the minimum width used in the procedure qualification for layers $\frac{7}{8}$ in. (22 mm) and less in thickness.

(c) The circumferential weld joint of the layered to layered sections shall be qualified with a simulated layer test plate as shown in Fig. ULW-32.1 for layer thicknesses $\frac{7}{8}$ in. (22 mm) and under. A special type of joint tensile specimen shall be made from the layer test coupon as shown in Fig. ULW-32.2. (See also Fig. ULW-32.4.) Face and root bend specimens shall be made of both the inner and outer weld to the thickness of the layer by cutting the weld to the layer thickness.

(d) The circumferential weld joint of the layer shell for layer thicknesses $\frac{7}{8}$ in. (22 mm) and under to the solid head, flange, or end closure shall be qualified with a simulated layer test coupon as shown in Fig. ULW-32.1 wherein the one side of the test coupon is solid throughout its entire thickness. A special type of joint tensile specimen shall be made from the test coupon as shown in Fig. ULW-32.3. (See also Fig. ULW-32.4.) Face and root bend specimens shall be made of both the inner and outer weld to the thickness of the layer by slicing the weld and solid portion to the layer thickness.

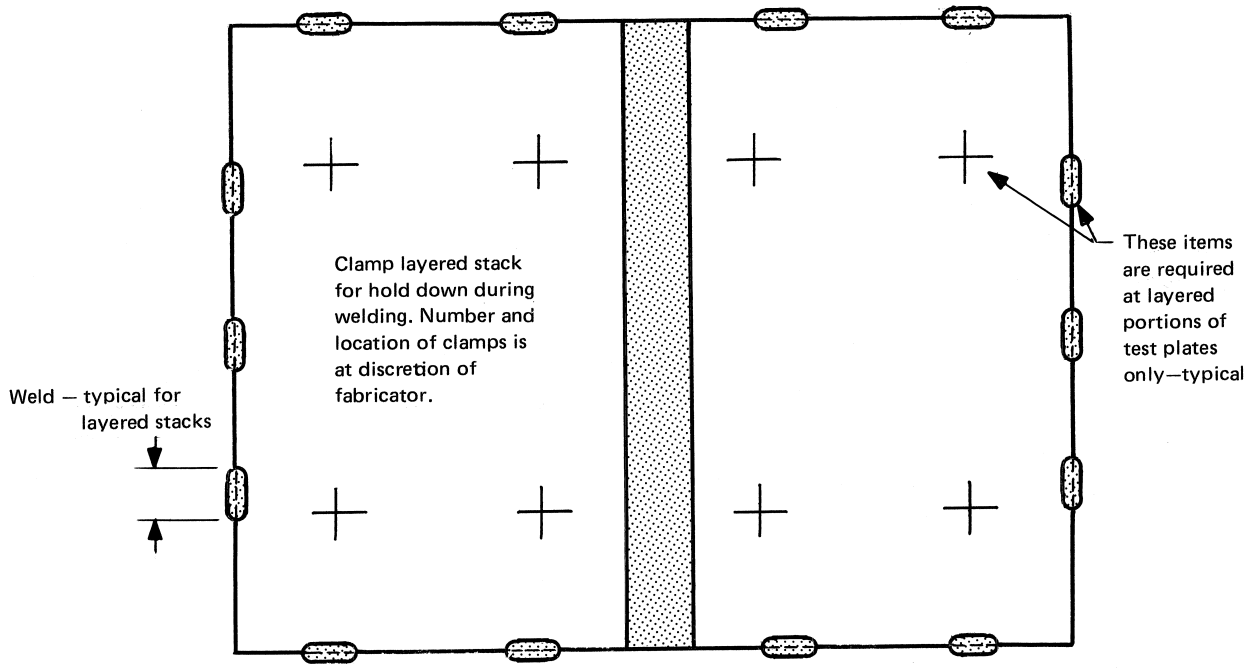
ULW-33 PERFORMANCE QUALIFICATION

Welding shall be performed only by welders and welding operators who have been qualified as given in Section IX. The minimum and maximum thicknesses

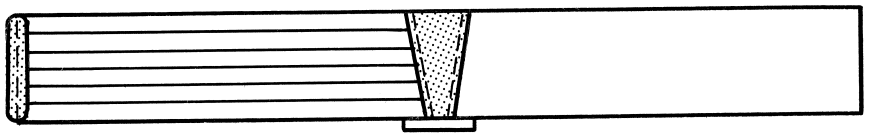
[1] Buttered means buildup overlay welding.

[2] Temper bead welding technique is done when the final beads of welding are made over-flush, deposited only on previous beads of welding for tempering purposes without making contact with the base metal, and then removing these final beads.

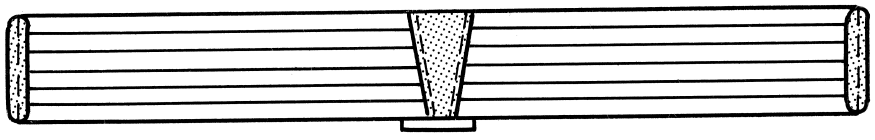
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Plan View of Solid to Layered and Layered to Layered Test Plates



Layered to Solid Test Plate



Layered to Layered Test Plate

FIG. ULW-32.1 SOLID-TO-LAYERED AND LAYERED-TO-LAYERED TEST PLATES

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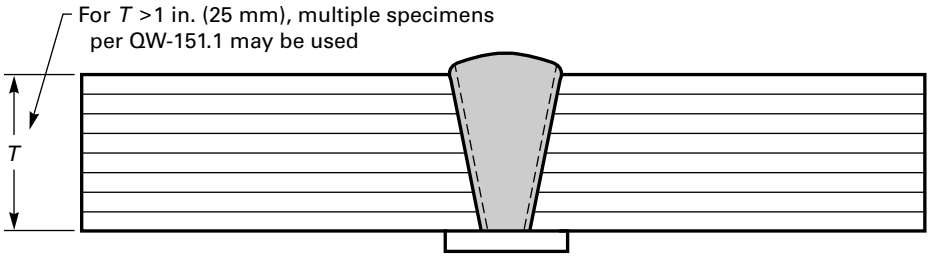


FIG. ULW-32.2

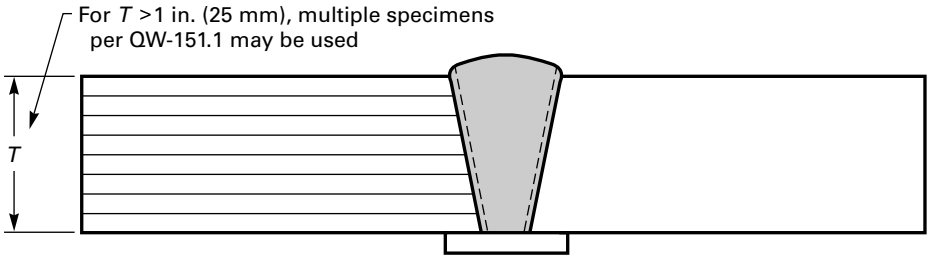
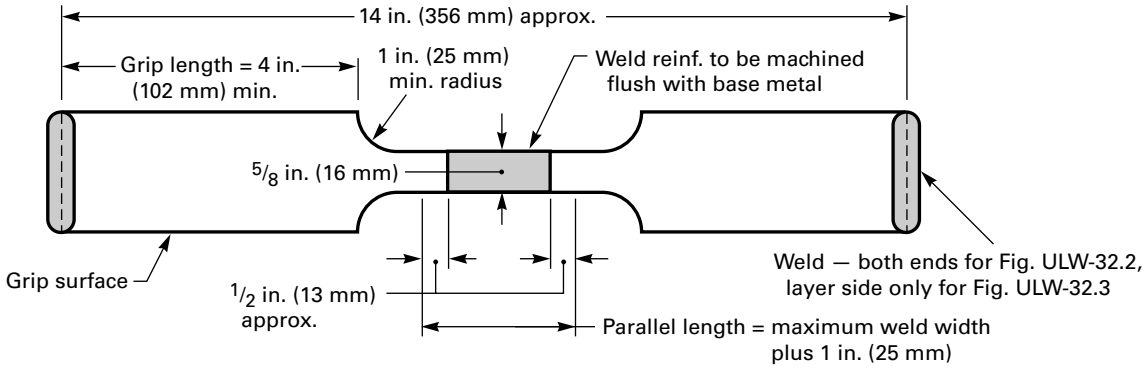
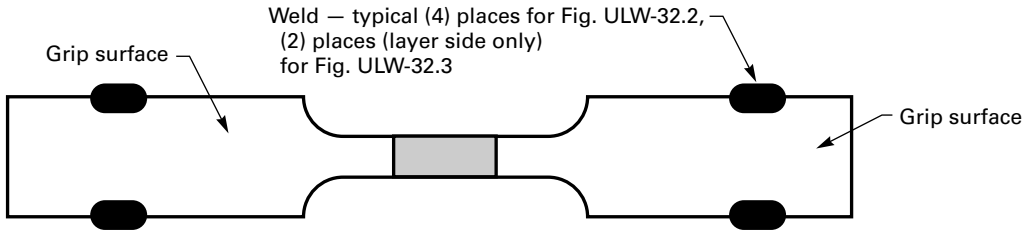


FIG. ULW-32.3



Specimen A



Specimen B (Alternative Specimen)

GENERAL NOTE:
Specimens A and B are plan views of Figs. ULW-32.2 and ULW-32.3 and are identical except for locations of grip surfaces and welds. All grip surfaces are to be be machined flat.

FIG. ULW-32.4 **01**

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qualified by any welder test plate shall be as shown on Table QW-452 of Section IX.

NONDESTRUCTIVE EXAMINATION OF WELDED JOINTS

ULW-50 GENERAL

The rules of the following paragraphs apply specifically to the nondestructive examination of pressure vessels and vessel parts that are fabricated using layered construction.

ULW-51 INNER SHELLS AND INNER HEADS

Category A and B joints in the inner shells of layered shell sections, and in the inner heads of layered heads before application of the layers, shall be examined throughout their entire length by radiography and meet the requirements of UW-51.

ULW-52 LAYERS — WELDED JOINTS

(a) Category A joints in layers $\frac{1}{8}$ in. (3.2 mm) through $\frac{5}{16}$ in. (8 mm) in thickness welded to the previous surface shall be examined for 100% of their length in accordance with Appendix 6 by the magnetic particle method using direct current.

(b) Category A joints in layers over $\frac{5}{16}$ in. (8 mm) through $\frac{5}{8}$ in. in thickness welded to the previous surface shall be examined for 100% of their length in accordance with Appendix 6 by the magnetic particle method using direct current. In addition, these joints shall be examined for 10% of their length at random in accordance with Appendix 12 ultrasonic method except that for the bottom 10% of the weld thickness the distance amplitude correction curve or reference level may be raised by 6 dB. The random spot examination shall be performed as specified in ULW-57.

(c) Category A joints in layers over $\frac{5}{8}$ in. (16 mm) through $\frac{7}{8}$ in. (22 mm) in thickness welded to the previous surface shall be examined for 100% of their length in accordance with Appendix 12 ultrasonic method except that for the bottom 10% of the weld thickness the distance amplitude correction curve or reference level may be raised by 6 dB.

(d) Category A joints in layers not welded to the previous surface shall be examined before assembly for 100% of their length by radiography and meet the requirements of UW-51.

(e) Joints in interlocking strips of helically wound construction joined by welding prior to wrapping shall be ground flush and examined 100% of their length by the magnetic particle method in accordance with Appendix 6.

(f) Welds in spirally wound strip construction with a winding or spiral angle of 75 deg. or less measured from the vessel axial center line shall be classified as Category A joints and examined accordingly.

ULW-53 LAYERS — STEP WELDED GIRTH JOINTS

(a) Category B joints in layers $\frac{1}{8}$ in. (3.2 mm) through $\frac{5}{16}$ in. (8 mm) in thickness shall be examined for 10% of their length in accordance with Appendix 6 by the magnetic particle method using direct current. The random spot examination shall be performed as specified in ULW-57.

(b) Category B joints in layers over $\frac{5}{16}$ in. (8 mm) through $\frac{5}{8}$ in. (16 mm) in thickness shall be examined for 100% of their length in accordance with Appendix 6 by the magnetic particle method, using direct current.

(c) Category B joints in layers over $\frac{5}{8}$ in. (16 mm) through $\frac{7}{8}$ in. (22 mm) in thickness shall be examined for 100% of their length in accordance with Appendix 6 by the magnetic particle method using direct current. In addition these joints shall be examined for 10% of their length in accordance with Appendix 12 ultrasonic examination, except that for the bottom 10% of the weld thickness the distance amplitude correction curve or reference level may be raised by 6 dB. The random spot examination shall be performed as specified in ULW-57.

(d) Category B joints in layers over $\frac{7}{8}$ in. (22 mm) in thickness shall be examined for 100% of their length in accordance with Appendix 12 ultrasonic method except that for the bottom 10% of the weld thickness the distance amplitude correction curve or reference level may be raised by 6 dB.

ULW-54 BUTT JOINTS

(a) Full Thickness Welding of Solid Section to Layered Sections. Category A, B, and D joints attaching a solid section to a layered section of any of the layered thicknesses given in ULW-52 shall be examined by radiography for their entire length in accordance with UW-51.

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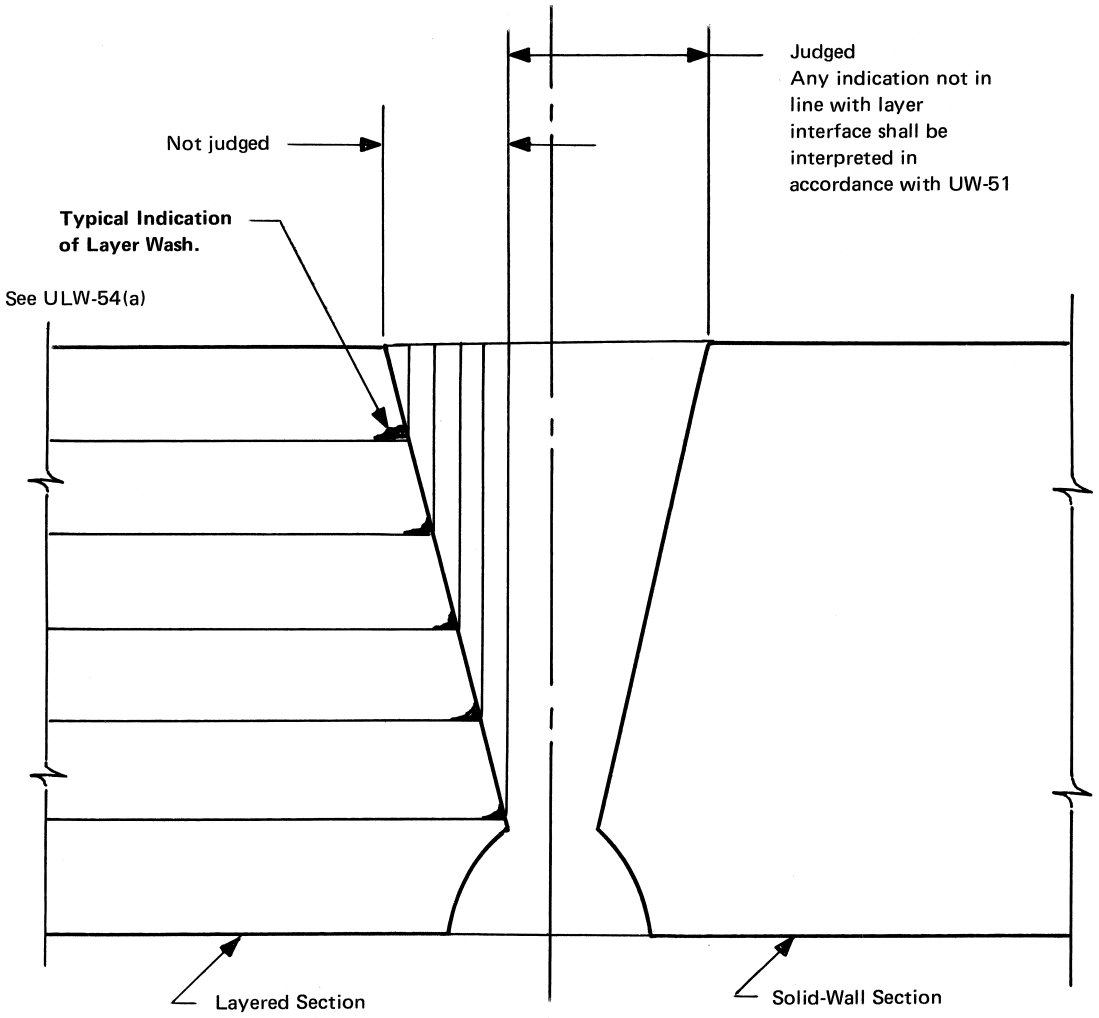


FIG. ULW-54.1

It is recognized that layer wash[3] or acceptable gaps (see ULW-77) may show as indications difficult to distinguish from slag on the radiographic film. Acceptance shall be based on reference to the weld geometry as shown in Fig. ULW-54.1. As an alternative, an angle radiographic technique, as shown in Fig. ULW-54.2, may be used to locate individual gaps in order to determine the acceptability of the indication.

(b) Full Thickness Welding of Layered Section to Layered Section. Category A and B joints attaching a layered section to a layered section need not be radiographed after being fully welded when the Category A hemispherical head and Category B welded joints of the inner shell or inner head made after application of the layers have been radiographed in accordance with UW-51. The inner shell or inner head thicknesses need not be radiographed in thicknesses over $^{7}/_{8}$ in. (22 mm) if the completed joint is radiographed. Weld joints in the inner shell or inner head welded after application of the layers of the inner shell or inner head weld joints shall be radiographed throughout their entire length and meet the requirements of UW-51.

[3] Layer wash is defined as the indications resulting from slight weld penetration at the layer interfaces.

ULW-55 FLAT HEAD AND TUBESHEET WELD JOINTS

Category C joints attaching layered shells or layered heads to flat heads and tubesheets as shown in Fig.

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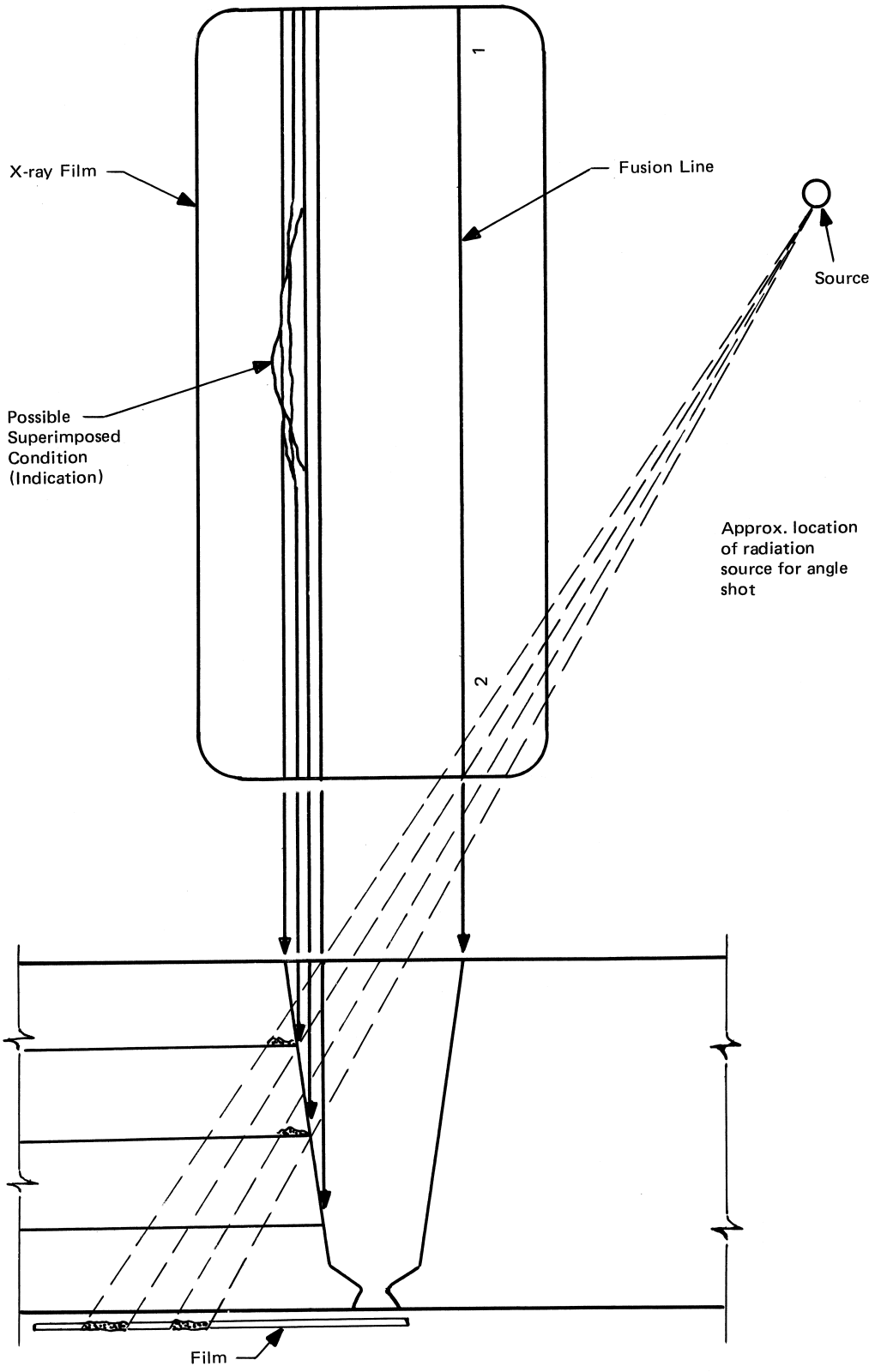


FIG. ULW-54.2

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ULW-17.3 shall be examined to the same requirements as specified in ULW-53 and ULW-54(a) for Category B joints.

ULW-56 NOZZLE AND COMMUNICATING CHAMBERS WELD JOINTS

Category D joints in layered shells or layered heads not requiring radiographic examination shall be examined by the magnetic particle method in accordance with Appendix 6. The partial penetration weld joining liner type nozzle as shown in Fig. ULW-18.1 sketches (i), (j), (k), and (l) to layered vessel shells or layered heads shall be examined by magnetic particle or liquid penetrant. Acceptance standards shall meet the requirements of Appendix 6 or 8, respectively, for magnetic particle and liquid penetrant examination.

ULW-57 RANDOM SPOT EXAMINATION AND REPAIRS OF WELD

The random ultrasonic examination of ULW-52(b) and ULW-53(c) and random magnetic particle examination of ULW-53(a) shall be performed as follows.

(1) The location of the random spot shall be chosen by the Inspector except that when the Inspector has been duly notified in advance and cannot be present or otherwise make the selection, the fabricator may exercise his own judgment in selecting the random spot or spots. The minimum length of a spot shall be 6 in. (152 mm).

(2) When any random spot examination discloses welding which does not comply with the minimum quality requirements of ULW-52(b), ULW-53(a), and ULW-53(c), two additional spots of equal length shall be examined in the same weld unit at locations away from the original spot. The locations of these additional spots shall be determined by the Inspector or fabricator as provided for the original spot examination.

(3) If either of the two additional spots examined shows welding which does not comply with the minimum quality requirements of ULW-52(b), ULW-53(a), and ULW-53(c), the entire unit 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 unit of weld represented shall be completely examined and defects only need be corrected.

(4) 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 random spot examined at one location in accordance with the foregoing requirements of ULW-52(b), ULW-53(a), and ULW-53(c).

FABRICATION

ULW-75 GENERAL

The rules in the following paragraphs apply to layered shells, layered heads, and layered transition sections that are fabricated by welding and shall be used in conjunction with the general requirements for fabrication in Subsection A, UG-75 through UG-85, with the exception of UG-83. For layered vessels, the minimum thickness permitted for layers is $\frac{1}{8}$ in. (3.2 mm).

ULW-76 VENT HOLES

Vent holes shall be provided to detect leakage of the inner shell and to prevent buildup of pressure within the layers as follows.

(a) In each shell course or head segment a layer may be made up of one or more plates. Each layer plate shall have at least two vent holes $\frac{1}{4}$ in. (6 mm) minimum diameter. Holes may be drilled radially through the multiple layers or may be staggered in individual layer plates.

(b) For continuous coil wrapped layers, each layered section shall have at least four vent holes $\frac{1}{4}$ in. (6 mm) minimum diameter. Two of these vent holes shall be located near each end of the section and spaced approximately 180 deg. apart.

(c) Vent holes are not required in helically wound interlocking strip construction.

(d) The minimum requirement for spirally wound strip layered construction shall be $\frac{1}{4}$ in. (6 mm) minimum diameter vent holes drilled near both edges of the strip. They shall be spaced for the full length of the strip and shall be located a distance of approximately $\pi R/\tan\theta$ from each other where

R = the mean radius of the shell, in. (mm)

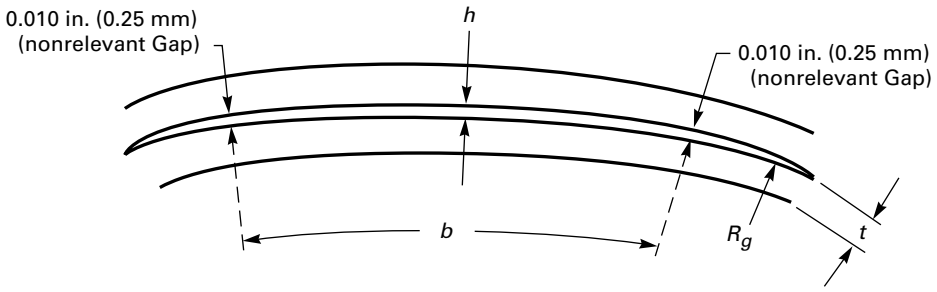
θ = the acute angle of spiral wrap measured from longitudinal center line, deg.

If a strip weld covers a vent hole, partially or totally, an additional vent hole shall be drilled on each side of the obstructed hole.

In lieu of the above, holes may be drilled radially through the multiple layers.

(e) Vent holes shall not be obstructed. If a monitoring system is used, it shall be designed to prevent buildup of pressure within the layers.

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A_g = area of gap (approx.) = $^2/_3 h\ b$, in.^{2} (mm^2)
R_g = radius of vessel at gap, in. (mm)
b = arc length of relevant radial gap, in. (mm)
h = radial gap, in. (mm)
t = layer thickness, in. (mm)

01 FIG. ULW-77

ULW-77 CONTACT BETWEEN LAYERS

(a) Category A weld joints shall be ground to ensure contact between the weld area and the succeeding layer, before application of the layer.

(b) Category A weld joints of layered shell sections shall be in an offset pattern so that the centers of the welded longitudinal joints of adjacent layers are separated circumferentially by a distance of at least five times the layer thickness.

(c) Category A weld joints in layered heads may be in an offset pattern; if offset, the joints of adjacent layers shall be separated by a distance of at least five times the layer thickness.

(d) After weld preparation and before welding circumferential seams, the height of the radial gaps between any two adjacent layers shall be measured at the ends of the layered shell section or layered head section at right angles to the vessel axis, and also the length of the relevant radial gap in inches shall be measured [neglecting radial gaps of less than 0.010 in. (0.25 mm) as nonrelevant]. An approximation of the area of the gap shall be calculated as indicated in Fig. ULW-77.

The gap area A_g shall not exceed the thickness of a layer expressed in square inches. The maximum length of any gap shall not exceed the inside diameter of the vessel. Where more than one gap exists between any two adjacent layers, the sum of the gap lengths shall not exceed the inside diameter of the vessel. The maximum height of any gap shall not exceed $^3/_{16}$ in. (4.8 mm).

It is recognized that there may be vessels of dimensions wherein it would be desirable to calculate a maximum permissible gap area. This procedure is provided for in Section VIII, Division 2 rules for layered vessels in lieu of the maximum gap area empirically given above, except that the maximum allowable stress S given in Section II, Part D, Tables 1A and 1B shall be used instead of the stress intensity S_m given in Tables 2A and 2B.

(e) In the case of layered spheres or layered heads, if the gaps cannot be measured as required in (d) above, measurement of gap heights shall be taken through vent holes in each layer course to assure that the height of layer gaps between any two layers does not exceed the gap permitted in (d) above. The spacing of the vent holes shall be such that gap lengths can be determined. In the event an excessive gap height is measured through a vent hole, additional vent holes shall be drilled as required to determine the gap length. There shall be at least one vent hole per layer segment.

(f) The requirements in (a) through (e) above do not apply to helically wound interlocking strip construction. See ULW-78(d).

ULW-78 ALTERNATIVE TO MEASURING CONTACT BETWEEN LAYERS DURING CONSTRUCTION

As an alternative to ULW-77, the following measurements shall be taken at the time of the hydrostatic test

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to check on the contact between successive layers, and the effect of gaps which may or may not be present between layers.

(a) The circumference shall be measured at the midpoint between adjacent circumferential joints, or between a circumferential joint and any nozzle in a shell course. Measurements shall be taken at zero pressure, and following application of hydrostatic test pressure, at the design pressure. The difference in measurements shall be averaged for each course in the vessel and the results recorded as average middle circumferential expansion e_m in inches.

(b) The theoretical circumferential expansion of a solid vessel of the same dimensions and materials as the layered vessel shall be calculated from the following formula:

$$e_{th} = \frac{1.7\pi P(2R - t_s)^2(2R + t_s)}{8ERt_s}$$

where

e_{th} = theoretical circumferential expansion, in. (mm)
R = mean radius
= outside radius − $t_s/2$, in. (mm)
P = internal design pressure, psi (kPa)
t_s = wall thickness, in. (mm)
E = modulus of elasticity [use 30×10^6 psi (207×10^6 kPa) for carbon steel]

(c) Acceptance criteria for circumferential expansion at the design pressure shall be as follows: e_m shall not be less than $0.5\, e_{th}$.

(d) For helically wound interlocking strip vessels, two hydrostatic tests shall be performed. The requirements for determining the maximum permissible elongation are as follows.

(1) During the first test, the longitudinal expansion shall be measured at design pressure, at test pressure, and again after the test pressure is reduced to design pressure. The difference in the measured lengths at design pressure shall not exceed 0.1% of the original length at design pressure.

(2) During the second test, the length of the vessel shall be measured at the test pressure and after the pressure has been completely released. The longitudinal contraction ϵ_L shall not exceed the tangential contraction ϵ_T of a solid wall vessel of the same dimensions, where

$$\epsilon_L = \frac{L_1 - L}{L}$$

and

$$\epsilon_T = \frac{1.7P}{E\,(y^2 - 1)}$$

where

ϵ_L = longitudinal contraction, in./in. (mm/mm)
ϵ_T = tangential contraction, in./in. (mm/mm)
L_1 = measured length of vessel at second test pressure, in. (mm)
L = final length of vessel at atmospheric pressure after the second test, in. (mm)
P = test pressure, psi (kPa)
E = modulus of elasticity, psi (kPa)
y = diameter ratio (O.D./I.D.)

INSPECTION AND TESTING

ULW-90 GENERAL

The inspection and testing of layered pressure vessels to be marked with the Code U Symbol shall be in accordance with UG-90 through UG-103.

MARKING AND REPORTS

ULW-115 GENERAL

(a) The rules for marking and reports of layered pressure vessels built under Part ULW shall meet the requirements given in UG-115 through UG-120.

(b) In addition, a description of the layered shell and/or layered heads shall be given on the Data Report describing the number of layers, their thickness or thicknesses, and type of construction. See W-2 and Table W-3 for the use of Form U-4 Manufacturer's Data Report Supplementary Sheet. An example of the use of Form U-4 illustrating the minimum required data for layered construction is given in Fig. W-3.1.

(c) In addition, the stamping below the Code symbol prescribed in UG-116(c) shall be the letters WL to designate layered construction.

PRESSURE RELIEF DEVICES

ULW-125 GENERAL

The provisions for pressure relief devices in UG-125 through UG-134 shall apply without supplement to pressure vessels fabricated in whole or in part of layered construction.

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