
API STD 12C
Fifteenth Edition
March 1958

**API SPECIFICATION
FOR
WELDED OIL STORAGE TANKS**

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New York, N. Y.**

Issued by

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Division of Production
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Note

This specification was originally adopted as tentative in 1935, and as standard in 1940. Revised editions were issued in 1942, 1944, 1946, 1948, 1950, 1951, 1952, 1954, 1955, and 1957. The present edition supersedes the 14th edition, dated October 1957. It includes changes adopted at the 1957 meeting, as detailed in Circ. PS-1117.

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SUGGESTIONS FOR ORDERING

The purchaser should state on his inquiry or purchase order the following:

Specification	API Std 12C
Number of tanks.....	
Diameter, ft.	
Height, ft.	
Nominal capacity, bbl.....	
Time of completion.....	
Freight and hauling.....	
Erection, location and facilities.....	Par. 5.1.2
Tank grade details.....	Par. 5.1.1, Appendix B
Plate specifications (bottom, shell, and roof)	
Bolting	Par. 2.9
Bottom design:	
Thickness of plates.....	Par. 3.2.1
Size of plates.....	Par. 3.2.1
Joint design	Par. 3.2.3
Shell design:	
Max. Sp. Gr. of contents.....	Par. 3.3.2
Thickness of plates (each course).....	Par. 3.3.4
Width of plates.....	Par. 3.3.7
Wind girders	Sect. 3.4
Roof and roof support design.....	Sect. 3.5, Appendix C
Tank appurtenances (type, size, and location)	Sect. 3.6
Stairways, platforms, and walkways.....	Tables 17, 18, 19
Shop Inspection	Sect. 4.2
Field inspection	Sect. 5.3
Bottom test	Par. 5.3.4
Shell Test	Par. 5.3.6

Roof test	Par. 5.3.7
Painting requirements	Par. 5.1.4
Special provisions (permits, fees, liability, etc.)	

The purchaser may exercise an option with respect to the following requirements.

Mill test reports.....	Par. 4.2.1
Bottom plate arrangement and welding procedure	Par. 5.2.9, 10
Shell plate alignment.....	Par. 3.3.8
Top angle orientation.....	Par. 3.3.10
Horizontal joint penetration and fusion.....	Par. 3.3.12
Roof column	Par. 3.5.6
Roof slope	Par. 3.5.7
Shell manhole design.....	Fig. 7
Shell nozzle design.....	Fig. 8, 9
Cleanout fitting support.....	Par. 3.6.9, Fig. 11
Roof nozzle flange design.....	Fig. 13, 14
Drawoff elbow design.....	Fig. 15, 16
Welding procedure qualification test reports	Par. 7.1.5
Welder or welding operator qualification test reports	Par. 7.1.5, 7.3.23
Welding procedure specification.....	Sect. 7.4
The following requirements are subject to agreement between the purchaser and the manufacturer.	
Shell joint tests.....	Part 6
Shell plate width.....	Par. 3.3.7
Sectioning method	Sect. 6.1
Closure of openings.....	Par. 6.1.19
Segment ownership	Par. 6.1.27
Radiographic method	Sect. 6.2
Film ownership	Par. 6.2.17

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API SPECIFICATION FOR WELDED STORAGE TANKS

Foreword

a. This specification is under the jurisdiction of the API Committee on Standardization of Tanks for Oil Storage.

b. Provisions for welding and details pertaining thereto, as given herein, were prepared in cooperation with the American Welding Society, these including definitions of welding and welded joints, and fabrication thereof; materials suitable for welding, including electrodes; qualification of welding procedures and welders; and inspection requirements for field welding.

c. This specification is not intended to cover storage tanks which are to be erected in areas subject to regulations which are more stringent than this specification. In such cases this specification should be followed insofar as it does not conflict with the local requirements.

d. Other specifications under the jurisdiction of the Committee on Standardization of Tanks for Oil Storage include the following:

Std 12A: Specification for Oil-Storage Tanks with Riveted Shells.

Covers material, design, fabrication, and erection requirements for vertical, cylindrical, above-ground steel tanks with riveted shells in nominal capacities of 240 to 255,000 bbl. (in standard sizes) for oil storage.

Std 12G: Specification for Aluminum-Alloy Welded Storage Tanks.

Covers material, design, fabrication, erection, and testing requirements for vertical, cylindrical, above-ground, closed and open-top, welded aluminum-alloy storage tanks in various sizes and capacities.

RP 12H: Recommended Practice for Installation of New Bottoms in Old Storage Tanks.

Covers method of replacing bottoms in old riveted or welded storage tanks with new bottom of concrete or steel.

e. Related specifications under the jurisdiction of the Committee on Lease Production Vessels include the following:

Std 12B: Specification for Bolted Production Tanks.

Covers material, design, and erection requirements for vertical, cylindrical, above-ground, bolted, steel, production tanks in nominal capacities of 100 to 10,000 bbl. (in standard sizes) for oil-field service. It also includes appurtenance requirements.

Std 12D: Specification for Large Welded Production Tanks.

Covers material, design, fabrication, and erection requirements for vertical, cylindrical, above-ground, closed-top, welded, steel, production tanks in capacities of 500 to 3,000 bbl. (in standard sizes) for oil-field service. It also includes appurtenance requirements.

Std 12E: Specification for Wooden Production Tanks.

Covers material, design, fabrication, and erection requirements for vertical, cylindrical, above-ground, closed-top, wooden, production tanks in nominal capacities of 130 to 1500 bbl. (in standard sizes) for oil-field service.

Std 12F: Specification for Small Welded Production Tanks.

Covers material, design, and construction requirements for vertical, cylindrical, above-ground, shop-welded, steel production tanks in nominal capacities of 90 to 400 bbl. (in standard sizes up to a maximum diameter of 12 ft.) for oil-field service.

f. Related standards and recommended practices issued by other Institute divisions, include the following:

Std 620: Recommended Rules for the Design and Construction of Large, Welded, Low-Pressure Storage Tanks.

Covers storage tanks for operation at internal pressures of 0.5 psig up to but not exceeding 15 psig.

RP 2000: Guide for Tank Venting.

Covers recommended practices for venting above-ground petroleum storage tanks designed to operate at or near atmospheric pressure. Recommended practices for testing venting devices are included.

Accident Prevention Manual No. 1, Cleaning Petroleum Storage Tanks:

Section A: Crude Oil and Unfinished Products Tanks.

Section B: Gasoline Tanks.

Inspection of Atmospheric and Low-Pressure Storage Tanks (Chapter XIII of Guide for Inspection of Refinery Equipment).

Contains a description of the design and construction of atmospheric and low-pressure storage tanks for crude, intermediate, and refined products, gas, chemicals and water; reasons for inspection and causes of deterioration; recommendations on frequency and time of inspection; procedures and tools required for inspection of tanks in service and out of service and of auxiliary equipment, including testing tanks and determining limits; methods of repairs; and recommendations concerning inspection records and reports.

1. SCOPE

1.1 This specification covers material, design, fabrication, erection, and testing requirements for vertical, cylindrical, above-ground, closed and open-top, welded steel storage tanks in various sizes and capacities, for internal pressures approximating atmospheric pressures.

1.2 This specification is designed to provide the oil industry with tanks of adequate safety and reasonable economy, for use in the storage of petroleum and its products and those other liquid products commonly handled and stored by the various branches of the industry. It does not present, nor is it contemplated to establish, a fixed series of allowable tank sizes; but rather it is intended to permit the selection by the purchaser of whatever size of tank may be required to best meet his particular needs.

1.3 Appendix A to this specification presents for ready reference design data relating to tanks which may be built under this specification. The data pre-

sented therein are for convenience and are not mandatory.

1.4 Nothing contained in this specification is to be construed as granting any right, by implication or otherwise, for manufacture, sale, or use in connection with any method, apparatus, or product covered by letters patent, nor as insuring anyone against liability for infringement of letters patent.

1.5 Compliance. The manufacturer is responsible for complying with all of the provisions of this specification. The purchaser may make any investigation necessary to satisfy himself of compliance by the manufacturer, and may reject any material that does not comply with this specification. It is urged that the purchaser avail himself of this right and furnish his own inspection independently of any supervisory inspection furnished by the manufacturer, and that the purchaser inspector follow closely all of the details of field construction and testing herein specified, which affect the integrity and safety of the completed structure.

2. MATERIAL

Plates

2.1 Plates shall conform to the latest revision of ASTM¹ A 7 (open-hearth or electric-furnace process only), A 283 grade C, or A 283 grade D, except that all plates in thickness greater than $\frac{1}{4}$ in. shall conform to A 283 grade C. Copper-bearing steel shall be used if so specified on the purchase order.

NOTE 1: As alternatives, plates conforming to ASTM A 131 grades A, B, and C; A 201 grades A and B; A 284 grade B; and A 373 are acceptable (without restriction as to thickness except as imposed in A 131 and A 373), and may be specified when the purchaser considers the severity of the service conditions warrants the use of these premium materials.

NOTE 2: The manufacturer shall state in his proposal the plate specification which he intends to use.

2.2 Plate specification on an edge-thickness basis is required² for all shell plates the thicknesses of which are determined by design computations. Shell plates for which minimum thicknesses have been fixed for practical reasons, and which will not under-run the theoretical required thickness by more than 0.01 in., also roof and bottom plates, may be specified on a weight basis. The plate thicknesses or weights, as stipulated herein are minima; thicker or heavier material may be required on the order at the option of the purchaser.

¹ASTM specifications referred to herein may be secured from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

²Plates may be purchased on the weight basis in compliance with this requirement, provided they are ordered sufficiently heavier than the nominal weight corresponding to the specified minimum thickness to insure that plates furnished by the mill will not under-run the theoretical thickness by more than 0.01 in.

2.3 Sheets. Sheets shall conform to the latest revision of ASTM A 245, grade C, open-hearth process only. Copper-bearing steel shall be used if so specified on the purchase order. Sheets may be ordered on a weight or thickness basis, at the option of the tank manufacturer.

2.4 Welding Electrodes. Manual arc-welding electrodes shall conform to the latest revision of ASTM A 233: Specifications for Mild Steel Arc-Welding Electrodes of the E-60 Series of Classification, suitable for the electric-current characteristics, the position of welding, and other conditions of intended use.

2.5 Structural Shapes. Structural shapes shall conform to the latest revision of ASTM A 7 (open-hearth or electric-furnace process only). Copper-bearing steel shall be used if so specified on the purchase order.

2.6 Castings. Castings shall conform to the latest revision of ASTM A 27, grade 60-30, fully annealed.

2.7 Piping. Except as otherwise specified herein, pipe and pipe couplings shall conform to the latest revision of API Std 5L. By agreement between the purchaser and the manufacturer, couplings for threaded connections may be supplied without recesses. When so supplied, the couplings in all other respects shall conform to API Std 5L. Pipe used for structural purposes shall conform to API Std 5L grade B or API Std 5LX, with respect to physical properties of the material.

2.8 Flanges. Hub slip-on welding and welding-neck flanges shall conform to the material requirements for forged carbon-steel flanges as specified in ASA B16.5. Plate-ring flanges shall conform to the requirements of Par. 2.1, within the thickness limits controlled therein, or to ASTM A 201, grade A for all thicknesses.

2.9 Bolting. Bolting shall conform to the latest revision of ASTM A 307.

NOTE: Purchasers should specify on their orders the desired shape of bolt heads and nuts, also whether regular or heavy dimensions are desired.

3. DESIGN

3.1 JOINT DESIGN

3.1.1 Definitions. The following definitions shall apply to tank joint designs.

a. **Double-Welded Butt Joint:** A joint between two abutting parts lying in approximately the same plane and welded from both sides.

b. **Single-Welded Butt Joint with Backing:** A joint between two abutting parts lying in approximately the same plane, welded from one side only using a strip, bar, or other suitable backing material.

c. **Double-Welded Lap Joint:** A joint between two overlapping members, in which the overlapped edges of both members are welded with fillet welds.

d. **Single-Welded Lap Joint:** A joint between two overlapping members, in which the overlapped edge of one member is welded with a fillet weld.

e. **Butt Weld:** A weld placed in a groove between two abutting members. Grooves may be square, V (single or double), or U (single or double), and may be either single or double beveled.

f. **Fillet Weld:** A weld of approximately triangular cross-section joining two surfaces approximately at right angles to each other, as in a lap joint, tee joint, or corner joint.

g. **Full-Fillet Weld:** A fillet weld whose size is equal to the thickness of the thinner member joined.

h. **Tack Weld:** A weld made to hold parts of a weldment in proper alignment until the final welds are made.

3.1.2 Size of Weld. The size of a weld shall be based

on the following dimensions:

a. **Groove Weld:** The joint penetration (depth of chamfering plus the root penetration when specified).

b. **Fillet Weld:** For equal-leg fillet welds, the leg length of the largest isosceles right triangle which can be inscribed within the fillet-weld cross section. For unequal-leg fillet welds, the leg lengths of the largest right triangle which can be inscribed within the fillet-weld cross section.

3.1.3 Joint Restrictions. The following restrictions on type and size of joints or welds shall apply:

a. Tack welds may not be considered as having any strength value in the finished structure.

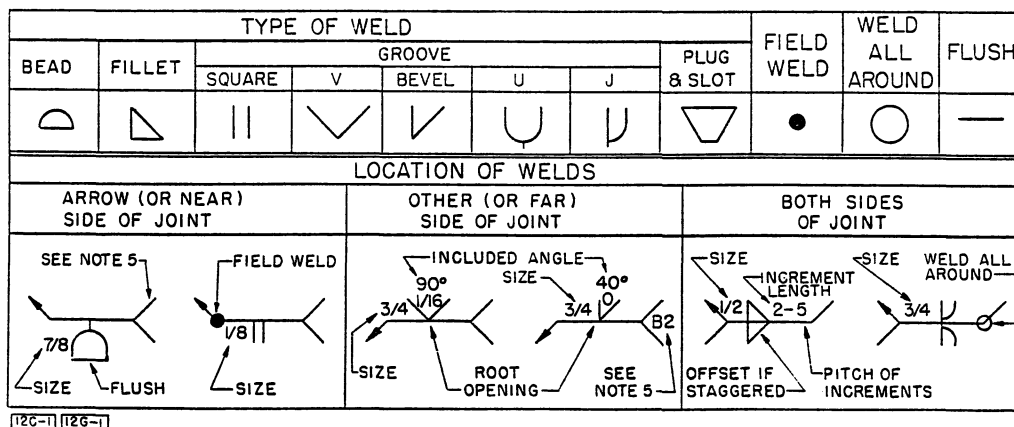
b. The minimum size of fillet welds shall be as follows: plates $\frac{1}{8}$ in. thick, full-fillet welds; plates over $\frac{1}{8}$ in. thick, not less than one-third the thickness of the thinner plate at the joint, with a minimum of $\frac{1}{8}$ in.

c. Single-welded lap joints are permissible only on bottom plates and roof plates.

d. Lap-welded joints, as tack welded, shall be lapped not less than five times the nominal thickness of the thinner plate joined, but in the case of double-welded lap joints need not exceed 2 in. and in the case of single-welded lap joints need not exceed 1 in.

3.1.4 Welding Symbols. Welding symbols used on drawings shall be those of the American Welding Society, as given in Fig. 1.

3.1.5 Typical Joints. Typical tank joints are shown in Fig. 2, 3, and 4.



- The side of the joint to which the arrow points is the arrow side and the opposite side of the joint is the other side.
- Arrow-side and other-side welds are same size unless otherwise shown.
- Symbols apply between abrupt changes in the direction of welding or to the extent of hatching or dimension lines, except where the all-around symbol is used.
- All welds are continuous and of user's standard proportions, unless otherwise shown.
- Tail of arrow used for specification process, or

other reference. (Tail may be omitted when reference not used.)

- When a bevel- or J-groove weld symbol is used, the arrow shall point with a definite break toward the member which is to be chamfered. (In cases where the member to be chamfered is obvious, the break in the arrow may be omitted.)
- Dimensions of weld sizes, increment lengths, and spacing, in inches.
- For more detailed instruction in the use of these symbols refer to Standard Welding Symbols, published by American Welding Society.

FIG. 1
WELDING SYMBOLS

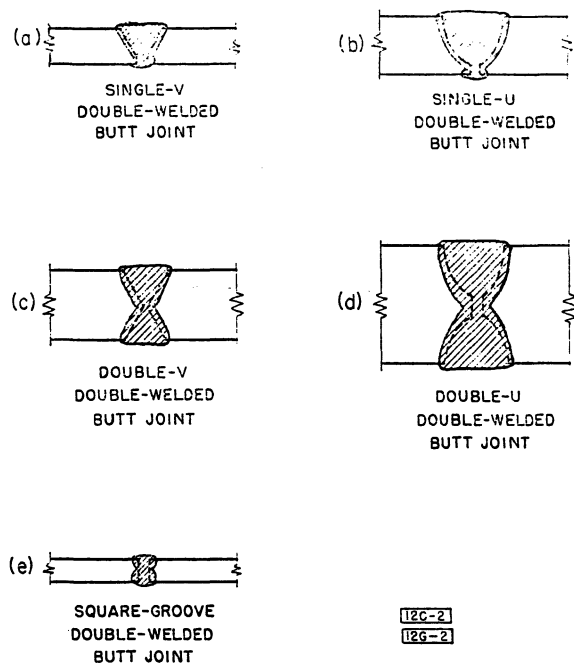


FIG. 2
TYPICAL VERTICAL JOINTS IN SHELL¹

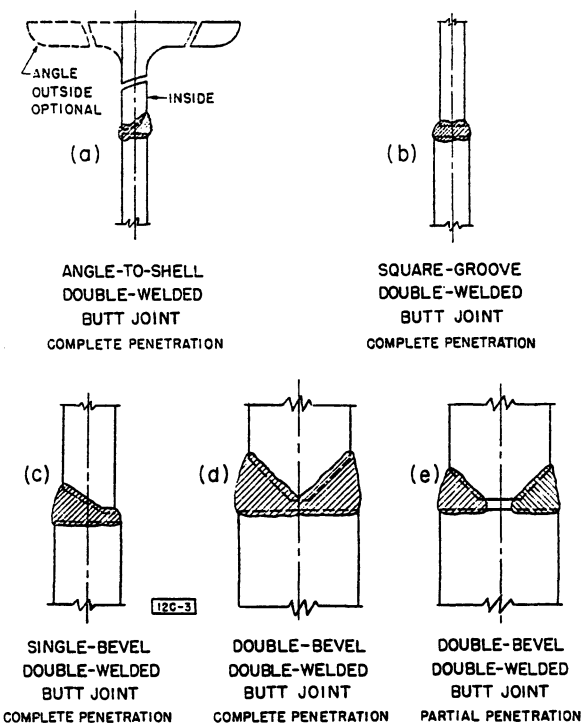
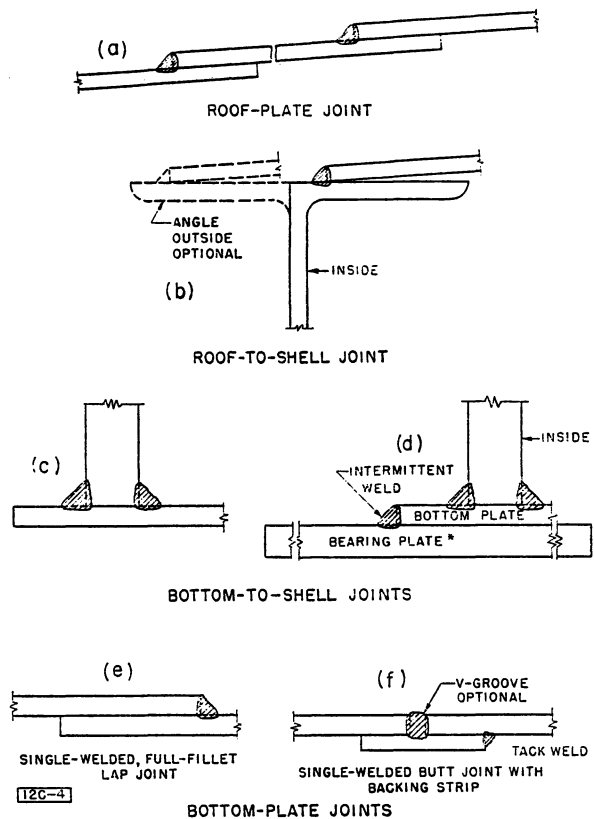


FIG. 3
TYPICAL HORIZONTAL JOINTS IN SHELL²



*See Appendix B for recommendations on bearing plates.

FIG. 4
TYPICAL ROOF AND BOTTOM JOINTS³

¹See Par. 3.3.11 for specific requirements on vertical shell joints.

²See Par. 3.3.12 for specific requirements on horizontal shell joints.

³See Par. 3.2.3 for specific requirements on bottom-plate joints; Par. 3.2.4 for specific requirements on bottom-to-shell joints; Par. 3.5.3 for specific requirements on roof plate joints; and Par. 3.5.4 on roof-to-top angle joints.

3.2 BOTTOM DESIGN

NOTE: Storage tanks, particularly in the larger sizes, impose appreciable bearing loads on the subgrade and it is recommended that consideration be given to providing suitable foundations to prevent uneven settlement with attendant distortion and possible failure of the tank. Details of recommended foundations are given in Appendix B herein.

Plate Sizes

3.2.1 All bottom plates shall have a minimum nominal thickness of $\frac{1}{4}$ in. (10.2 per sq. ft. See Par. 2.2). All rectangular plates shall preferably have a minimum width of 72 in. All sketch plates (bottom plates upon which the shell rests) which have one end rectangular, shall also preferably have a minimum width of 72 in. for the rectangular end.

3.2.2. Bottom plates shall be ordered of sufficient size so that when trimmed at least one-inch width will project beyond the outside edge of the weld attaching the bottom to the shell plate.

Design

3.2.3 Bottoms shall be built to one of two alternative methods of construction:

a. Lap-welded bottom plates shall be reasonably rectangular and square-edged. Three-plate laps in tank bottoms shall not be closer than 12 in. from each other and also from the tank shell. Bottom plates need be welded on the top side only, with a continuous full-fillet weld on all seams. The plates under the bottom ring shell connection shall have the outer ends of the joints fitted and lap welded to form a smooth bearing for the shell plates as shown in Fig. 5.

b. Butt-welded bottom plates shall have the parallel edges prepared for butt welding with either square or V grooves. If square, the root opening shall be not less than $\frac{1}{4}$ in. The butt welds shall be made by applying a backing strip $\frac{1}{8}$ in. thick or heavier by tack welding to the under side of the plate. A metal spacer shall be used, if necessary, to maintain the root opening between the adjoining plate edges. The manufacturer may submit other methods of butt welding the bottom for the purchas-

er's approval. Three-plate joints in tank bottoms shall not be closer than 12 in. from each other and also from the tank shell.

3.2.4 The attachment between the bottom edges of the lowest course shell plate and the bottom plate shall be a continuous fillet weld laid on each side of the shell plate. The size of such welds shall be not greater than $\frac{1}{2}$ in., and neither less than the nominal thickness of the bottom plates or shell plates (whichever is smaller) nor less than the following values.

Maximum Thickness of Shell Plate, in.	Size of Fillet Weld, in.
$\frac{1}{8}$	$\frac{1}{8}$
Over $\frac{1}{8}$ to $\frac{3}{4}$	$\frac{1}{4}$
Over $\frac{3}{4}$ to $1\frac{1}{4}$	$\frac{1}{2}$
Over $1\frac{1}{4}$ to $1\frac{1}{2}$	$\frac{3}{4}$

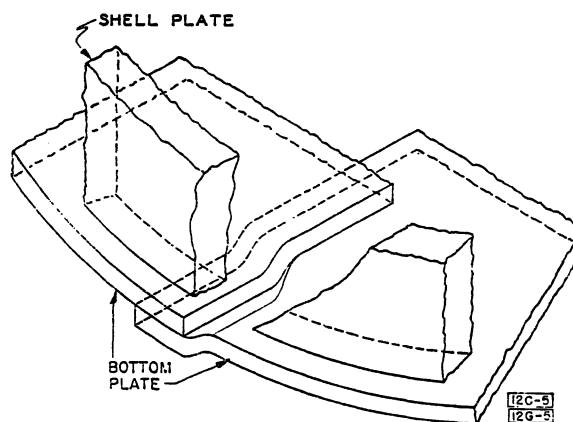


FIG. 5
METHOD OF PREPARING LAP-WELDED
BOTTOM PLATES UNDER TANK SHELL
See Par. 3.2.3a.

3.3 SHELL DESIGN

See Appendix A for typical tank sizes and shell plate thicknesses

3.3.1 Working Stresses. The following maximum allowable working stresses shall be used in design:

a. The maximum tensile stress before applying the factor for efficiency of joint shall be 21,000 lb. per sq. in.

b. The strength of fillet welds for structural attachment shall be computed as 13,600 lb. per sq. in. of cross section measured in the throat of the weld for transverse welds, and 75 per cent of this value for longitudinal welds. The throat of a fillet weld shall be assumed as 0.707 times the shorter leg of the fillet weld.

Loads

3.3.2 Stresses shall be computed on the assumption that the tank is filled with water at 60 deg. F.¹ or the liquid to be stored, if heavier than water. The tension in each ring shall be computed 12 in. above the centerline of the lower horizontal joint of the course in question. In computing these stresses, the tank diameter shall be taken as the nominal² diameter of the bottom course.

3.3.3 Isolated radial loads on tank shells, such as caused by heavy loads from platforms and elevated walkways between tanks, shall be distributed by rolled structural sections, plate ribs, or built-up members, preferably in a horizontal position.

Sizes and Thicknesses of Shell Plates

3.3.4 The minimum thicknesses of shell plates shall be computed from the stress on the vertical joints using a joint efficiency factor of 0.85.

NOTE: The following formula may be used in calculating the minimum thickness of shell plate:

$$t = 0.0001456 \times D \times (H-1) \times S$$

Wherein:

t = minimum thickness, in inches

D = nominal inside diameter of tank, in feet²

H = height, in feet, from the bottom of the course under consideration to the top of the top angle or to the bottom of any overflow which limits the tank filling height.

S = Specific gravity of liquid to be stored but in no case less than 1.0.

3.3.5 In no case shall the nominal thickness of shell plates (including shell extensions for floating roofs) be less than the following:

Nominal Tank ² Diameter, ft.	Nominal Thickness, in.
Smaller than 50	$\frac{1}{8}$
50 to, but not including, 120	$\frac{1}{4}$
120 to 200, incl.	$\frac{3}{8}$
Over 200	$\frac{1}{2}$

¹Water at 60 deg. F. weighs 62.37 lb. per cu. ft.

²Nominal tank diameter shall be the center line diameter of the shell plates, unless otherwise specified by the purchaser.

3.3.6 The maximum nominal thickness of tank shell plates shall be $1\frac{1}{2}$ in.

3.3.7 The width of shell plates shall be as agreed upon between the purchaser and the manufacturer, but preferably should not be less than 72 in. Plates which are to be butt welded shall be properly squared.

Arrangement of Members

3.3.8 The tank shell shall be designed to have all courses truly vertical. Unless otherwise specified, abutting shell plates at horizontal joints shall have a common vertical centerline. Within any three consecutive courses, vertical joints shall not be in alignment but shall be offset from each other a minimum distance of $5t$, t being the plate thickness of the thicker course at the point of offset, except that this requirement need not apply to courses for which the plate thickness is established in accordance with Par. 3.3.5.

3.3.9 The wide face of unsymmetrical V- or U-butt joints may be on the outside or the inside of the tank shell, at the option of the manufacturer.

3.3.10 Except as specified for open-top tanks in Par. 3.4.6, tank shells shall be supplied with top angles of not less than the following sizes: tanks 35 ft. and smaller in diameter — $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ in.; tanks over 35 ft. through 60 ft. in diameter — $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{8}$ in.; tanks larger than 60 ft. in diameter — $3 \times 3 \times \frac{3}{8}$ in. The outstanding leg of the top angle may extend inside or outside the tank shell at the purchaser's option.

3.3.11 Vertical Joints. Vertical joints shall be double welded butt joints with complete penetration and complete fusion. The suitability of plate preparation and welding procedure shall be determined in accordance with Sect. 7.2, Welding Procedure Qualification.

3.3.12 Horizontal Joints. Horizontal joints shall be double-welded butt joints and shall have complete fusion with the base metal over the required depth of weld. The suitability of plate preparation and welding procedure shall be determined in accordance with Sect. 7.2: Welding Procedure Qualification. Horizontal joints shall have complete penetration and complete fusion for a distance of 3 in. on each side of all vertical joint junctions. The remainder of the joint shall conform to the applicable requirements as follows:

- Single-beveled butt joints, including the top angle-to-shell joints, shall have complete penetration and complete fusion.
- Square-groove and double-beveled joints, if the thickness of either plate is $\frac{3}{8}$ in. or less, shall have complete penetration and complete fusion.
- Square-groove and double-beveled joints, if the thicknesses of both plates are greater than $\frac{3}{8}$ in., shall have at least $\frac{3}{8}$ penetration. Any lack of penetration or fusion plus any undercutting (see Par. 5.2.4 regarding undercutting) shall not exceed $\frac{1}{8}$ of the thickness of the thinner plate; and the zone lacking penetration or fusion shall be located substantially at the center of the thinner plate.

Shell Openings

NOTE: *The following requirements on shell openings are intended to restrict the use of apertures to those providing for attachment to the shell by welding. The only exceptions are bolted door sheets. The design requirements for these are given in Sect. 3.6.*

3.3.13 Openings in tank shells larger than required to accommodate a 2-in. standard-weight coupling shall be reinforced. The minimum cross-sectional area of the reinforcement shall not be less than the product of the vertical diameter of the hole cut in the tank shell and the shell-plate thickness required by Par. 3.3.4. The cross-sectional area of the reinforcement shall be measured vertically, coincident with the diameter of the opening.

3.3.14 All effective reinforcements shall be made within a distance, above or below the centerline of the shell opening, equal to the vertical dimension of the hole in the tank shell plate. The reinforcement may be provided by any one or by any combination of the following:

- a. The attachment flange of the fitting.
- b. The reinforcing plate.
- c. The portion of the neck of the fitting which may be considered as reinforcement according to Par. 3.3.15.
- d. Any excess shell plate thickness beyond that required by Par. 3.3.4, within a vertical distance both above and below the centerline of the hole in the shell, equal to the vertical dimension of the hole in the tank shell plate.

3.3.15 The following portions of the neck of a fitting may be considered a part of the area of reinforcement:

- a. That portion extending outwardly from the outside surface of the tank shell plate for a distance equal to four times the neck wall thickness or, if the neck wall thickness is reduced within this distance, to the point of transition.
- b. That portion lying within the shell-plate thickness.
- c. That portion extending inwardly from the inside surface of the tank shell plate for a distance as specified in Subpar. a.

3.3.16 The aggregate strength of the weld attaching a fitting to the shell plate or to an intervening reinforcing plate, or to both, shall equal at least the proportion of the forces, passing through the entire reinforcement, which is computed to pass through the fitting considered.

3.3.17 The aggregate strength of the welding attaching any intervening reinforcing plate to the shell plate shall at least equal the proportion of the forces, passing through the entire reinforcement, which is

computed to pass through the reinforcing plate considered.

3.3.18 The attachment welding to the shell, along the outer periphery of the flanged fitting or reinforcing plate, shall be considered effective only for the parts lying outside of the area bounded by vertical lines drawn tangent to the shell opening. The outer peripheral welding, however, shall be applied completely around the reinforcement. All the inner peripheral welding shall be considered effective. The strength of the effective attachment welding shall be considered as its shear resistance at the stress values given for fillet welds in Par. 3.3.1b. The outer peripheral weld shall be of a size equal to the thickness of the shell plate or reinforcing plate, whichever is thinner except that, when low-type nozzles are used with the reinforcing plate extending to the tank bottom (see Fig. 8), the size of that portion of the peripheral weld which attaches the reinforcing plate to the bottom plate shall conform to Par. 3.2.4. The inner peripheral welding shall be large enough to sustain the remainder of the loading.

3.3.19 When two or more openings are located so close that their normal reinforcing-plate edges are closer than ten times the thickness of the thicker reinforcing plate, with a minimum of 6 in., they shall be treated and reinforced as follows:

- a. All such openings shall be included in a single reinforcing plate, which shall be proportioned for the largest opening in the group.

- b. If the normal reinforcing plates for the smaller openings in the group, considered separately, would fall within the area limits of the solid portion of a normal plate for the largest opening, the smaller openings may be included in a normal plate for the largest opening without increase in size of that plate; provided, however, that if any opening intersects the vertical centerline of another, the total width of the final reinforcing plate along the vertical centerline of either opening shall not be less than the sum of the widths of the normal plates for the openings involved.

- c. If the normal reinforcing plates for the smaller openings, considered separately, would not fall within the area limits of the solid portion of a normal plate for the largest opening, the group reinforcing-plate size and shape shall be such as to include the outer limits of the normal reinforcing plates for all of the openings in the group. Change of size from the outer limits of the normal plate for the largest opening to the outer limits of that for the smaller opening farthest therefrom shall be by uniform straight taper unless the normal plate for any intermediate opening would extend beyond the limits so fixed, in which case uniform straight tapers shall join the outer limits of the several normal plates. Provisions of Subpar. b. with respect to openings on the same or adjacent vertical centerlines shall also apply in this case.

Flush-Type Cleanout Fitting

NOTE: Because of the restraint imposed by the tank bottom and the geometry of the reinforcement, cleanout fittings having the bottom member flush with the tank bottom require special consideration as provided in the following requirements. For selected sizes of fittings, dimensional details are covered by Par. 3.6.8. See Par. 3.6.1 for restrictions on designs of cleanout fittings.

3.3.20 Cleanout fittings of the flush type shall conform to the following requirements:

a. The opening shall be rectangular, except that the upper corners of the opening shall have a radius at least equal to one third the greatest height of the clear opening. The width or height of the clear opening shall not exceed 48 in.

b. The reinforced opening shall be completely preassembled into a first-ring shell plate.

c. If any plate in the unit has a thickness greater than $\frac{5}{8}$ in., the completed unit, including shell plate, shall be thermally stress relieved at a temperature of 1100 to 1200 deg. F. for 1 hr. per inch of thickness.

3.3.21 The cross-sectional area of the shell reinforcement over the top of the opening shall not

be less than $\frac{K_1 h t}{2}$

Wherein:

K_1 = the area coefficient as given on Fig. 6, Detail A.

h = the greatest vertical height of the clear opening, in inches.

t = the shell-plate thickness, in inches, required by Par. 3.3.4.

3.3.22 In no case shall the thickness of the shell reinforcing plate be less than the product of coefficient K_2 as given on Fig. 6, Detail B, and the shell-plate thickness required by Par. 3.3.4.

3.3.23 The reinforcement in the plane of the shell shall be provided within a height L above the bottom of the opening. L shall not exceed $1.5h$ except that $L-h$ shall not be less than $\frac{h}{2K_2}$, nor less than 6 in.

in case of small openings. Where the latter exception results in a height L greater than $1.5h$, only that portion of the reinforcement within a height of $1.5h$ shall be considered effective in satisfying the provisions of Par. 3.3.21.

3.3.24 The reinforcement required by Par. 3.3.21 may be provided by any one or by any combination of the following:

- The shell reinforcing plate.
- Any excess shell-plate thickness beyond that required by Par. 3.3.4.
- That portion of the neck plate equal to the thickness of the reinforcing plate.

3.3.25 The width of the tank-bottom reinforcing plate at the centerline of the opening shall be 10 in. plus the combined thickness of the shell and shell reinforcing plates. The minimum thickness of the bottom reinforcing plate, t_b , in inches, shall be determined as follows:

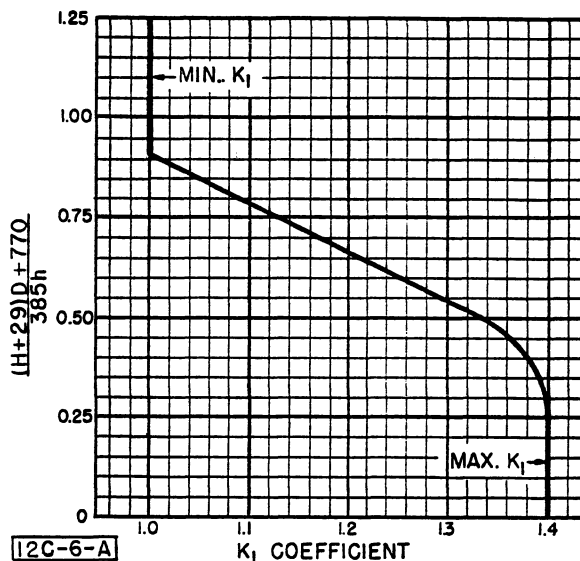
$$t_b = \frac{h^2}{14,000} + \frac{b}{310} \sqrt{H}$$

Wherein:

b = horizontal width of clear opening, in inches.

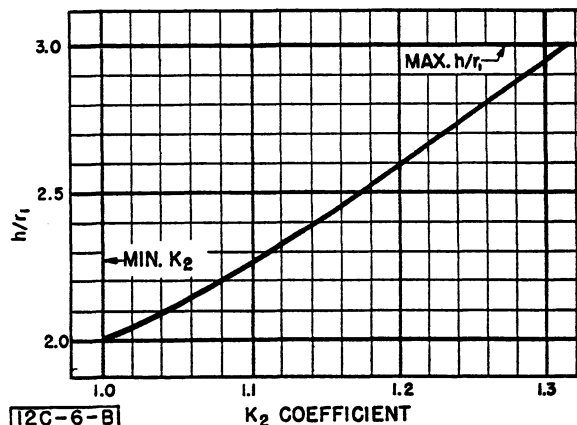
H = height of tank shell, in feet.

h = the greatest vertical height of the clear opening, in inches.



DETAIL A
 K_1 COEFFICIENT FOR DETERMINING MINIMUM SHELL REINFORCEMENT AREA AT TOP OF OPENING

See Par. 3.3.21



DETAIL B
 K_2 COEFFICIENT FOR DETERMINING MINIMUM SHELL REINFORCEMENT PLATE THICKNESS

See Par. 3.3.22

Wherein:

h = greatest vertical height of clear opening, in inches.

r_1 = upper corner radius of clear opening, in inches.

H = height of tank, in feet.

D = inside diameter of tank, in feet.

FIG. 6
DESIGN FACTORS FOR FLUSH-TYPE CLEANOUT FITTINGS

The following requirements on bolted door sheets are based on specific design requirements as follows:

Bolted Door Sheets

3.3.26 The minimum net cross-sectional area of the door plates, excluding the tapered ends, shall not be less than the product of the shell plate thickness and the vertical height of the cut out in the shell plus twice the bolt-hole diameter:

$$t_b (h_b - N_1 d) = t_s (h_c + 2d)$$

3.3.27 The shear stress in the gross section of the bolts shall not exceed 16,000 lb. per sq. in.

3.3.28 The bearing stress on bolts and bolt holes shall not exceed 32,000 lb. per sq. in. and the fit of the turned bolt in the reamed hole shall conform to the standards of the American Institute of Steel Construction.

3.3.29 The strength of the bolted connection shall be at least 90 per cent of the strength of the unbolted shell plate. For shear loading on the flush-type door sheet:

$$N \times a \times 16,000 = t_s (h_c + 2.5d + f) \times \frac{21,000}{21,000 + 0.90}$$

For shear loading on the raised type door sheet:
 $N \times a \times 16,000 = t_s (h_c + 4d) \times 21,000 \times 0.90$

3.3.30 The distance between centers of bolt holes shall not be less than 3 times the bolt diameter, and the bolt hole spacing at the sealing edge of the plate not exceed 7 times the sum of the minimum door-sheet thickness plus the nominal bolt diameter plus the washer thickness (if washers are used).

3.3.31 The tensile stress in the net section of the door plate at the first row of bolt holes next to the shell plate cutout, shall not exceed 21,000 lb. per sq. in. and at subsequent rows shall not exceed 21,000 lb. per sq. in. after allowance is made for the total shearing value or bearing value (whichever is less) of the bolts in the preceding row or rows.

3.3.32 For flush-type bolted door sheets:

- a. The girder shall be designed to withstand a bending moment which would result if the ends of the girder were on hard ground and the center unsupported.
- b. The load on the girder shall be equal to the weight of a column of water with the following dimensions: a, 0.03 times the tank radius, in feet; b, width of shell cutout plus two feet; c, the tank height, in feet.
- c. The design length of the girder shall be equal to the width of the shell cutout plus two feet.

In the preceding equations:

- t_s = thickness of shell plate, in inches.
- t_b = thickness of door plate, in inches.
- h_b = height of door plate in inches.
- h_c = Height of shell cutout, in inches.
- d = diameter of bolts and bolt holes in inches.
- a = cross-sectional area of bolts, in square inches.
- N = number of bolts required in each end section of door plate.
- N_1 = number of bolts in first row of bolts next to the shell cutout.

NOTE: When the difference in diameter of the bolt and bolt holes, because of wear, approximates 0.020 in., it is recommended that the holes be reamed and fitted with oversize milled-body bolts. However, the holes should not be reamed to the extent that the efficiency of the bolted connection becomes less than 85 per cent. This point is reached when the bolt-hole diameters become $\frac{1}{4}$ in. larger than the bolt diameters specified in Tables 20 and 21.

3.4 DESIGN OF WIND GIRDERS FOR OPEN-TOP TANKS

3.4.1 Open-top tanks shall be provided with stiffening rings to maintain roundness when the tank is subjected to wind loads. Stiffening rings shall be located at or near the top of the top course, and preferably on the outside of the tank shell.

3.4.2 The required minimum section modulus of the stiffening ring shall be determined by the equation:

$$Z = 0.0001 D^2 H_2$$

Wherein:

Z = section modulus, in inches, cubed.
D = nominal diameter of tank, in feet.
H₂ = height of tank shell, in feet, including any "freeboard" provided above the maximum filling height as a guide for a floating roof.

3.4.3 The section modulus of the stiffening ring shall be based upon the properties of the applied members and may include a portion of the tank shell for a distance of 16 plate thicknesses below and, if applicable, above the ring shell attachment. When curb angles are attached to the top edge of the shell ring by butt welding, this distance shall be reduced by the width of the vertical leg of the angle.

NOTE: Section moduli values for typical ring members are given in Appendix A.

3.4.4 Stiffening rings may be made of either structural sections, formed plate sections, or sections built up by welding, or of combinations of such types of sections assembled by welding. The outer periphery of stiffening rings may be circular or polygonal.

3.4.5 The minimum size of angle for use alone, or as a component in a built-up stiffening ring, shall be 2½ x 2½ x ¼ in. The minimum nominal thickness of plate for use in formed or built-up stiffening rings shall be ¼ in.

3.4.6 When stiffening rings are located more than 2 ft. 0 in. below the top of the shell, the tank shall be provided with a 2½ x 2½ x ⅜-in. top curb angle for ⅜-in. shells and a 3 x 3 x ¼-in. angle for shells greater than ⅜-in., or other members of equivalent section modulus.

3.4.7 Rings of such design that liquid may be trapped thereon shall be provided with adequate drain holes.

3.4.8 Stiffening rings or portions thereof which are regularly used as a walkway, shall have a width of not less than 24 in. clear of the projecting curb angle on the top of the tank shell, shall be located preferably 3 ft. 6 in. below the top of the curb angle, and shall be provided with a standard railing on the unprotected side and at the ends of the section so used.

3.4.9 When a stair opening is installed through a stiffening ring, the section modulus of that portion of the ring outside the opening, and including the transition section, shall conform to the requirements of Par. 3.4.2. The shell adjacent to such opening shall be stiffened with an angle, or bar placed horizontally. The other sides of the opening shall be stiffened with an angle, or bar placed vertically. The cross-sectional area of these rim stiffeners shall be at least equivalent to the cross-sectional area of that portion of shell included in the section modulus calculations of the stiffening ring (Par. 3.4.3). These stiffeners, or additional members, shall furnish a suitable toe board around the opening. The stiffening members shall extend beyond the end of the opening for a distance equal to, or greater than, the minimum depth of the regular ring sections. The end stiffening members shall frame into the side stiffening members and shall be connected to them in such manner as to develop their full strength.

3.4.10 Supports shall be provided for all stiffening rings when the dimension of the horizontal leg or web exceeds 16 times the leg or web thickness. Such supports shall be spaced at intervals as required for the dead load and vertical live load that may be placed upon the ring. However, the spacing shall not exceed 24 times the width of the outside compression flange.

3.4.11 Continuous welds shall be used for all joints which, because of their location, may be subjected to corrosion from entrapped moisture or cause rust markings on the tank shell. Full-penetration butt welds shall be used for joining ring sections.

3.5 ROOF DESIGN

3.5.1 Definitions. The following definition shall apply

- Column-Supported Cone Roof.** A column-supported cone roof is a roof formed to approximately the surface of a right cone. The principal support for the roof is provided by internal roof column and rafters.
- Self-Supporting Cone Roof.** A self-supporting cone roof is a roof formed to approximately the surface of a right cone. The roof is supported only on its periphery (without supporting columns).
- Self-Supporting Dome Roof.** A self-supporting dome roof is a roof formed to approximately a spherical surface and supported only on its periphery (without supporting columns).
- Self-Supporting Umbrella Roof.** A self-supporting umbrella roof is a modified dome roof so formed that any horizontal section is a regular polygon with as many sides as there are roof plates.

Column-Supported Cone Roof

3.5.2 Loading. The roof and supporting structure of a column-supported cone roof shall be designed to support a live load of not less than 25 lb. per sq. ft. of projected area, in addition to the dead load.

3.5.3 Thickness. Roof plates shall have a minimum nominal thickness of $\frac{3}{8}$ in. (7.65 lb. per sq. ft.; see Par. 2.2). Roof plates shall be welded on the top side only, with continuous full-fillet welds on all seams.

3.5.4 Attachment. Roof plates shall be attached to the top angle of the tank with a continuous fillet weld on the top side only. The size of the weld shall be $\frac{3}{8}$ in., or smaller if so specified on the purchase order. Roof plates shall not be attached to the rafters.

NOTE: These restrictions are intended to provide a frangible joint which will fail preferentially to the tank shell, in case of excessive internal pressure, also to provide flexibility of the tank roof for the same reason.

3.5.5 Allowable Stresses. All parts of the structure shall be so proportioned that the sum of the maximum static stresses, in pounds per square inch, shall not exceed the following:

Tension

Rolled steel, on net section.....	18,000
Welds, on section through weld throat.....	15,600

Compression

Rolled steel, on short lengths or where lateral deflection is prevented.....	18,000
Welds, on section through weld throat.....	18,000
On gross section of columns.....	18,000

$$1 + \frac{L^2}{18,000 r^2}$$

with a maximum of.....15,000
Wherein: L is the unbraced length of the column, and r is the corresponding least radius of gyration of the section, both in inches.

For main compression members, the ratio L/r shall not exceed.....180

For bracing and other secondary members, the ratio L/r shall not exceed.....200

Bending

On extreme fibers of rolled sections, and built-up sections, net section, if lateral deflection is prevented.....18,000

When the unsupported length L exceeds $15 \times b$ (the width of the compression flange) the stress, in pounds per square inch, in the latter shall not exceed.....
$$20,000 \div \left(1 + \frac{L^2}{2,000 b^2} \right)$$

The laterally unsupported length of beams and girders shall not exceed $40 \times b$ (the width of the compression flange).

The foregoing restrictions limiting beams to lengths with an L/b ratio not greater than 40, and to stress not greater than permitted by the formula for L/b ratios greater than 15, do not apply to rafters which are in contact with the steel roof plating, it being assumed that under full load conditions, friction between the roof sheets and the rafters will provide adequate lateral support to the compression flanges of the rafters.

Shearing

On end welds for structural attachment.....13,600

On side welds for structural attachment.....10,200

On the gross area of the webs of beams and girders, where h (the clear distance between web flanges in inches) is not more than $60t$ (the thickness of the web, in inches), or when the web is adequately stiffened 12,000

On the gross area of the webs of beams and girders, if the web is not stiffened where h is more than $60 \times t$ the greatest average shear per square inch, V/A , shall not exceed.....
$$18,000 \div \left(1 + \frac{h^2}{7,200 t^2} \right)$$

Wherein: V is the total shear, and A is gross area of web in square inches.

3.5.6 Roof Columns. Structural shapes or, at the option of the purchaser, steel pipes shall be used for roof columns. Clip guides shall be installed on tank bottoms to prevent lateral movement of column bases. Rafter clips shall be welded to the tank shell; column-base clip guides shall be welded to the tank bottom. All other structural attachments shall be either bolted, riveted, or welded.

3.5.7 Roof Slope. The slope of column-supported conical roofs shall be $\frac{3}{4}$ in. in 12 in., or other value as ordered by the purchaser. If the rafters are set directly on chord girders, producing slightly varying rafter slopes, the slope of the flattest rafter shall conform to the specified or ordered roof slope.

3.5.8 Rafters. Rafters shall have a minimum web thickness of 0.17 in. and shall be spaced so that, in the outer ring, their centers shall not be more than 2 pi ft.

(2 times 3.1416) apart, measured along the circumference of the tank. Spacing on inner rings shall not be greater than 5½ ft. In earthquake territory, ¾-in. diameter tie rods shall be placed between the rafters in the outer ring. These tie rods may be omitted if I or H sections are used as rafters.

3.5.9 Self-Supporting Cone Roofs. Self-supporting cone roofs shall conform to the following requirements*.

- a. Maximum $\theta = 37$ deg. (tangent = 9:12)
- b. Minimum $\sin \theta = 0.165$ (slope 2 in. in 12 in.)
- c. Minimum $t = \frac{D}{400 \sin \theta}$ but not less than ⅜ in.
- d. Maximum $t = \frac{1}{2}$ in.
- e. The cross-sectional area of the top angle, in square inches, plus the cross-sectional areas of the shell and roof plates within a distance of 16 times their thicknesses, measured from their most remote point of attachment to the top angle, shall equal or exceed $\frac{D^2}{3,000 \sin \theta}$.

Wherein:

θ = angle of cone elements with the horizontal, in degrees.

D = nominal diameter of the tank shell, in feet.

t = nominal thickness of the roof plates, in inches.

3.5.10 Self-Supporting Dome and Umbrella Roofs. Self-supporting dome and umbrella roofs shall conform to the following requirements.*

*The formulas applying to self-supporting roofs provide for a live load of 25 lb. per sq. ft.

- a. $R = D$ (unless otherwise specified by the purchaser)
- b. Minimum $R = 0.80D$
- c. Maximum $R = 1.2D$
- d. Minimum $t = \frac{R}{200}$ but not less than ⅜ in.
- e. Maximum $t = \frac{1}{2}$ in.
- f. The cross-sectional area of the top angle, in square inches, plus the cross-sectional areas of the shell and roof plates, within a distance of 16 times their thicknesses, measured from their most remote point of attachment to the top angle, shall equal or exceed $\frac{DR}{1,500}$.

Wherein:

R = radius of curvature of the roof, in feet.

D = nominal diameter of the tank shell, in feet.

t = nominal thickness of the roof plates, in inches.

3.5.11 The top angle sections for self-supporting roofs shall be joined by butt welds having complete penetration and fusion. Joint efficiency factors need not be applied in conforming to the requirements of Par. 3.5.9 and 3.5.10.

3.5.12 For self-supporting roofs, whether of the cone, dome, or umbrella types, the edges of the roof plates, at the option of the manufacturer, may be flanged horizontally to rest flat against the top angle to improve welding conditions.

3.6 TANK APPURTENANCES

General

3.6.1 When appurtenances are installed on tanks conforming to this specification, the use of appurtenances as specified herein is required, except that alternative designs of appurtenances, other than flush-type, cleanout fittings and bolted door sheets, which provide equivalent strength, tightness, and utility, are permissible if so agreed to by the purchaser. Flush-type cleanout fittings and bolted door sheets shall conform to the designs specified in Par. 3.6.8 and 3.6.11, until existing requirements are revised to permit alternative designs as may be shown to be safe by additional field experience or further development work.

3.6.2 Manhole necks, nozzle necks, reinforcing plates, and shell-plate openings, which have either sheared or oxygen-cut surfaces, shall have such surfaces made uniform and smooth, with the corners rounded, except where such surfaces are fully covered by attachment welds.

Shell Manholes

3.6.3 Shell manholes shall conform to Fig. 7 and Tables 1 through 5. Manhole reinforcing plates, and segments thereof if not made in one piece, shall be provided with a ¾-in. diameter tell-tale hole (for the

purpose of detecting leakage through the interior welds). Such holes shall be located substantially on the horizontal centerline and shall be left open to the atmosphere.

3.6.4 Manhole frames may be press-formed or of built-up welded construction. The dimensions listed in the tables are given to cover both types of construction. Allowance has been made for thinning of the neck of the formed type in the pressing operation, or for the minimum neck thickness listed for the built-up type.

3.6.5 The maximum diameter of the shell cutout shall be the sum of the inside diameter of the frame plus four times the attachment flange thickness plus one inch. Dimensions are listed in the tables for a pressed frame using a constant-diameter ring die, and for a built-up frame. The latter dimensions apply conservatively to a pressed frame using a constant-diameter plug die.

Shell Nozzles

3.6.6 Shell nozzles shall conform to Fig. 8 and 9, and Tables 6, 7, and 8. Nozzle reinforcing plates, and segments thereof if not made in one piece, shall be pro-

vided with a ¼-in. diameter tell-tale hole, located substantially on the horizontal centerline and left open to the atmosphere.

3.6.7 Details and dimensions specified herein are for nozzles installed with their axes perpendicular to the shell plate. Nozzles may be installed at an angle of other than 90 deg. to the shell plate in a horizontal plane, provided the width of the reinforcing plate (dimension *W*, Fig. 8 and Table 6) is increased by the amount that the horizontal chord of the opening cut in the shell plate (dimension *D_p*, Fig. 8 and Table 7) increases as the opening changes from circular to elliptical in making the angular installation. In addition, nozzles not larger than 3-in. nominal pipe size, for insertion of thermometer wells, sampling connections, or other purposes not involving the attachment of extended piping, may be installed at an angle of 15 deg. or less, off perpendicular in a vertical plane, without modification of the nozzle reinforcing plate.

Flush-Type Cleanout Fittings

3.6.8 Flush-type cleanout fittings shall conform to Par. 3.3.20, Fig. 10 and Tables 9, 10, and 11.

3.6.9 When a flush-type cleanout fitting is installed on a tank resting on an earth grade without concrete or masonry walls under the tank shells, provision shall be made to support the fitting and retain the grade by either of the following methods.

Method A: Install a vertical steel bulkhead plate under the tank, along the contour of the tank shell and symmetrical with the opening as shown in Fig. 11, Method A.

Method B: Install a concrete or masonry retaining wall under the tank, with its outer face conforming to the contour of the tank shell as shown in Fig. 11, Method B.

3.6.10 When a flush-type cleanout fitting is installed on a tank resting on a ring wall, a notch having the dimensions shown in Fig. 11, Method C, shall be provided to accommodate the cleanout fitting.

3.6.11 When a flush-type cleanout fitting is installed on a tank resting on an earth grade inside a foundation retaining wall, a notch shall be provided in the retaining wall to accommodate the fitting and a supplementary inside retaining wall shall be provided to support the fitting and retain the grade. The dimensions shall be as shown in Fig. 11, Method D.

3.6.12 Bolted Door Sheets. Flush-type bolted door sheets shall conform to Fig. 19 and Table 20.

3.6.13 When a flush-type bolted door sheet is installed on a tank resting on an earth grade with or without a concrete retaining wall and without a concrete or masonry wall under the tank shell, provision shall be made to support the fitting and retain the grade by the method shown in Fig. 20, Method A.

3.6.14 When a flush-type bolted door sheet is installed on a tank resting on a ring wall, a cutout having the dimensions shown in Fig. 20, Method B shall be provided.

3.6.15 Raised-type bolted door sheets shall conform to Fig. 21 and Table 21.

3.6.16 Roof Manholes. Roof manholes shall conform to Fig. 12 and Table 12. Where work is expected to be carried on through the manhole opening during the use of the tank, it is recommended that the roof structure around the manhole be suitably reinforced.

3.6.17 Roof Nozzles. Flanged roof nozzles shall conform to Fig. 13 and Table 13. Threaded nozzles shall conform to Fig. 14 and Table 14.

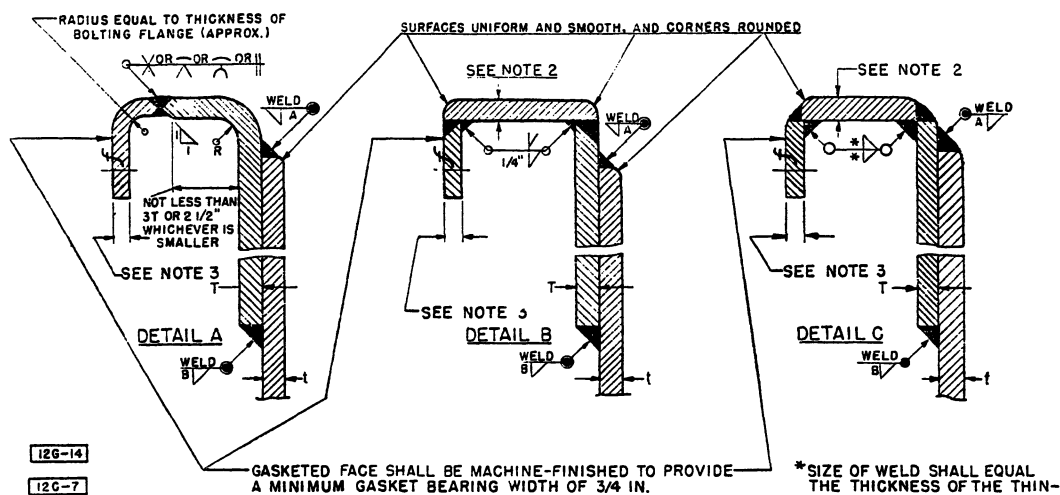
3.6.18 Water Draw-Off Elbows. Water draw-off elbows shall conform to Fig. 15 and Table 15. Cast steel fittings conforming to Fig. 16 and Table 16 may be substituted, at purchaser's option, and attached by welding.

3.6.19 Draw-Off Sumps. Draw-off sumps shall conform to Fig. 17.

3.6.20 Scaffold-Cable Support. Supports for scaffold cables shall conform to Fig. 18.

3.6.21 Threaded Connections. Threaded piping connections shall be female, threads to be the API line-pipe thread in accordance with API Std 6A: Threads in Valves, Fittings, and Flanges.

3.6.22 Platforms, Walkways, and Stairways. Platforms, walkways, and stairways shall be in accordance with Tables 17, 18, and 19.



NOTE 1: Gasket material shall be long-fiber asbestos sheet, unless otherwise specified.
NOTE 2: See Tables 2 through 5.
NOTE 3: See Table 1.

See Tables 1, 2, 3, 4, and 5

TABLE 1
SHELL MANHOLE COVER PLATE AND BOLTING FLANGE THICKNESS
See Fig. 7. All dimensions in inches except as otherwise stated.

1 Max. Tank Height, ft.	2 Equivalent Pressure,* psi.	3 Minimum Cover Plate Thickness				7 Minimum Bolting Flange Thickness After Finishing			
		20-in. Manhole	24-in. Manhole	30-in. Manhole	36-in. Manhole	20-in. Manhole	24-in. Manhole	30-in. Manhole	36-in. Manhole
21	9.1	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$
27	11.7	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{7}{16}$
32	13.9	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
40	17.4	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{16}$
45	19.5	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$
54	23.4	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{11}{16}$
65	28.2	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
75	32.5	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{11}{16}$

*Equivalent pressure is based on water loadings.

TABLE 2
20-IN. SHELL MANHOLE
See Fig. 7. All dimensions in inches.

1	2	3	4	5	6	7	8	9	10	11	
Shell Thickness and Manhole Attachment Flange Thickness ¹ <i>t and T</i>	Size of Fillet		Approx. Radius <i>R</i>	Attachment Flange		Frame Using Constant-Diameter Ring Die		Built-Up Frame or Frame Using Constant-Diameter Plug Die			Add Reinforcement if Neck Thickness is Less Than ²
	Weld <i>A</i>	Weld <i>B</i>		Length of Side <i>L</i>	Width <i>W</i>	Inside Diam. of Manhole Frame <i>ID_s</i>	Max. Diam. of Hole in Shell ³ <i>D_{HR}</i>	Inside Diam. of Manhole Frame <i>ID_p</i>	Max. Diam. of Hole in Shell <i>D_{HP}</i>		
$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{8}$	46	55	22 $\frac{5}{8}$	24 $\frac{1}{4}$	20	21 $\frac{3}{4}$		
$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	46	55	22 $\frac{1}{2}$	24 $\frac{1}{2}$	20	22		
$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	45 $\frac{3}{4}$	54 $\frac{3}{4}$	22 $\frac{3}{8}$	24 $\frac{1}{2}$	20	22 $\frac{1}{4}$		
$\frac{3}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	45 $\frac{1}{2}$	54 $\frac{1}{2}$	22 $\frac{1}{4}$	24 $\frac{3}{4}$	20	22 $\frac{1}{2}$		
$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	45 $\frac{1}{4}$	53 $\frac{3}{4}$	22 $\frac{1}{8}$	24 $\frac{3}{4}$	20	22 $\frac{3}{4}$		
$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	45	53 $\frac{1}{2}$	22	25	20	23		
$\frac{5}{8}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	44 $\frac{3}{4}$	53	21 $\frac{7}{8}$	25	20	23 $\frac{1}{4}$		
$\frac{1}{2}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	44 $\frac{3}{4}$	53	21 $\frac{3}{4}$	25 $\frac{1}{4}$	20	23 $\frac{1}{2}$		
$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	44 $\frac{1}{2}$	52 $\frac{1}{2}$	21 $\frac{5}{8}$	25 $\frac{1}{4}$	20	23 $\frac{3}{4}$		
$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	44 $\frac{1}{4}$	52 $\frac{1}{4}$	21 $\frac{1}{2}$	25 $\frac{1}{2}$	20	24		
$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	44	51 $\frac{3}{4}$	21 $\frac{1}{2}$	25 $\frac{1}{2}$	20	24 $\frac{1}{4}$	$\frac{1}{8}$	
$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	44	51 $\frac{3}{4}$	21 $\frac{1}{4}$	25 $\frac{3}{4}$	20	24 $\frac{1}{2}$	$\frac{3}{8}$	
$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	44 $\frac{1}{4}$	52	21 $\frac{1}{8}$	25 $\frac{3}{4}$	20	24 $\frac{3}{4}$	$\frac{1}{2}$	
1	$\frac{1}{2}$	1	1	44 $\frac{1}{2}$	52 $\frac{1}{4}$	21	26	20	25	$\frac{7}{16}$	
1 $\frac{1}{8}$	$\frac{1}{2}$	1 $\frac{1}{8}$	1	44 $\frac{3}{4}$	52 $\frac{1}{2}$	20 $\frac{7}{8}$	26	20	25 $\frac{1}{4}$	$\frac{7}{16}$	
1 $\frac{1}{2}$	$\frac{1}{8}$	1 $\frac{1}{2}$	1	44 $\frac{3}{4}$	52 $\frac{1}{2}$	20 $\frac{3}{4}$	26 $\frac{1}{4}$	20	25 $\frac{1}{2}$	$\frac{1}{2}$	
1 $\frac{1}{8}$	$\frac{1}{8}$	1 $\frac{1}{8}$	1	45	52 $\frac{3}{4}$	20 $\frac{5}{8}$	26 $\frac{1}{4}$	20	25 $\frac{3}{4}$	$\frac{1}{8}$	
1 $\frac{1}{4}$	$\frac{5}{8}$	1 $\frac{1}{4}$	1	45	52 $\frac{3}{4}$	20 $\frac{1}{2}$	26 $\frac{1}{2}$	20	26	$\frac{5}{8}$	
1 $\frac{1}{8}$	$\frac{5}{8}$	1 $\frac{1}{8}$	1	45 $\frac{1}{4}$	53	20 $\frac{3}{4}$	26 $\frac{1}{2}$	20	26 $\frac{1}{4}$	$\frac{5}{8}$	
1 $\frac{3}{8}$	$\frac{1}{2}$	1 $\frac{3}{8}$	1	45 $\frac{1}{4}$	53	20 $\frac{1}{4}$	26 $\frac{3}{4}$	20	26 $\frac{3}{4}$	$\frac{1}{2}$	
1 $\frac{7}{8}$	$\frac{1}{2}$	1 $\frac{7}{8}$	1	45 $\frac{1}{2}$	53 $\frac{1}{4}$	20 $\frac{1}{8}$	26 $\frac{3}{4}$	20	26 $\frac{3}{4}$	$\frac{1}{2}$	
1 $\frac{1}{2}$	$\frac{3}{4}$	1 $\frac{1}{2}$	1	45 $\frac{1}{2}$	53 $\frac{1}{4}$	20	27	20	27	$\frac{3}{4}$	

Diameter of bolt circle D_B=26 $\frac{1}{4}$ in.

Diameter of cover plate D_C=28 $\frac{3}{4}$ in.

¹If a thicker shell plate is used than is required for the hydrostatic loading (Sect. 3.3, Shell Design), the excess shell-plate thickness, within a vertical distance, both above and below the centerline of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate, may be considered as reinforcement, and the thickness T of the manhole attachment flange may be decreased accordingly. In such cases, the reinforcement and the attachment welding shall conform to the design limits specified in Sect. 3.3, for reinforcement of shell openings.

²The minimum neck thickness shall be the thickness of the shell plate, or the allowable finished thickness of the bolting flange (see Table 1), whichever is the thinner, but in no case shall the neck in a built-up manhole be thinner than the thicknesses given in Col. 11. If the neck thickness on a built-up manhole is greater than the required minimum, the manhole attachment flange may be decreased accordingly within the limits specified in Sect. 3.3, Shell Design.

³Hole in shell may be made oval, with horizontal major diameter of 29 in. where necessary for removal of rigid scaffold brackets.

TABLE 3
24-IN. SHELL MANHOLE
See Fig. 7. All dimensions in inches.

1	2	3	4	5	6	7	8	9	10	11
Shell Thickness and Manhole Attachment Flange Thickness ¹ <i>t</i> and <i>T</i>	Size of Fillet		Approx. Radius <i>R</i>	Attachment Flange		Frame Using Constant-Diameter Ring Die		Built-Up Frame or Frame Using Constant-Diameter Plug Die		Add Reinforcement if Neck Thickness is Less Than ²
	Weld <i>A</i>	Weld <i>B</i>		Length of Side <i>L</i>	Width <i>W</i>	Inside Diam. of Manhole Frame <i>ID_R</i>	Max. Diam. of Hole in Shell <i>D_{HR}</i>	Inside Diam. of Manhole Frame <i>ID_P</i>	Max. Diam. of Hole in Shell <i>D_{HP}</i>	
$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	54	65	26 $\frac{5}{8}$	28 $\frac{1}{4}$	24	25 $\frac{3}{4}$	
$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	54	64 $\frac{3}{4}$	26 $\frac{1}{2}$	28 $\frac{1}{2}$	24	26	
$\frac{1}{8}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	53 $\frac{3}{4}$	64 $\frac{1}{2}$	26 $\frac{3}{4}$	28 $\frac{1}{2}$	24	26 $\frac{1}{4}$	
$\frac{3}{8}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	53 $\frac{1}{2}$	64	26 $\frac{1}{4}$	28 $\frac{3}{4}$	24	26 $\frac{1}{2}$	
$\frac{1}{2}$	$\frac{3}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	53 $\frac{1}{2}$	64	26 $\frac{1}{2}$	28 $\frac{3}{4}$	24	26 $\frac{3}{4}$	
$\frac{1}{2}$	$\frac{3}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	53 $\frac{1}{4}$	63 $\frac{1}{2}$	26	29	24	27	
$\frac{5}{8}$	$\frac{3}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	53	63	25 $\frac{7}{8}$	29	24	27 $\frac{1}{4}$	
$\frac{1}{2}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	52 $\frac{3}{4}$	62 $\frac{3}{4}$	25 $\frac{3}{4}$	29 $\frac{1}{4}$	24	27 $\frac{1}{2}$	
$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	52 $\frac{1}{2}$	62 $\frac{1}{4}$	25 $\frac{5}{8}$	29 $\frac{1}{4}$	24	27 $\frac{3}{4}$	
$\frac{3}{4}$	$\frac{3}{16}$	$\frac{3}{4}$	$\frac{3}{4}$	52 $\frac{1}{2}$	62 $\frac{1}{4}$	25 $\frac{1}{2}$	29 $\frac{1}{2}$	24	28	
$\frac{1}{2}$	$\frac{3}{16}$	$\frac{1}{2}$	$\frac{3}{4}$	52 $\frac{1}{4}$	61 $\frac{3}{4}$	25 $\frac{3}{8}$	29 $\frac{1}{2}$	24	28 $\frac{1}{4}$	
$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	52 $\frac{1}{4}$	61 $\frac{3}{4}$	25 $\frac{1}{4}$	29 $\frac{3}{4}$	24	28 $\frac{1}{2}$	$\frac{1}{8}$
$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	52 $\frac{1}{4}$	61 $\frac{3}{4}$	25 $\frac{1}{4}$	29 $\frac{3}{4}$	24	28 $\frac{3}{4}$	$\frac{1}{8}$
1	$\frac{7}{16}$	1	1	52 $\frac{3}{4}$	62 $\frac{1}{4}$	25	30	24	29	$\frac{1}{8}$
$1\frac{1}{16}$	$\frac{7}{16}$	$1\frac{1}{16}$	1	52 $\frac{3}{4}$	62 $\frac{1}{4}$	24 $\frac{7}{8}$	30	24	29 $\frac{1}{4}$	$\frac{1}{8}$
$1\frac{1}{8}$	$\frac{1}{2}$	$1\frac{1}{8}$	1	53	62 $\frac{1}{2}$	24 $\frac{3}{4}$	30 $\frac{1}{4}$	24	29 $\frac{1}{2}$	$\frac{1}{8}$
$1\frac{1}{8}$	$\frac{1}{2}$	$1\frac{1}{8}$	1	53	62 $\frac{1}{2}$	24 $\frac{5}{8}$	30 $\frac{1}{4}$	24	29 $\frac{3}{4}$	$\frac{1}{8}$
$1\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$	1	53 $\frac{1}{4}$	62 $\frac{3}{4}$	24 $\frac{1}{2}$	30 $\frac{1}{2}$	24	30	$\frac{1}{8}$
$1\frac{1}{8}$	$\frac{5}{8}$	$1\frac{1}{8}$	1	53 $\frac{1}{4}$	62 $\frac{3}{4}$	24 $\frac{3}{8}$	30 $\frac{1}{2}$	24	30 $\frac{3}{4}$	$\frac{5}{16}$
$1\frac{3}{8}$	$\frac{5}{8}$	$1\frac{3}{8}$	1	53 $\frac{1}{2}$	63	24 $\frac{1}{4}$	30 $\frac{3}{4}$	24	30 $\frac{1}{2}$	$\frac{5}{16}$
$1\frac{1}{8}$	$\frac{5}{8}$	$1\frac{1}{8}$	1	53 $\frac{1}{2}$	63	24 $\frac{1}{8}$	30 $\frac{3}{4}$	24	30 $\frac{3}{4}$	$\frac{1}{2}$
$1\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{2}$	1	53 $\frac{3}{4}$	63 $\frac{1}{4}$	24	31	24	31	$\frac{3}{4}$

Diameter of bolt circle $D_B=30\frac{1}{4}$ in.Diameter of cover plate $D_C=32\frac{1}{4}$ in.

¹If a thicker shell plate is used than is required for the hydrostatic loading (Sect. 3.3, Shell Design), the excess shell-plate thickness, within a vertical distance, both above and below the centerline of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate, may be considered as reinforcement, and the thickness *T* of the manhole attachment flange may be decreased accordingly. In such cases, the reinforcement and the attachment welding shall conform to the design limits specified in Sect. 3.3, for reinforcement of shell openings.

²The minimum neck thickness shall be the thickness of the shell plate, or the allowable finished thickness of the bolting flange (see Table 1), whichever is the thinner, but in no case shall the neck in a built-up manhole be thinner than the thicknesses given in Col. 11. If the neck thickness on a built-up manhole is greater than the required minimum, the manhole attachment flange may be decreased accordingly within the limits specified in Sect. 3.3, Shell Design.

TABLE 4
30-IN. SHELL MANHOLE
 See Fig. 7. All dimensions in inches.

1	2	3	4	5	6	7	8	9	10	11
Shell Thickness and Manhole Attachment Flange Thickness ¹ <i>t</i> and <i>T</i>	Size of Fillet		Approx. Radius <i>R</i>	Attachment Flange		Frame Using Constant-Diameter Ring Die		Built-Up Frame or Frame Using Constant-Diameter Plug Die		
	Weld <i>A</i>	Weld <i>B</i>		Length of Side <i>L</i>	Width <i>W</i>	Inside Diam. of Manhole Frame <i>ID_F</i>	Max. Diam. of Hole in Shell <i>D_{HR}</i>	Inside Diam. of Manhole Frame <i>ID_F</i>	Max. Diam. of Hole in Shell <i>D_{HR}</i>	Add Reinforcement if Neck Thickness is Less Than ²
$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	66	79 $\frac{1}{4}$	32 $\frac{5}{8}$	34 $\frac{1}{4}$	30	31 $\frac{3}{4}$	
$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	66	79 $\frac{1}{4}$	32 $\frac{1}{2}$	34 $\frac{1}{2}$	30	32	
$\frac{5}{16}$	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	65 $\frac{3}{4}$	78 $\frac{3}{4}$	32 $\frac{3}{8}$	34 $\frac{1}{2}$	30	32 $\frac{1}{4}$	
$\frac{3}{8}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	65 $\frac{1}{4}$	78 $\frac{3}{4}$	32 $\frac{1}{4}$	34 $\frac{1}{2}$	30	32 $\frac{1}{2}$	
$\frac{7}{16}$	$\frac{3}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	65 $\frac{1}{4}$	78	32 $\frac{1}{8}$	34 $\frac{1}{2}$	30	32 $\frac{3}{4}$	
$\frac{1}{2}$	$\frac{3}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	65 $\frac{1}{4}$	78	32	35	30	33	
$\frac{5}{8}$	$\frac{3}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	65	77 $\frac{1}{2}$	31 $\frac{7}{8}$	35	30	33 $\frac{1}{4}$	
$\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	64 $\frac{3}{4}$	77	31 $\frac{3}{4}$	35 $\frac{1}{4}$	30	33 $\frac{1}{2}$	
$1\frac{1}{8}$	$\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	64 $\frac{1}{2}$	76 $\frac{3}{4}$	31 $\frac{1}{8}$	35 $\frac{1}{4}$	30	33 $\frac{3}{4}$	
$\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	64 $\frac{1}{2}$	76 $\frac{3}{4}$	31 $\frac{1}{2}$	35 $\frac{1}{2}$	30	34	
$1\frac{1}{8}$	$\frac{3}{8}$	$1\frac{1}{8}$	$\frac{3}{4}$	64 $\frac{1}{4}$	76 $\frac{1}{4}$	31 $\frac{3}{8}$	35 $\frac{1}{2}$	30	34 $\frac{1}{4}$	
$\frac{7}{8}$	$\frac{3}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	64 $\frac{1}{4}$	76 $\frac{1}{4}$	31 $\frac{1}{4}$	35 $\frac{3}{4}$	30	34 $\frac{1}{2}$	$\frac{1}{8}$
$1\frac{1}{8}$	$\frac{3}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$	64 $\frac{1}{4}$	76 $\frac{1}{4}$	31 $\frac{1}{8}$	35 $\frac{3}{4}$	30	34 $\frac{3}{4}$	$\frac{1}{8}$
1	$\frac{3}{8}$	1	1	64 $\frac{3}{4}$	76 $\frac{3}{4}$	31	36	30	35	$\frac{1}{8}$
$1\frac{1}{8}$	$\frac{3}{8}$	$1\frac{1}{8}$	1	64 $\frac{3}{4}$	76 $\frac{3}{4}$	30 $\frac{7}{8}$	36	30	35 $\frac{1}{4}$	$\frac{1}{8}$
$1\frac{1}{4}$	$\frac{7}{16}$	$1\frac{1}{4}$	1	65	77	30 $\frac{3}{4}$	36 $\frac{1}{4}$	30	35 $\frac{1}{2}$	$\frac{1}{4}$
$1\frac{3}{8}$	$\frac{7}{16}$	$1\frac{3}{8}$	1	65	77	30 $\frac{1}{8}$	36 $\frac{1}{4}$	30	35 $\frac{3}{4}$	$\frac{1}{8}$
$1\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$	1	65 $\frac{1}{4}$	77 $\frac{1}{4}$	30 $\frac{1}{2}$	36 $\frac{1}{2}$	30	36	$\frac{1}{8}$
$1\frac{3}{8}$	$\frac{1}{2}$	$1\frac{3}{8}$	1	65 $\frac{1}{4}$	77 $\frac{1}{4}$	30 $\frac{3}{8}$	36 $\frac{1}{2}$	30	36 $\frac{1}{4}$	$\frac{5}{16}$
$1\frac{5}{8}$	$\frac{1}{2}$	$1\frac{5}{8}$	1	65 $\frac{1}{2}$	77 $\frac{1}{2}$	30 $\frac{1}{4}$	36 $\frac{3}{4}$	30	36 $\frac{1}{2}$	$\frac{5}{8}$
$1\frac{7}{8}$	$\frac{3}{4}$	$1\frac{7}{8}$	1	65 $\frac{1}{2}$	77 $\frac{1}{2}$	30 $\frac{1}{8}$	36 $\frac{3}{4}$	30	36 $\frac{3}{4}$	$1\frac{1}{8}$
$1\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	1	65 $\frac{3}{4}$	77 $\frac{3}{4}$	30	37	30	37	$\frac{3}{4}$

Diameter of bolt circle $D_B=36\frac{1}{4}$ in.Diameter of cover plate $D_C=38\frac{1}{4}$ in.

¹If a thicker shell plate is used than is required for the hydrostatic loading (Sect. 3.3, Shell Design), the excess shell-plate thickness, within a vertical distance, both above and below the centerline of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate, may be considered as reinforcement, and the thickness *T* of the manhole attachment flange may be decreased accordingly. In such cases, the reinforcement and the attachment welding shall conform to the design limits specified in Sect. 3.3, for reinforcement of shell openings.

²The minimum neck thickness shall be the thickness of the shell plate, or the allowable finished thickness of the bolting flange (see Table 1), whichever is the thinner, but in no case shall the neck in a built-up manhole be thinner than the thicknesses given in Col. 11. If the neck thickness on a built-up manhole is greater than the required minimum, the manhole attachment flange may be decreased accordingly within the limits specified in Sect. 3.3, Shell Design.

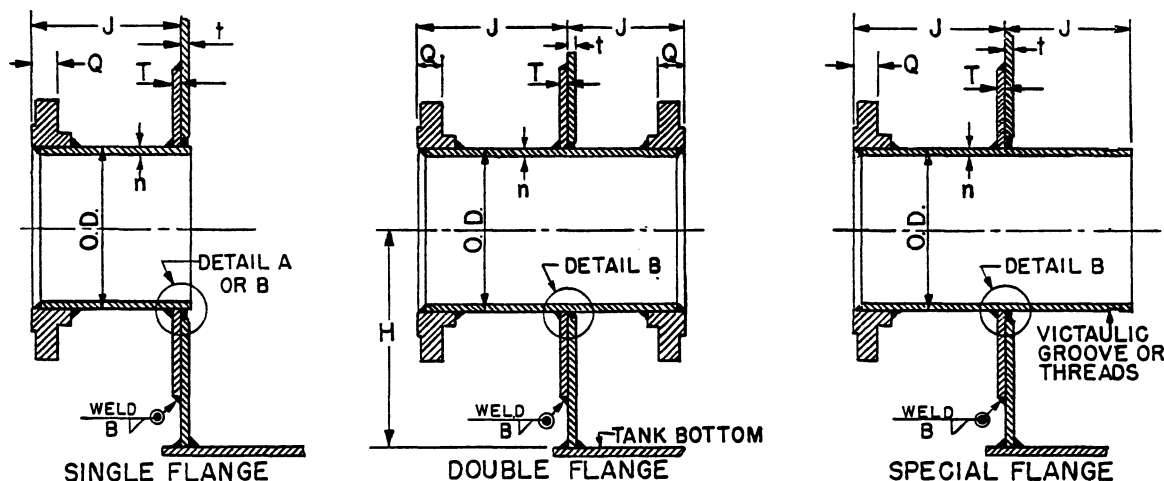
TABLE 5
36-IN. SHELL MANHOLE
 See Fig. 7. All dimensions in inches.

1	2	3	4	5	6	7	8	9	10	11
Shell Thickness and Manhole Attachment Flange Thickness ¹ <i>t</i> and <i>T</i>	Size of Fillet		Approx. Radius <i>R</i>	Attachment Flange		Frame Using Constant-Diameter Ring Die		Built-Up Frame or Frame Using Constant-Diameter Plug Die		
	Weld <i>A</i>	Weld <i>B</i>		Length of Side <i>L</i>	Width <i>W</i>	Inside Diam. of Manhole Frame <i>ID_R</i>	Max. Diam. of Hole in Shell <i>D_{BR}</i>	Inside Diam. of Manhole Frame <i>ID_F</i>	Max. Diam. of Hole in Shell <i>D_{BF}</i>	Add Reinforcement if Neck Thickness is Less Than ²
$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	78	93%	38%	40 $\frac{1}{4}$	36	37%	
$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	78	93%	38 $\frac{1}{2}$	40 $\frac{1}{2}$	36	38	
$\frac{3}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	77 $\frac{3}{4}$	93 $\frac{1}{4}$	38 $\frac{3}{8}$	40 $\frac{1}{2}$	36	38 $\frac{1}{4}$	
$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	77 $\frac{1}{2}$	93 $\frac{1}{2}$	38 $\frac{1}{2}$	40 $\frac{1}{2}$	36	38 $\frac{1}{2}$	
$\frac{5}{8}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	77 $\frac{1}{4}$	92 $\frac{1}{2}$	38 $\frac{1}{8}$	40%	36	38%	
$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	77 $\frac{1}{2}$	92 $\frac{1}{2}$	38	41	36	39	
$\frac{7}{8}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	77	92	37 $\frac{7}{8}$	41	36	39 $\frac{1}{4}$	
1	$\frac{1}{4}$	1	1	76 $\frac{3}{4}$	91 $\frac{1}{2}$	37 $\frac{3}{4}$	41 $\frac{1}{4}$	36	39 $\frac{1}{2}$	
$1\frac{1}{8}$	$\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	76 $\frac{1}{2}$	91 $\frac{1}{4}$	37%	41 $\frac{1}{4}$	36	39%	
$1\frac{1}{4}$	$\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	76 $\frac{1}{2}$	91	37 $\frac{1}{2}$	41 $\frac{1}{2}$	36	40	
$1\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	76 $\frac{1}{4}$	90%	37 $\frac{3}{8}$	41 $\frac{1}{2}$	36	40 $\frac{1}{4}$	
$1\frac{3}{4}$	$\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	76 $\frac{1}{4}$	90%	37 $\frac{1}{2}$	41%	36	40 $\frac{1}{2}$	
2	$\frac{7}{8}$	2	2	76 $\frac{1}{4}$	90%	37 $\frac{1}{8}$	41%	36	40%	$\frac{1}{8}$
$2\frac{1}{8}$	$\frac{1}{2}$	$2\frac{1}{8}$	1	76 $\frac{3}{4}$	91 $\frac{1}{4}$	37	42	36	41	$\frac{1}{8}$
$2\frac{1}{4}$	$\frac{3}{4}$	$2\frac{1}{4}$	1	76 $\frac{3}{4}$	91 $\frac{1}{4}$	36 $\frac{7}{8}$	42	36	41 $\frac{1}{4}$	$\frac{1}{8}$
$2\frac{1}{2}$	$\frac{1}{2}$	$2\frac{1}{2}$	1	77	91 $\frac{1}{2}$	36%	42 $\frac{1}{4}$	36	41 $\frac{1}{2}$	$\frac{1}{4}$
$2\frac{3}{4}$	$\frac{3}{4}$	$2\frac{3}{4}$	1	77	91 $\frac{1}{2}$	36%	42 $\frac{1}{4}$	36	41%	$\frac{1}{8}$
3	$\frac{1}{2}$	3	1	77 $\frac{1}{4}$	91%	36 $\frac{1}{2}$	42 $\frac{1}{2}$	36	42	$\frac{1}{8}$
$3\frac{1}{8}$	$\frac{1}{2}$	$3\frac{1}{8}$	1	77 $\frac{1}{4}$	91%	36%	42 $\frac{1}{2}$	36	42 $\frac{1}{4}$	$\frac{5}{8}$
$3\frac{1}{4}$	$\frac{1}{2}$	$3\frac{1}{4}$	1	77 $\frac{1}{2}$	92	36 $\frac{1}{4}$	42 $\frac{3}{4}$	36	42 $\frac{1}{2}$	$\frac{5}{8}$
$3\frac{1}{2}$	$\frac{1}{2}$	$3\frac{1}{2}$	1	77 $\frac{1}{2}$	92	36 $\frac{1}{8}$	42 $\frac{3}{4}$	36	42 $\frac{3}{4}$	$1\frac{1}{8}$
$3\frac{3}{4}$	$\frac{1}{2}$	$3\frac{3}{4}$	1	77 $\frac{3}{4}$	92 $\frac{1}{4}$	36	43	36	43	$\frac{3}{4}$

Diameter of bolt circle $D_B=42\frac{1}{4}$ in.Diameter of cover plate $D_C=44\frac{3}{4}$ in.

¹If a thicker shell plate is used than is required for the hydrostatic loading (Sect. 3.3, Shell Design), the excess shell-plate thickness, within a vertical distance, both above and below the centerline of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate, may be considered as reinforcement, and the thickness *T* of the manhole attachment flange may be decreased accordingly. In such cases, the reinforcement and the attachment welding shall conform to the design limits specified in Sect. 3.3, for reinforcement of shell openings.

²The minimum neck thickness shall be the thickness of the shell plate, or the allowable finished thickness of the bolting flange (see Table 1), whichever is the thinner, but in no case shall the neck in a built-up manhole be thinner than the thicknesses given in Col. 11. If the neck thickness on a built-up manhole is greater than the required minimum, the manhole attachment flange may be decreased accordingly within the limits specified in Sect. 3.3, Shell Design.



(a) REGULAR TYPE FLANGED NOZZLES-3 IN. AND LARGER

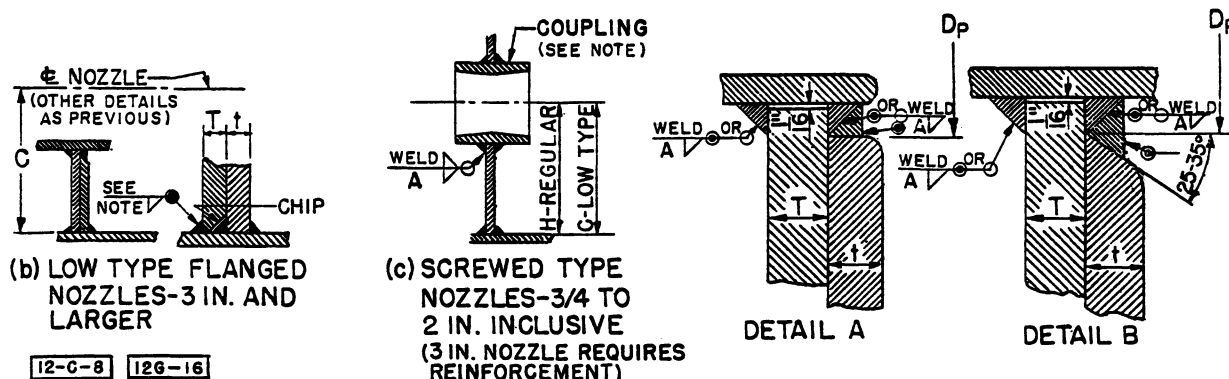


Illustration (c): See Par. 3.6.21: Threaded Connections, regarding couplings used in shell nozzles.

See Tables 6, 7, and 8

TABLE 6
SHELL NOZZLES

See Fig. 8. All dimensions in inches.

1	2	3	4	5	6	7	8	9
Size of Nozzle	O.D. of Pipe	Flanged Nozzle Pipe Wall Thickness, min. ⁽¹⁾ s	Diameter of Hole in Reinf. Plate D _r	Length of Side of Reinf. Plate L	Width of Reinf. Plate W	Distance Shell to Flange Face, min. J	Distance from Bottom of Tank to Center of Nozzle, min.	
							Regular Type H	Low Type C
36	36		36½	72¾	88	14	40	36¾
34	34		34½	68¾	83½	13	38	34¾
32	32	See Table 7,	32½	64¾	78½	13	36	32¾
30	30	Col. 2	30½	60¾	73½	12	34	30¾
28	28		28½	56¾	68¾	12	32	28¾
26	26		26½	52¾	64	12	30	26¾
24	24	0.50	24½	49½	60	12	28	24¾
22	22	0.50	22½	45½	55½	11	26	22¾
20	20	0.50	20½	41½	50½	11	24	20¾
18	18	0.50	18½	37½	45½	10	22	18¾
16	16	0.50	16½	33½	40¾	10	20	16¾
14	14	0.50	14½	29½	36	10	18	14¾
12	12¾	0.50	12¾	27	33	9	17	13½
10	10¾	0.50	10¾	23	28¾	9	15	11½
8	8¾	0.50	8¾	19	23¾	8	13	9¾
6	6¾	0.432	6¾	15¾	19½	8	11	7¾
4	4¾	0.337	4¾	12	15¾	7	9	6
3	3¾	0.300	3¾	10¾	13½	7	8	5½
*2	2¾	0.218	2¾	-----	-----	6	7	3½
*1½	1.90	0.200	2	-----	-----	6	6	3
†3	4.00	Coupling	4½	11¾	14¾	----	9	5¾
*2	2.875	"	3	-----	-----	----	7	3
*1½	2.200	"	2¾	-----	-----	----	6	3
*1	1.576	"	1½	-----	-----	----	5	3
*¾	1.313	"	1½	-----	-----	----	4	3

¹Extra-strong pipe, API Std 5L for sizes up to 12 in. incl.; over 12 in to 24 in. incl. ASTM A 53, A 134, A 135, or A 139, of latest issue. Pipe made from formed plate electrically butt welded, may be substituted for any of the above mentioned pipe sections.

*Flanged and screwed nozzles in 2-in. pipe size and smaller do not require reinforcing plates. D_r will be the diameter of the hole in the shell plate and Weld A will be as given in Col. 6, Table 7. Reinforcing plates may be used if desired.

†Screwed nozzle in the 3-in. pipe size requires reinforcement.

TABLE 7
SHELL NOZZLES: PIPE, PLATE, AND WELDING SCHEDULES

See Fig. 8. All dimensions in inches.

1	2	3	4	5	6
Shell Thickness and Reinf. Plate Thickness ⁽¹⁾ <i>t</i> and <i>T</i>	36", 34", 32", 30", 28" and 26" Flanged Nozzle Pipe Wall Thickness, min. <i>n</i>	Maximum Diameter of Hole in Shell Plate (<i>D_p</i>) Equals OD of Pipe Plus the Following Values	Size of Fillet Weld <i>B</i>	Size of Fillet Weld <i>A</i> for Nozzles Larger than 2"	Size of Fillet Weld <i>A</i> for Nozzles 2", 1½", 1" and ¾"
⅛	⅛	⅝	⅛	¼	¼
¼	¼	⅝	¼	¼	¼
⅜	⅜	⅝	⅜	¼	¼
½	½	⅝	½	¼	¼
⅝	⅝	⅝	⅝	¼	¼
¾	¾	⅝	¾	¼	¼
1	1	⅝	1	¼	¼
1 ⅛	1 ⅛	⅝	1 ⅛	¼	⅝
1 ¼	1 ¼	⅝	1 ¼	¼	⅝
1 ½	1 ½	¾	1 ½	⅝	⅝
1 ¾	1 ¾	¾	1 ¾	⅝	⅝
2	2	¾	2	⅝	⅝
2 ⅛	2 ⅛	¾	2 ⅛	⅝	⅝
2 ¼	2 ¼	¾	2 ¼	⅝	⅝
2 ½	2 ½	¾	2 ½	⅝	⅝
2 ¾	2 ¾	¾	2 ¾	⅝	⅝
3	3	¾	3	⅝	⅝
3 ⅛	3 ⅛	¾	3 ⅛	⅝	⅝
3 ¼	3 ¼	¾	3 ¼	⅝	⅝
3 ½	3 ½	¾	3 ½	⅝	⅝
3 ¾	3 ¾	¾	3 ¾	⅝	⅝
4	4	1 ⅛	4	⅝	⅝
4 ⅛	4 ⅛	1 ⅛	4 ⅛	⅝	⅝
4 ¼	4 ¼	1 ⅛	4 ¼	⅝	⅝
4 ½	4 ½	1 ⅛	4 ½	⅝	⅝
4 ¾	4 ¾	1 ⅛	4 ¾	⅝	⅝
5	5	1 ¼	5	⅝	⅝
5 ⅛	5 ⅛	1 ¼	5 ⅛	⅝	⅝
5 ¼	5 ¼	1 ¼	5 ¼	⅝	⅝
5 ½	5 ½	1 ¼	5 ½	⅝	⅝
5 ¾	5 ¾	1 ¼	5 ¾	⅝	⅝
6	6	1 ¾	6	⅝	⅝
6 ⅛	6 ⅛	1 ¾	6 ⅛	⅝	⅝
6 ¼	6 ¼	1 ¾	6 ¼	⅝	⅝
6 ½	6 ½	1 ¾	6 ½	⅝	⅝
6 ¾	6 ¾	1 ¾	6 ¾	⅝	⅝
7	7	1 ¾	7	⅝	⅝
7 ⅛	7 ⅛	1 ¾	7 ⅛	⅝	⅝
7 ¼	7 ¼	1 ¾	7 ¼	⅝	⅝
7 ½	7 ½	1 ¾	7 ½	⅝	⅝
7 ¾	7 ¾	1 ¾	7 ¾	⅝	⅝
8	8	1 ¾	8	⅝	⅝
8 ⅛	8 ⅛	1 ¾	8 ⅛	⅝	⅝
8 ¼	8 ¼	1 ¾	8 ¼	⅝	⅝
8 ½	8 ½	1 ¾	8 ½	⅝	⅝
8 ¾	8 ¾	1 ¾	8 ¾	⅝	⅝
9	9	1 ¾	9	⅝	⅝
9 ⅛	9 ⅛	1 ¾	9 ⅛	⅝	⅝
9 ¼	9 ¼	1 ¾	9 ¼	⅝	⅝
9 ½	9 ½	1 ¾	9 ½	⅝	⅝
9 ¾	9 ¾	1 ¾	9 ¾	⅝	⅝
10	10	1 ¾	10	⅝	⅝
10 ⅛	10 ⅛	1 ¾	10 ⅛	⅝	⅝
10 ¼	10 ¼	1 ¾	10 ¼	⅝	⅝
10 ½	10 ½	1 ¾	10 ½	⅝	⅝
10 ¾	10 ¾	1 ¾	10 ¾	⅝	⅝
11	11	1 ¾	11	⅝	⅝
11 ⅛	11 ⅛	1 ¾	11 ⅛	⅝	⅝
11 ¼	11 ¼	1 ¾	11 ¼	⅝	⅝
11 ½	11 ½	1 ¾	11 ½	⅝	⅝
11 ¾	11 ¾	1 ¾	11 ¾	⅝	⅝
12	12	1 ¾	12	⅝	⅝
12 ⅛	12 ⅛	1 ¾	12 ⅛	⅝	⅝
12 ¼	12 ¼	1 ¾	12 ¼	⅝	⅝
12 ½	12 ½	1 ¾	12 ½	⅝	⅝
12 ¾	12 ¾	1 ¾	12 ¾	⅝	⅝
13	13	1 ¾	13	⅝	⅝
13 ⅛	13 ⅛	1 ¾	13 ⅛	⅝	⅝
13 ¼	13 ¼	1 ¾	13 ¼	⅝	⅝
13 ½	13 ½	1 ¾	13 ½	⅝	⅝
13 ¾	13 ¾	1 ¾	13 ¾	⅝	⅝
14	14	1 ¾	14	⅝	⅝
14 ⅛	14 ⅛	1 ¾	14 ⅛	⅝	⅝
14 ¼	14 ¼	1 ¾	14 ¼	⅝	⅝
14 ½	14 ½	1 ¾	14 ½	⅝	⅝
14 ¾	14 ¾	1 ¾	14 ¾	⅝	⅝
15	15	1 ¾	15	⅝	⅝
15 ⅛	15 ⅛	1 ¾	15 ⅛	⅝	⅝
15 ¼	15 ¼	1 ¾	15 ¼	⅝	⅝
15 ½	15 ½	1 ¾	15 ½	⅝	⅝
15 ¾	15 ¾	1 ¾	15 ¾	⅝	⅝
16	16	1 ¾	16	⅝	⅝
16 ⅛	16 ⅛	1 ¾	16 ⅛	⅝	⅝
16 ¼	16 ¼	1 ¾	16 ¼	⅝	⅝
16 ½	16 ½	1 ¾	16 ½	⅝	⅝
16 ¾	16 ¾	1 ¾	16 ¾	⅝	⅝
17	17	1 ¾	17	⅝	⅝
17 ⅛	17 ⅛	1 ¾	17 ⅛	⅝	⅝
17 ¼	17 ¼	1 ¾	17 ¼	⅝	⅝
17 ½	17 ½	1 ¾	17 ½	⅝	⅝
17 ¾	17 ¾	1 ¾	17 ¾	⅝	⅝
18	18	1 ¾	18	⅝	⅝
18 ⅛	18 ⅛	1 ¾	18 ⅛	⅝	⅝
18 ¼	18 ¼	1 ¾	18 ¼	⅝	⅝
18 ½	18 ½	1 ¾	18 ½	⅝	⅝
18 ¾	18 ¾	1 ¾	18 ¾	⅝	⅝
19	19	1 ¾	19	⅝	⅝
19 ⅛	19 ⅛	1 ¾	19 ⅛	⅝	⅝
19 ¼	19 ¼	1 ¾	19 ¼	⅝	⅝
19 ½	19 ½	1 ¾	19 ½	⅝	⅝
19 ¾	19 ¾	1 ¾	19 ¾	⅝	⅝
20	20	1 ¾	20	⅝	⅝
20 ⅛	20 ⅛	1 ¾	20 ⅛	⅝	⅝
20 ¼	20 ¼	1 ¾	20 ¼	⅝	⅝
20 ½	20 ½	1 ¾	20 ½	⅝	⅝
20 ¾	20 ¾	1 ¾	20 ¾	⅝	⅝

¹If a thicker shell plate is used than is required for the hydrostatic loading (Sect. 3.3, Shell Design), the excess shell plate thickness, within a vertical distance, both above and below the centerline of the hole in the tank shell plate, equal to the vertical dimension of the hole in the tank shell plate, may be considered as reinforcement, and the thickness *T* of the manhole attachment flange may be decreased accordingly. In such cases, the reinforcement and the attachment welding shall conform to the design limits specified in Sect. 3.3, for reinforcement of shell openings.

²API Std 5LX; ASTM A 134, A 135, or A 139 of latest issue. Pipe made from formed plate electrically butt welded, may be substituted for any of the above mentioned pipe sections.