CHAPTER X

ELECTRODE BOILERS

General Requirements

397. Application.—This Chapter applies to Electrode Steam Boilers for all voltages for any working pressure and for temperatures not exceeding 650°F.

Electrode Boilers shall only be of the following construction :

(*a*) Riveted Steel Boilers.

(*b*) Fusion Welded Steel Boilers.

(*c*) Seamless Shell Steel Boilers.

398. Where applicable the general terms of Chapter I relating to certificates from makers, Inspecting Authorities, etc., and of Chapter III concerning construction shall be followed.

399. The material specifications for structural parts of Electrode Boilers shall comply with Chapter II as regards the process of manufacture, chemical composition, mode of manufacture and tests, and the certificates for the steel plates, rivets and bars where applicable, provided that the ultimate tensile stress and elongation of materials shall be between the limits given below :—

(1) For riveted construction as in Regulation 16.

(2) For fusion welded construction as in Regulation 234.

(3) For seamless construction as in Regulation 344, Table I as for seamless carbon steel pipes.

RIVETED STEEL BOILERS

400. Construction and Workmanship.—The requirements as regards the preparation of plates, cylindrical shells, butt-straps, end plates, barstays, angle rings, inspection, openings, rivet holes, riveting, fullering and caulking shall comply with the relevant provisions of Chapter III.

401. Working Pressure of Shells.—Determination of working pressure of shells shall comply with Regulation 176.

402. Strength of Riveted Joints.—Strength of riveted joints shall comply with Regulations 177, 178 and 179.

403. Thickness of Butt-Straps.—Thickness of butt-straps shall comply with Regulation 182.

404. Maximum pitch of rivets in Longitudinal Joints.—Maximum pitch of rivets in longitudinal seam shall comply with Regulation 183.

405. Spacing of rows of rivets.—Spacing of rows of rivets and distance between rivet hole and edge of plate shall comply with Regulation 184.

406. End and Circumferential Seams.—End and Circumferential Seams shall comply with Regulation 104.

407 Manholes and other openings in Shells :—

(*a*) Uncompensated opening shall comply with Regulation 187.

(*b*) Compensated openings shall comply with Regulations 170, 171 and 186.

408. Dished End Plates with pressure on concave side.—Where an end plate is dished to semi-ellipsoidal or partially spherical form, the inside radius of dishing shall be not greater than the outside diameter of the flange (*see* Figure 23).

Wherever practicable, the inside corner radius shall be 12.5 per cent. of the inside diameter and in no case shall be less than 6 per cent. of the inside diameter.

For ends of semi-ellipsoidal from the ratio of the major axis to the minor axis shall be not greater than 2.

Where an end plate is dished to semi-ellipsoidal or partially spherical form and has a flanged-in-manhole or access opening, the thickness shall be increased by not less than 15 per cent. of the thickness computed by the formula for an end plate without an opening, but in no case shall this increase be less than 1/8 inch.

The depth in inches of the flange G (*see* Fig. 23) forming the access opening measured from the outer surface of the place at the minor axis of the opening shall be not less than:

$$G=\sqrt{T\times W}$$

where T=thickness of the end plate in inches.

W=length of minor axis in inches.

The corner radius of the manhole flange vm (*see* Fig. 23) shall be not less than 1 in.

In case where full compensation is provided for an un-flanged opening cut in a dished end plate, no additional thickness is necessary.

Where it is not practicable to make a dished end plate in one piece, fusion welded seams welded from each side of the plate may be employed provided the appropriate constants as given below are introduced into the formula for obtaining the thickness. The limits of pressure and diameter specified in Regulation 416 shall, however, apply.

The maximum working pressure shall be determined by the following formula but in no case shall the thickness at the edge of the flange for connecting to the shell be less than the thickness of the unpierced seamless shell as determined by Equation (1).

$$W.P. = \frac{(t-2)\times C\times S}{D\times K} \quad .. \quad .. \quad .. \quad \text{Equation (97)}$$

where t = thickness of plate in thirty-seconds of an inch.

WP= working pressure in pounds per square inch.

D = outside diameter of the flange in inches.

K = a factor dependent upon the ratio $\frac{h}{D}$—where h is the external height, generally obtained from the curve shown in Figure 22 or by Equation 75. In no case shall K be taken as less than :

$$1\cdot15\frac{R}{D} \text{ or } 0\cdot12\frac{D}{R}$$

S = minimum ultimate stress of plate in tons per square inch.

C = constant, as follows :

a. Where the end plate is in one piece.

C = 35.

b. Where the end plate is not one piece.

C = 32 where Class I requirements are complied with.

= 27 where Class II requirements are complied with.

The thickness to be used in the formulae is the thickness of the end after manufacture and is applicable over the whole area of the end up to the point where for ends of partially spherical shape, the dishing radius joins the corner radius; from this point a gradual thinning is permissible up to a maximum of 10 per cent. of the thickness 't' at the point where the corner radius joins the straight portion of the flanged end. A similar gradual thinning is permissible for ends of semi-ellipsoidal shape. This permissible reduction in thickness also applies to the flange for the manhole opening.

Where a dished end plate is pierced with more than one opening for electrodes or other fittings, the openings shall be so arranged as to provide an unpierced annulus not less than 2 in. wide measured from the centre of the corner radius.

Where the diameter of such opening is not greater than 2-1/2 inches and the value of the ligament $\frac{p-d}{P}$ is not less than $\frac{I}{K}$ compensation is not required.

where d is greater than 2-1/2 inches or $\frac{p-d}{P}$ is less than $\frac{I}{K}$ full compensation shall be provided where—

p= pitch of openings in inches.
d= diameter of openings in inches.
K= factor (*see* Equation above).

409. Seatings for Mounting.—Where the working pressure is not greater than 250 lb./sq. in. mountings having screwed ends not exceeding ¾ inch, Standard Pipe Thread may be used.

The mountings may be screwed:

(*i*) Directly into the boiler shell plates, nuts being fitted on the waterside or

(*ii*) Into steel distance pieces (*see* Fig. 35), the length of thread engaged being is no case less than the bore of the mounting plus one quarter inch.

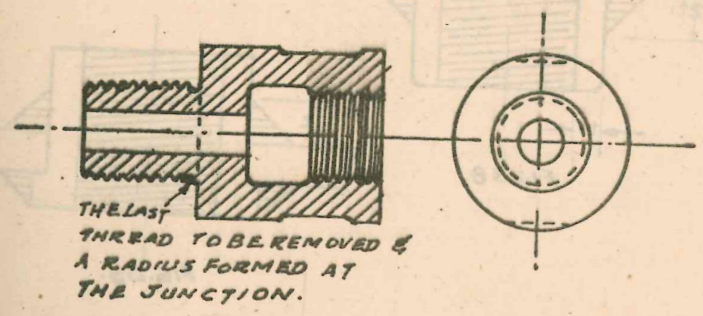


FIG. 35. TYPICAL MILD STEEL DISTANCE PIECE FOR MOUNTINGS

That distance piece shall be made solid from mild steel and shall be screwed into the boiler pieces and fitted with nuts on the water side. The walls of the distance plates shall be not less in thickness than one-quarter inch at the bottom of the thread.

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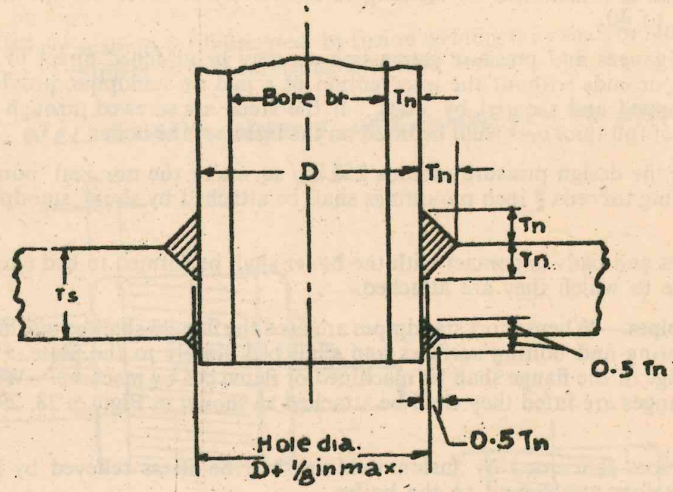


FIG.41.A.

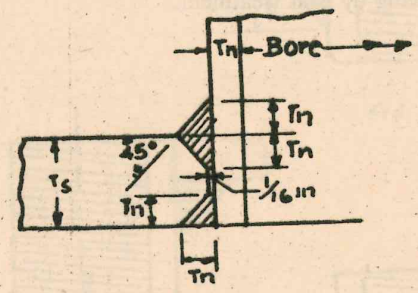


FIG.41.B

Minimum weld attachment for standpipes 5 in. bore and under, with plate thickness to Ts equal to 1.5 Tn. or Greater.

Figs. 41-A and 41-B—Minimum weld attachments for standpipes up to and including 5 in. bore not requiring compensating plates.

NOTE: THE TYPES SHOWN IN 'A' AND 'B' ARE PERMITTED ONLY WHERE THE ELECTRODES AND TECHNIQUE TO BE USED HAVE BEEN SHOWN BY SEPERATELY PREPARED TEST SPECIMENS TO GIVE FULL PENETRATION, WITH SOUND WELD METAL AT THE ROOT OF THE GROOVES

Where the outside diameter of the standpipe exceeds 5 inches plus twice the thickness of the shell plate in inches, the standpipe may be secured by fusion welding as shown in Figures 42 and 43. The standpipe and the entire plate to which it is attached shall be stress relieved by heat treatment.

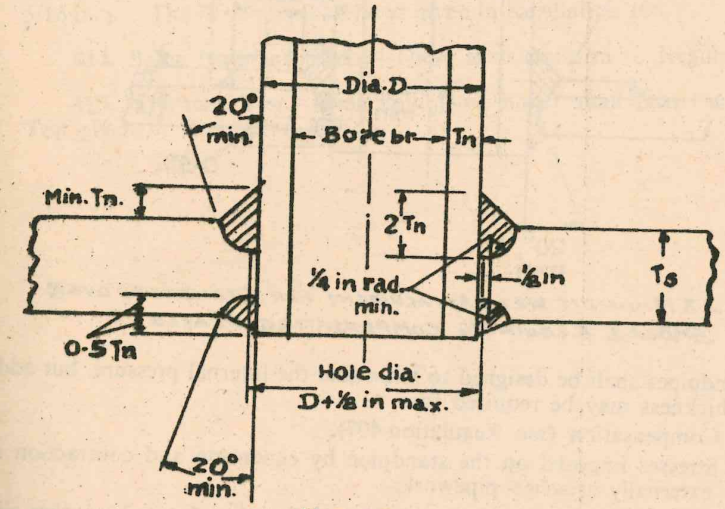
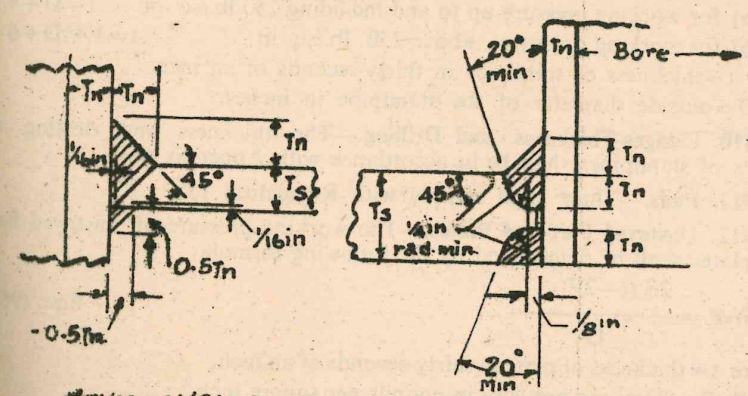


FIG.42A



MINIMUM WELD DIMENSIONS WHERE PLATE THICKNESS Ts IS LESS THAN 1·5 Tn

FIG.42C

FIG42B

Figs. 42-A, 42-B, and 42-C —Minimum weld attachments for standpipes over 5 in. bore not requiring compensating plates.

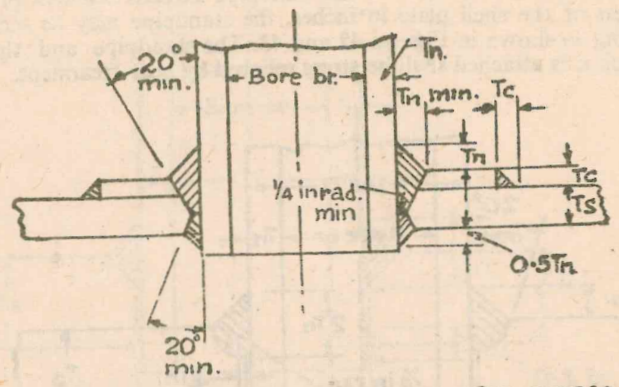


FIG 43. MINIMUM WELD ATTACHMENT FOR STANDPIPES OVER 5IN BORE REQUIRING COMPENSATING PLATES.

Standpipes shall be designed to withstand the internal pressure, but additional thickness may be required for:

(1) Compensation (*see* Regulation 407).

(2) Stresses imposed on the standpipe by expansion and contraction of externally attached pipework.

The thickness of the standpipe shall be not less than 1/4 inch or that give by the following formulae, whichever is the greater:

(*a*) for working pressure up to and including 250 lb./sq. in....t=D+4

(*b*) for working pressures above 250 lb./sq. in.....t=1.4 D+6

where t=thickness of standpipe in thirty-seconds of an inch.

D=outside diameter of the standpipe in inches.

410. Flanges-Thickness and Drilling.—The thickness and drilling of flanges of standpipes shall be in accordance with Appendix (E).

411. Pads.—These shall comply with Regulation 155.

412. Unstayed Flat-End Plates.—The working pressure of unstayed flat-end plates shall be determined by the following formula:

$$W.P.=\frac{2S\,(t-2)^2}{D^2} \quad \text{Eqn. (98)}$$

Where t=thickness of plate in thirty-seconds of an inch.

W.P.=Working pressure in pounds per square inch.

D=Diameter in inches of the pitch circle of the bolts or rivets when the plate is attached to an outside flange or the internal diameter of the shell when the plate is attached to an inside flange.

S=Minimum tensile stress of the plate in tons per square inch.

In no case shall the thickness of an unstayed flate-end plate be less than 3/8 inch.

Where an unstayed flat-end plate is pierced for electrodes or other fittings by openings having a diameter not greater than 2½ inches and the pitch of the openings in inches is not less than four times the diameter of the openings in inches, compensation is not required.

Where the diameter of the openings in an unstayed flat-end plate is greater than 2½ inches or the pitch in inches is less than four times the diameter of the openings, adequate compensation shall be provided in the manner described in Regulations 170, 171 and 186.

413. Thickness of Angle Rings.—Where flange or angle rings are used for pressure purposes in no case shall the thickness after machining be less than 5/16 inch. The thickness shall be as given in Regulation 106.

414. Bolts, Nuts and Studs.—These shall conform to Regulation 208.

415. Hydraulic Test.—Each completed boiler shall pass the Hydraulic Test given in Regulation 379(*a*).

FUSION WELDED BOILERS

416. Construction and Workmanship.—Construction and workmanship shall comply with the provisions made in Chapter V for fusion welded drums subject to the following conditions, namely:—

Class I boilers shall comply with the requirements of Chapter V. For end plate connection by welding, the type of seam shown in figure 44 may be adopted.

Class II boilers shall comply with the following requirements.

The longitudinal seams shall comply with Regulation 253. For end plate connections by welding any of the following types of seams, may be adopted (*see* Figures 44 to 49).

FORMS OF WELDED JOINTS FOR CIRCUMFERENTIAL SEAMS-ACCEPTABLE FOR ALL CLASSES OF BOILERS.

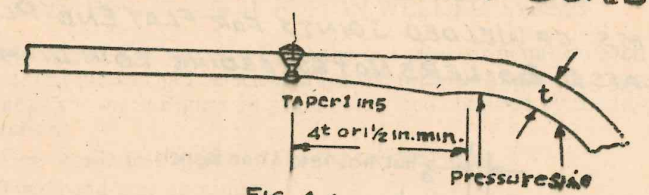


FIG. 44.

ACCEPTABLE FOR CLASS II BOILERS.

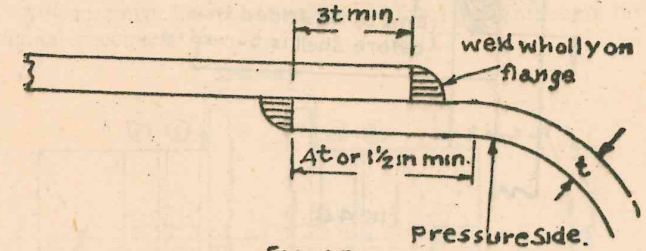


FIG. 45.

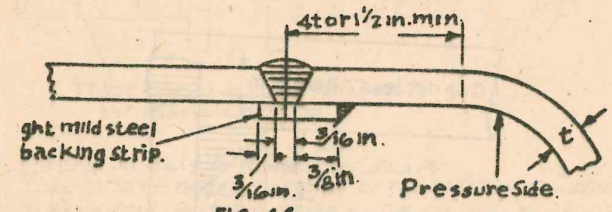


FIG. 46.

Forms of welded joints for circumferential seams acceptable for seamless shell boilers and for Class II welded boilers.

FOR PLATES OVER 3/4 IN. THICK, WIDTH OF GAP BETWEEN THE EDGES OF THE PLATES TO BE AGREED UPON BY INSPECTING AUTHORITY & MANUFACTURER.

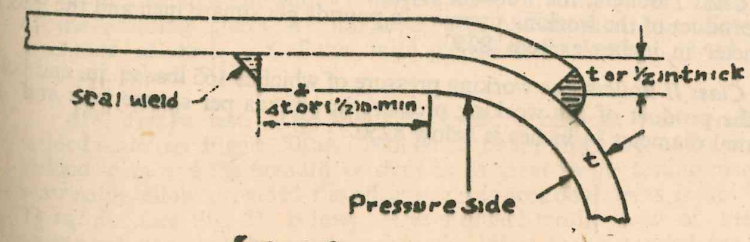


FIG. 47.

Forms of welded joints for circumferential seams acceptable for seamless shell boilers and for Class II welded boilers.

FORMS OF WELDED JOINTS FOR FLAT END PLATES FOR CLASS II BOILERS NOT EXCEEDING 20IN DIAMETER.

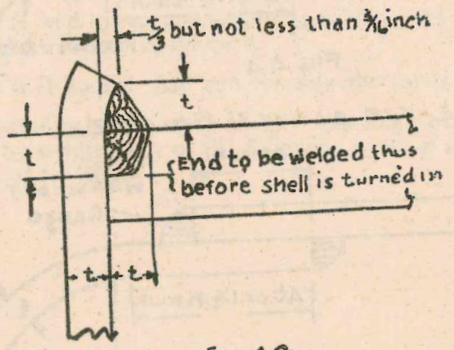


FIG 48.

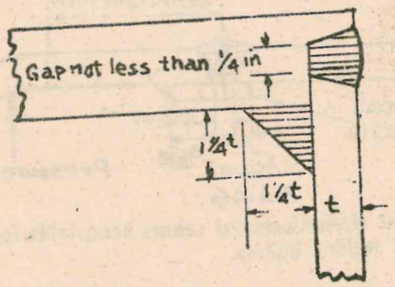


FIG.49.

Class I Boilers, the working pressure of which exceeds 165 lbs./sq. in. or the product of the working pressure in pounds per square inch and the internal diameter in inches exceeds 8250.

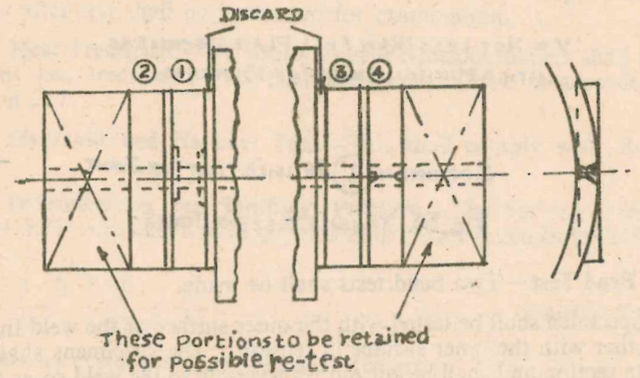
Class II Boilers, the working pressure of which is 165 lbs./sq. in. and below or the product of the working pressure in pounds per square inch and the internal diameter in inches is below 8250.

TESTS FOR CLASS II FUSION WELDED SEAMS

417. Selection of Test pieces.—From the test plate or plates on each longitudinal seam, test pieces shall be selected for the following tests the specimens being cut out as shown in Figure 50 given below and stamped by the Inspector for identification:

(*a*) One tensile test specimen for the welded seam.
(*b*) Two bend test specimens.
(*c*) One nick break test specimen.

The remainder of each set of test plates shall be retained for any retest required. Any specimen for retest shall be cut from the same set of test plates as the original specimen.

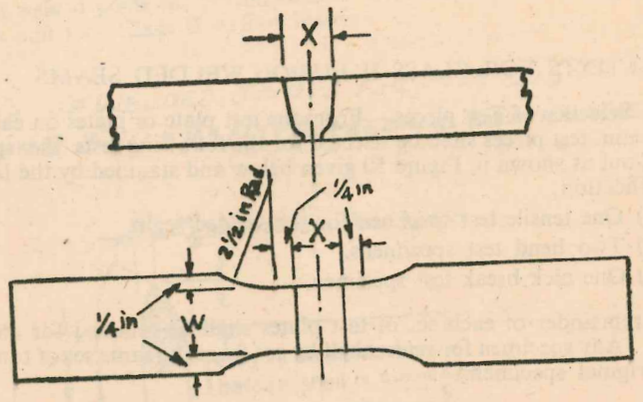


1. TENSILE TEST FOR WELDED SEAM.
2. BEND TEST: OUTER SURFACE OF THE WELD IN TENSION.
3. BEND TEST: INNER SURFACE OF THE WELD IN TENSION.
4. NICK BREAK TEST.

FIG.50 DETAILS OF TEST PLATES.

Surfaces of tensile and bend specimens corresponding with the outside and inside of the shell, shall be only lightly dressed so that the rolled surface of the parent metal is not wholly removed, except that where the rolled surfaces of the abutting plates are not level with one another, one plate may be machined at each face of the weld provided the depth of metal removed does not exceed 1/32 in.

418. Tensile test.—The specimen shall be cut out transversely to the welded seam (*see* Figure 50) and shall be of the full thickness of the plate at the welded seam and the breadth W shall be as great as the testing machine will reasonably allow provided the effective cross-sectional areas is not less than 1½ sq. in. (*see* Fig. 51 below). The ultimate tensile stress of the welded seam specimen shall be not less than the lower limit specified for the plate (*see* Table under Regulation 16.)



'W = NOT LESS THAN FULL PLATE THICKNESS WITH A MINIMUM WIDTH OF 1½ INCHES.

SPECIMEN (1) TENSILE TEST FOR JOINT.

FIG. 51 TENSILE TEST FOR JOINT

419. Bend Test.—Two bend tests shall be made.

One specimen shall be tested with the outer surface of the weld in tension, and the other with the inner surface in tension. The specimens shall be rectangular in section and shall be cut out transversely to the weld so as to have a width of not less than one-and-a-half times the thickness of the plate. The sharp corners of the specimens shall be rounded to a radius not exceeding ten per cent of the thickness of the specimen.

Where the plate thickness does not exceed 1¼ inches the thickness of the specimen shall be equal to the full thickness of the test plate. Where the plate thickness exceeds 1¼ inches the thickness of the specimen shall be at least 1-¼ inches. The specimen to be tested with the outer surface of the weld in tension shall be prepared by cutting to waste the metal local to the inner surface of the weld, so that the desired specimen thickness is obtained.

The specimen to be tested with the inner surface in tension shall be prepared by cutting to waste the metal local to the outer surface of the weld so that the desired metal thickness is obtained. Where the thickness of the plate permits, both specimens may be cut from the same piece of plate, the specimens being located in the plate one above the other. Each specimen shall be mounted with the weld midway between the supports, set apart at a distance of not more than 5.2 times the thickness of the specimen and pushed through the supports with a former having a diameter equal to three times the thickness of the specimen (*see* Figure 20).

On completion of the test no crack or defect at the outer surface of the specimen shall be greater than 1/16 inch measured across the specimen or 1/8 inch measured along the length of the specimen. Premature failure at

corners of the specimen shall not be considered cause for rejection. (*see* Figure 20, Specimen A)

420. Nick Break Test.—The specimen shall be rectangular in section and cut transversely to the weld so as to have a width not less than one-and-half times its thickness. The slot shall be cut in one side of the specimen through the centre of the weld and perpendicular to the outer face of the vessel. The specimen shall then be broken in the weld and the fracture shall reveal a sound homogeneous-weld, substantially free from slag inclusions, porosity and coarse crystallinity.

421. Retests.—Should any of the tests fail, two retests shall be made on specimens cut from the same plate and both retests shall meet the specified requirements.

422. Specimens after Tests.—If required by the Inspecting Authority, the specimens after test shall be forwarded for examination.

423. Heat Treatment.—All fusion welded electrode boilers shall be stress-relieved by heat-treatment. The heat-treatment shall be in accordance with Regulation 267.

424. Hydraulic and Hammer Test.—This shall comply with Regulation 268.

425. Determination for Working Pressure.—The working pressure of cylindrical shells with fusion welded seams shall be calculated from the following formula:—

$$W.P. = \frac{(t-2) \times S \times C}{D} \quad \ldots\ldots\ldots\ldots \text{Equation [99]}$$

Where t = thickness of shell plate in thirty-seconds of an inch.
D = internal diameter of shell in inches.
S = Ultimate tensile stress in tons per square inch.
C = 32 for Class I boilers.
C = 27 for Class II boilers.

In no case the thickness of cylindrical shells with fusion welded seams be less than those given in table below :—

Minimum Thickness for Fusion Welded Shells

Class	Internal diameter inches	Minimum thickness inches
II	Up to and including 24	1/4
	Over 24 up to and including 36	5/16
	Over 36	3/8

In no case shall the factor of safety of the cylindrical shell and ends be less than 4.

426. Welds and compensation for manholes and branches.—Welded compensating ring fitted to manhole and other openings shall conform to Figures 52 to 56.

WELDS AND COMPENSATION FOR MANHOLES AND BRANCHES.

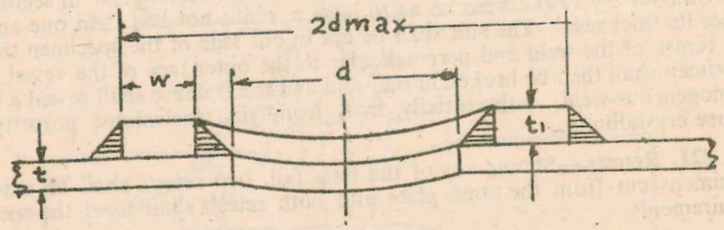


FIG. 52 EXTERNAL COMPENSATING RING

NOTE. 2wt1 SHALL BE NOT LESS THAN dt WHERE t IS THE CALCULATED PLATE THICKNESS.

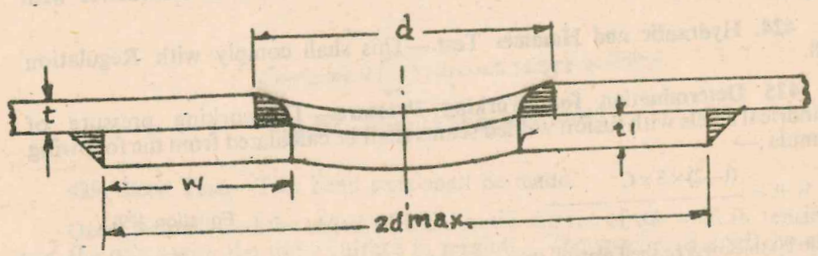


FIG. 53 INTERNAL COMPENSATING RING.

NOTE. 2wt1 SHALL BE NOT LESS THAN dt WHERE t IS THE CALCULATED PLATE THICKNESS.

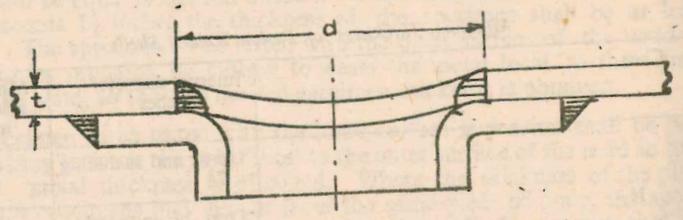


FIG. 54. ELLIPTICAL MANHOLE FLANGED FRAME WELDED TO SHELL.

NOTE. WHERE THE CROSS SECTIONAL AREA OF THE FRAME MEASURED ALONG A LINE PARALLEL TO THE AXIS OF THE SHELL IS LESS THAN dt, THE DIFFERENCE SHALL BE MADE UP BY AN EXTERNAL COMPENSATING RING, WHERE t' IS THE CALCULATED PLATE THICKNESS.

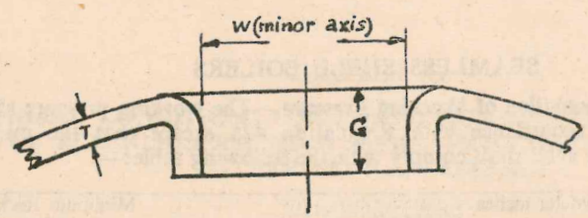


FIG. 55 ELLIPTICAL PRESSED MANHOLES IN DISHED END PLATE.

NOTE: T = CALCULATED PLATE THICKNESS IN INCHES PLUS $\frac{1}{8}$ IN. G (IN INCHES) = $\sqrt{TW}$.

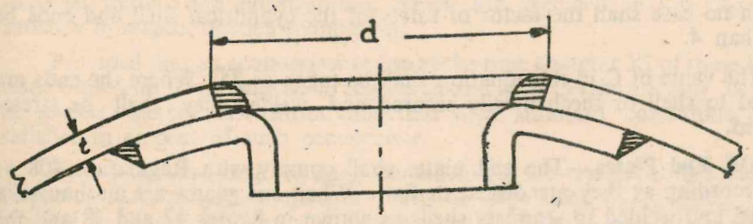


FIG. 56 ELLIPTICAL MANHOLE FRAME WELDED TO DISHED END PLATE

NOTE: WHERE THE CROSS SECTIONAL AREA OF THE FRAME MEASURED ON THE MAJOR AXIS OF THE OPENING d IS LESS THAN dt, THE DIFFERENCE SHALL BE MADE UP BY AN EXTERNAL COMPENSATING RING, WHERE t' IS THE CALCULATED PLATE THICKNESS.

427. Manholes and other openings in Shells.—Manholes and other openings in boiler shells shall be placed away from any welded seam. Oval openings shall be arranged with their minor axis parallel to the longitudinal centre line of the boiler.

(*a*) Un-compensated openings shall comply with Regulation 187.

(*b*) Compensated openings shall comply with Regulations 170, 171, 186 and 279.

428. Dished End Plates with pressure on Concave Side.—This shall comply with Regulation 408.

429. Unstayed Flat End Plates.—The working pressure of unstayed flat end plates shall comply with Regulation 412.

Where the diameter of the openings in an unstayed flat end plate is greater than 2½ inches or the pitch in inches is less than four times the diameter of the holes full compensation shall be provided as in Regulation 279.

430. Thickness of Angle Rings.—Thickness of angle rings shall comply with Regulation 413.

431. Bolts, nuts and studs shall comply with Regulation 208.

432. Seatings and mountings shall comply with Regulation 409.

433. Hydraulic Test.—The requirement of Hydraulic Test shall comply with Regulation 379(*a*).

SEAMLESS SHELL BOILERS

434. Determination of Working Pressure.—The working pressure shall be determined in accordance with Regulation 425 except that the minimum thickness of the shell shall comply with the following table:—

Internal diameter inches	Minimum thickness inches
Up to and including 24	1/4
Over 24 up to and including 36	5/16
Over 36	3/8

In no case shall the factor of safety of the cylindrical shell and ends be less than 4.

The value of C in the equation shall be taken as 35. Where the ends are welded to shell or mechanically secured and welded they shall be stress-relieved.

435. End Plates.—The end plates shall comply with Regulation 408 or 412 according as they are dished or flat. When end plates are mechanically secured and welded to seamless shells as shown in figures 47 and 48 and the welds are stress-relieved, the pressure and other limitations specified in respect of Class II boilers in Regulation 416 shall not apply.

436. Manholes and other opening in the Shells.—These shall comply with Regulation 407.

437. Mountings, Fittings and Connections (For all types of Electrode Boilers).—Mountings, fittings and connections shall comply with Regulation 281.

In the case of electrode boilers one means of indicating water level of the tubular water level gauge-glass type and one means of feeding the boiler shall suffice and the Safety Valves shall be of spring loaded type.

If an Electrode boiler is fitted with a magnetic valve, the said valve will be accepted in lieu of the second safety valve, provided the source of power supply to both the valve and the boiler is the same and both are operated by one single switch.