CHAPTER V

FUSION WELDED AND SEAMLESS FORGED DRUMS FOR WATER TUBE BOILERS AND SUPERHEATERS

233. General Requirements.—Where applicable the general terms of Chapter I relating to Certificates from Makers, Inspecting Authorities, etc., and of Chapter III concerning construction should be followed.

MATERIALS OF CONSTRUCTION

234. (*a*) **Materials for Fusion Welded Boiler Drums.**—The requirements of Chapter II, so far as they relate to plates, shall apply, excepting that the chemical composition, tensile strength and elongation of the material used shall conform to the following, as may be applicable to the quality of steels concerned :—

Chemical Composition (ladle analysis)

Carbon Steels	
*Carbon	0·25% maximum
Silicon	0·35% maximum
Manganese	0·40 to 0·90%
Phosphorus	0·05% maximum
Sulphur	0·05% maximum

*A carbon content not exceeding 0·35% may be permitted, subject to the approval of the Inspecting Authority.

Manganese Steels	
Carbon	0·23% maximum
Silicon	0·15 to 0·60%
Manganese	0·90 to 1·40%
Phosphorus	0·05% maximum
Sulphur	0·05% maximum
Molybdenum Steels	
Carbon	0·21% maximum
Silicon	0·15 to 0·35%
Manganese	0·50 to 0·90%
Phosphorus	0·05% maximum
Sulphur	0·05% maximum
Molybdenum	0·25 to 0·60%
Chromium-Molybdenum Steels	
Carbon	0·21% maximum
Silicon	0·15 to 0·35%
Manganese	0·40 to 0·80%
Phosphorus	0·04% maximum
Sulphur	0·04% maximum
Chromium	0·7 to 1·15%
Molybdenum	0·40 to 0·65%

Mechanical Properties at 20°C (68°F)

Kind of Steel	Tensile strength minimum kg./mm²	Tensile strength minimum tons/sq. in.	*elongation on $L_o = 5\,d_o$ or $L_o = 5{\cdot}65\sqrt{A_o}$ % minimum
Carbon Steels :			
(1)	35	22	22
(2)	38·5	24·5	21
(3)	41	26	20
(4)	44	28	19
(5)	47	30	18
Manganese Steels :			
(1)	47	30	18
(2)	52	33	16
Molybdenum Steels	44	28	19
Chromium-Molybdenum Steels	42	27	20

**Note*—

L_o = original gauge length;

d_o = original diameter, and

A_o = original area of cross section.

NOTE.—A range of not more than 20 per cent of the minimum tensile strength shall be permitted in each class of material.

(*b*) Plates over 2" in thickness before being fabricated, shall be uniformly heat treated to produce grain refinement. Heat treatment involving quenching in a liquid medium is not permitted.

SEAMLESS FORGED DRUMS

* **235. Process of Manufacture.**—Carbon steel for seamless steel drums shall be made by the Open Hearth or an Electric Process, acid or basic.

* **236. Chemical Analysis.**—The steel shall contain not more than 0·05 per cent of sulphur or of phosphorus.

237. Freedom from defects.—The drum shall be free from surface defects and shall be machined to the prescribed dimensions.

Defects in forgings shall not be repaired without the previous sanction of the Inspecting Officer.

238. Heat Treatment.—Each drum shall be efficiently heat treated :

(*a*) At various stages during manufacture, as required.

(*b*) On completion of the forging process but prior to the hydraulic test.

239. Mechanical Tests.—Material shall comply with the mechanical tests herein specified.

Sufficient material shall be left on the open end or ends of each forging to enable tangential test pieces to be taken. These tests shall consist of not less than one tensile and one bend test from each open end. In the case of drums with open ends the test material shall not be parted off before heat treatment. If the drums are closed in at the ends the test rings shall be parted off immediately before this operation; subsequently the test rings and the forging shall be similarly, and simultaneously heat treated in the same furnace.

240. Selection of Test Pieces.—(*a*) All test pieces shall be selected by the Inspecting Officer and shall be tested in his presence and he shall satisfy himself that the conditions herein prescribed are fulfilled.

(*b*) **Tensile Test Pieces.**—The ultimate tensile stress and elongation shall be determined from the standard test piece C or subsidiary standard round test piece (*see* Appendix B).

(*c*) **Tensile Test.**—The ultimate tensile stress and minimum elongation shall be as shown in Table below :—

Ultimate tensile stress and minimum elongation for seamless forged drums

Ultimate tensil stress	Minimum elongation
Tons/sq. inch	per cent
28—32	25
32—36	21
34—38	19

Should a tensile test piece break outside the middle half of the test gauge length the test may be discarded and another test be made of the same drum.

(*d*) **Bend test pieces.**—Bend test pieces shall be of rectangular section 1 inch wide by ¾inch thick. The edges shall be rounded to a radius of 1/16 inch. The test pieces shall be bent over the thinner section.

(*e*) **Bend Tests.**—The test pieces shall, when cold, be capable of being bent without fracture, through an angle of 180°, the internal radius of the bend being not greater than that specified in table below :—

	Internal radius of bend
	inch
Upto 32	3/8
Above 32 and up to 36	½
Above 36 and up to 38	¾

Bend tests may be made by pressure or, by blows.

241. Additional tests before rejection.—Should either a tensile or bend test fail, two further tests of the type which failed may be made on test pieces cut from the same test rings. If the results obtained from these re-tests are satisfactory, the drum shall be accepted, provided that in other respects it fulfils the conditions of this Chapter. If these re-tests do not give satisfactory results the drum represented may be re-heat-treated together with the remainder of the test rings, and presented for further testings.

In all cases where final re-tests do not give satisfactory results, the drum represented by the test pieces which fail shall be rejected.

242. Discard.—Sufficient discard shall be made from the top and bottom of each ingot to ensure soundness in the portion for forging.

243. Forging.—The forging, shall be made from a solid cast ingot, punched, bored or trepanned, or alternatively, hollow, cast ingots may be used. The resultant wall in the case of the solid cast ingot, or the wall of hollow ingot as cast shall be reduced in thickness by at least one-half in the process of forging.

TUBES, PIPES IN BOILERS, HEADERS AND STEEL CASTINGS

244. Tubes.—(*a*) Tubes shall be of cold drawn weldless or hot finished weldless or electric-resistance-welded steel and shall comply with regulations 36 to 63.

* **Pipes.**—(*b*) Pipes forming an integral part of the boiler unit shall comply with the provisions of Chapter VIII.

245. Headers.—Headers and similar pressure parts shall be of forged steel, seamless steel pipes or of cast steel and shall comply with the relevant provisions of Chapter II, in all other respects excepting the chemical composition tensile strength and elongation of the respective materials, which shall comply with the following, as may be applicable :—

Chemical Composition (*Ladle analysis*)

***Carbon Steels*	
Carbon	0·25% maximum
Silicon	0·35% maximum
Manganese	0·30% maximum
Phosphorus	0·05% maximum
Sulphur	0·05% maximum

**A carbon content not exceeding 0·35% may be permitted, subject to the approval of the Inspecting Authority.

Manganese Steels	
Carbon	0·23% maximum
Silicon	0·20 to 0·60%
Manganese	0·90 to 1·30%
Phosphorus	0·05% maximum
Sulphur	0·05% maximum
Molybdenum Steels	
Carbon	0·20% maximum
Silicon	0·10 to 0·45%
Manganese	0·35 to 0·80%
Phosphorus	0·05% maximum
Sulphur	0·05% maximum
Molybdenum	0·25 to 0·65%
Chromium-Molybdenum Steels	
(1) Carbon	0·18% maximum
Silicon	0·10 to 0·60%
Manganese	0·35 to 0·70%
Phosphorus	0·05% maximum
Sulphur	0·05% maximum
Chromium	0·7 to 1·25%
Molybdenum	0·4 to 0·7%

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(2) Carbon	.. ..	0·15% maximum
Silicon	.. ..	0·10 to 0·50%
Manganese	.. ..	0·35 to 0·70%
Phosphorus	.. ..	0·04% maximum
Sulphur	.. ..	0·04% maximum
Chromium	.. ..	2·0 to 2·5%
Molybdenum	.. ..	0·9 to 1·2%

Mechanical properties at 20° *C* (68° *F*)

Kind of Steel	Tensile strength minimum		*elongation on $L_o = 5d_o$ or $L_o = 5{\cdot}65\sqrt{A_o}$ % minimum
	kg/mm²	tons/sq. in.	
Carbon Steels :			
(1)	31·5	20	25
(2)	45	28	21
Manganese Steels :			
(1)	47	30	23
(2)	52	33	19
Molybdenum Steels	37·5	24	22
Chromium-Molybdenum Steels			
(1)	39	25	20
(2)	39	25	20

**Note*

L_o = original gauge length;
d_o = original diameter, and
A_o = original area of cross-section.

246. Steel Castings.—Steel castings for pressure parts shall comply with Regulations 73 to 80 (28 to 35 tons per sq. in).

FUSION WELDED DRUMS

247. Definition of term 'Fusion Weld'.—The term 'Fusion Weld' is, for the purpose of this Chapter, applicable to all welded joints made by the metal arc process with covered electrodes or other electric arc process in which the arc stream and the deposited weld metal are shielded from atmospheric contamination.

It is intended that this Chapter shall apply to the single run or heavy run welding process and that welded boiler drums manufactured by that process shall conform with all Regulations of this Chapter, excepting those in which divergence is necessary solely because of special requirements essential for the most efficient utilisation of that process. Thus all Regulations governing quality of material, construction workmanship and testing (both non-destructive and otherwise) are applicable.

When welded drums ordered to this Chapter are made by the single run or heavy run process it will be understood that Regulations 252 and 267 do not apply in their entirety.

248. Equipment of Workshop.—(*a*) The welding plant and equipment are to be of good quality and maintained in an efficient working condition. The welding apparatus is be installed under cover and arranged so that the welding work may be carried out in positions free from draughts and adverse weather conditions. The procedure is to be such that there is regular and systematic supervision of the welding works, and the welding operators are to be subjected by the works officials to pericdic tests for quality of workmanship. Records of these tests are to be kept and are to be available to the Inspecting Officers for scrutiny.

(*b*) The Works should be equipped with an efficient testing laboratory which should include apparatus suitable for carrying out tensile, bend and impact tests micro-examination of specimens and X-ray examination of the actual joints in pressure vessels. The Works should also be equipped with a suitable heat treating furnace having satisfactory means for temperature control, but as an alternative arrangements may be made whereby the drums can be heat-treated elsewhere.

249. Constructional details and preparation for welding.—The manufacturer shall supply the Inspecting Authority with a fully dimensioned sectional drawing showing in full detail the construction of the drum(s) for approval before putting the work in hand.

A full sized dimensioned sketch of the weld grooves for the longitudinal and circumferential seams shall be shown on the drawing.

Full sized dimensioned sketches shall also be shown of the details of the joints for stand pipes, branch pipes and seating and the position of these joints relative to the longitudinal and circumferential seams and other openings shall be indicated.

250. Preparation of plates.—The edges of all plates shall be prepared and surfaced by machining or chipping or flame cutting.

Before welding is commenced, the grooves shall be thoroughly cleaned of rust, oil or other foreign matter.

Before welding of the joint is commenced (apart from tack welding) it shall be ascertained that the chamfered edges are in alignment and that the defects in alignment between the surface of the plates do not exceed the following limits :—

10 per cent of the nominal plate thickness, with a maximum of 3 mm (1/8 inch) for longitudinal joints.

10 per cent of the nominal plate thickness, plus 1 mm (3/64 inch), with a maximum of 4 mm (5/32 inch) for circumferential joints.

If plate edges of unequal thickness are abutted and the difference between the surfaces exceeds the limit mentioned as above on either side, the thicker plate shall be thinned to a smooth taper for a distance not less than 4 times the offset including, if so desired, the width of the weld. In longitudinal joints, the middle lines of the plates shall be in alignment within 10 per cent, of the thickness of the thicker plate with a maximum of 3 mm (1/8 inch).

251. Cylindrical shells of drums.—Each drum shell plate shall be of cylindrical form to the extreme edges of the plate. The bending shall be done entirely by machine and local heating or hammering is prohibited. Where the plates are bent to a diameter less than 40 times the plate thickness they shall be efficiently heat-treated after bending to relieve internal stresses unless during the last stage of bending they have been uniformly heated throughout.

* **252. Method of making welded joints.**—The seams shall be welded from both sides of the plate. Before the second side of the plate is welded, the metal at the bottom of the first side shall be removed by grinding, chipping or machining.

Additional runs of metal shall be deposited at both surfaces of the welded seams so that the weld metal at the level of the surfaces of the plate is refined as far as possible. The surfaces of the welds shall thereafter be machined or ground so as to provide, smooth contours and to be flush with the respective surfaces of the plate. There shall be no undercutting at the junctions.

The positions of the welds shall be marked permanently to facilitate their location.

Not less than two runs of metal shall be deposited at each weld fixing standpipes, branch pipes and seatings.

Each run of weld metal shall be thoroughly cleaned and freed from slag before the next run is deposited.

253. Type of welded joints.—The longitudinal circumferential seams shall be made with butt joints of the single or double U or Vee type.

* **254. Number of joints.**—Where, having regard to the approved design, the dimensions are such that the shell cannot be made from a single plate, it shall be made with the minimum number of joints and the longitudinal seams in successive rings shall not fall in line.

* **255. Position of tube holes.**—Tube holes may be machined through welded seams after the seams have been radiographed and stress-relieved. The efficiency of the welded seam (ratio of stress Col. B to stress Col. A, Table under Regulations 271) shall be taken into account when determining the efficiency of ligaments in the direction of the weld (*see* Regulations 215) except where the distance from the edge of the hole to the edge of the welds is greater than $\frac{1}{2}$ in. The edge of the weld shall be considered to be the edge of the weld groove as machined in the plate prior to welding.

256. Circularity of drums.—The difference between the internal diameter of the drum measured at any cross section and the nominal internal diameter of the drum should not exceed 1 per cent of the latter.

Any departure of profile measured on the outside of the drum with a gauge of the designed form of the exterior of the drum and of length equal to a quarter of the internal diameter, shall not exceed the percentage given in table below :—

Nominal internal diameter of drum	Percentage of nominal internal diameter
Up to and including 36 inches	0.375
Over 36 up to and including 45 inches	0·35
Over 45 inches	0·3

Flats at the welded seams shall not be permitted and any local departure from circularity shall be gradual.

257. Mechanical test and test plates for fusion welded seams.—(*a*) Fusion Welded joints shall comply with the mechanical tests herein specified.

Not less than one set of test plates shall be provided to represent the welding of each longitudinal seam.

The test plates may be attached at each end of the longitudinal seam or the set may be located at one end only.

(*b*) Where the drum shell is formed in two or more courses, the staggered longitudinal seam shall be regarded as a continuous longitudinal seam, provided the welding be effected in one reasonably continuous operation and by the same operator or operators.

(*c*) Where there are circumferential seams only or where the method of welding the circumferential seam differs from that employed for the longitudinal seams, the method of providing the test plates shall be decided by the Inspecting Authority.

(*d*) The test plates shall be of a size sufficient for the preparation of the test pieces specified in Regulation 258 (*a*) and for any repeat test pieces that may be required. The material for each set of test plates shall be cut from the respective plate or plates forming the appropriate seam, and before being cut shall be stamped by the Inspecting Officer.

(*e*) When the analysis of the plates is approved by the Inspecting Authority and is considered sufficiently similar, the test plates may be cut from one drum shell plate only.

(*f*) In the case of insufficient material being available on the shell plate to permit the cutting of test pieces, these shall be acceptable if they are made from another plate provided it is made from the same cast.

(*g*) The weld groove in the test plates shall be similar to that adopted for the corresponding edges of the longitudinal seam, and the respective fusion faces shall be in continuous alignment. The test plates shall be reinforced or supported during welding in order to prevent undue warping.

The weld metal in the test plates and the seam shall be of the same grade of electrode and shall be deposited continuously at the same operation.

(*h*) The weld in any test plate shall not be repaired unless agreed by the Inspecting Authority and the repairs shall be done in such a manner as will ensure that the repaired seam in the test plate is still representative of the material in the main seam.

(*i*) Where it is desired to straighten test plates which have warped during welding they may be straightened at a temperature below the temperature of heat treatment of the drum to which they belong. Straightening shall take place before final heat treatment.

(*j*) For heat treatment, *see* Regulation 267.

(*k*) If any defects in the weld metal of a test plate are revealed by radiographical examination, the position of these shall be clearly marked on the

plate and test pieces shall be selected from such parts of the test plates as may be decided by the Inspecting Authority.

258. Selection of Test Pieces*.—(*a*) 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 Figs. 16 and 17 and stamped by the Inspecting Officer for identification :—

(*i*) One tensile test specimen for the welded joint.

(*ii*) One all-weld metal tensile test specimen.

(*iii*) Two bend test specimens.

(*iv*) Two Izod impact test specimens.

(*v*) One specimen for micro and macro examination.

The remainder of each set of test plates shall be retained for any re-tests required. Any specimen for re-test shall be cut off from the same set of test plate, as the original specimen.

(*b*) Surfaces of tensile, bend and Izod impact specimens corresponding with the outside or inside of the drums 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.

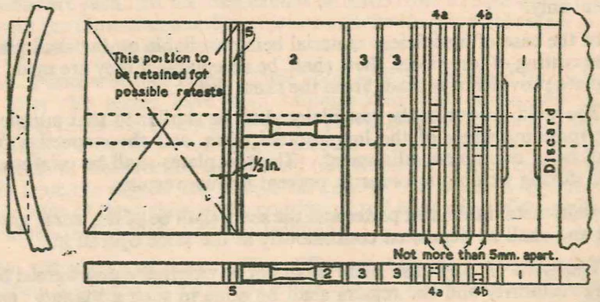


Fig. 16. Details of test plates.

1. Tensile test for joint.
2. Tensile test for all-weld metal.
3. Bend test, outer and inner surfaces of plate (at weld).
4. a. Izod impact test, outer surface of plate.
   b. Izod impact test, inner surface of plate.
5. Micro and macro specimen.

*Examples showing approximate dispositions of the test pieces in the test plates are shown in figs, 16 and 17.

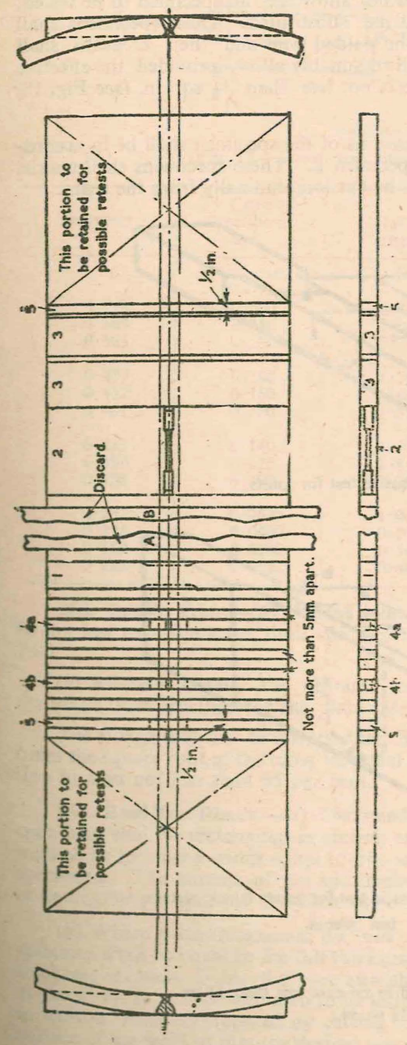
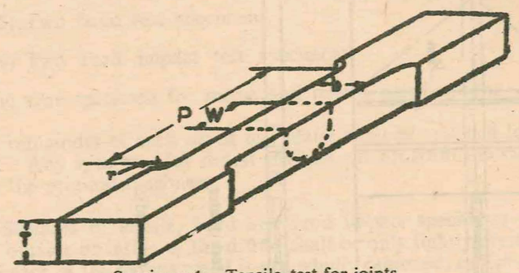


Fig. 17.—Details of test plates.

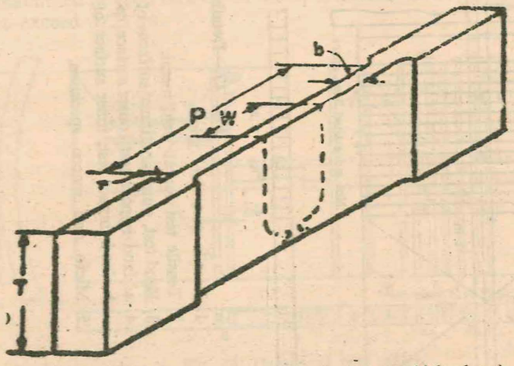
1. Tensile test for joint.
2. Tensile test for all-weld metal.
3. Bend test, outer and inner surfaces of plate (at weld).
4. a. Izod impact test, outer surface of plate.
   b. Izod impact test, inner surface of plate.
5. Micro and macro specimen.

259. Tensile Test Pieces.—(*a*) **Welded Joint.**—The dimensions of the specimens shall be in accordance with the sketch in Fig. 18, Specimen 1, and the specimen shall be cut transversely to the welded seam. When the capacity of the available testing machine does not allow the full specimen to be tested, two narrower tensile specimens shall be substituted. These specimens shall be the full thickness of the plate at the welded joint and their breadths shall be as great as the testing machine will reasonably allow, provided the effective cross sectional area of the test piece is not less than $1\frac{1}{2}$ sq. in. (*see* Fig. 18, Specimen 1*a*).

(*b*) **All-weld Metal.**—The dimensions of the specimen shall be in accordance with the sketch in Fig. 19, Specimen 2. These specimens shall consist entirely of deposited metal and shall be cut longitudinally from the seam.



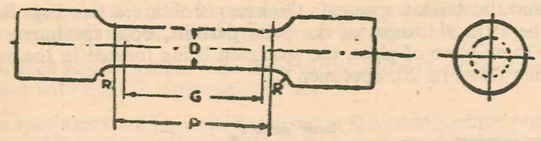
Specimen 1.—Tensile test for joints.



Specimen 1*a*.—Tensile test for joints (thick plates).

Fig. 18.—Tensile test pieces.

T=Thickness of plate.
b=Breadth of test piece :
Specimen 1. Not less than T and in no case less than $1\frac{1}{2}$ in.
Specimen 1*a*. T×*b* not less than $1\frac{1}{2}$ sq. in.
W=Width of weld groove.
P=Parallel length, minimum=3×W.
r=Radius at shoulder, minimum=$\frac{1}{2}$ in.



Specimen 2.

Fig. 19.—Tensile test pieces : all weld-metal

Diameter D	Cross sectional area	Gauge length	parallel length minimum	Radius at shoulder minimum
in.	sq. in.	in.	in.	in
0·798	0·500	2·82	3·18	0·70
0·564	0·250	2·00	2·25	0·50
0·505	0·200	1·79	2·01	0·45
0·479	0·180	1·70	1·91	0·42
0·452	0·160	1·60	1·80	0·40
0·437	0·150	1·55	1·74	0·39
0·423	0·140	1·50	1·69	0·37
0·399	0·125	1·41	1·58	0·35
0·358	0·100	1·26	1·42	0·31
0·282	0·0625	1·00	1·12	0·25
0·226	0·0400	0·80	0·90	0.20
0·159	0·0200	0·56	0·63	1·14
0·125	0·0122	0·44	0·50	0·11

260. Tensile Tests.—(*a*) **Welded joint.**—The ultimate tensile stress shall be not less than the lower limit specified for the plate (*see* table under Reg. 234).

(*b*) **All-weld Metal.**—The ultimate tensile stress shall be not less than the lower limit specified for the plate (*see* table under Reg. 234).

The elongation shall be not less than 20 per cent on a gauge length of four times the square root of the cross sectional area of the specimen, and the reduction in area not less than 35 per cent.

261. Bend Test Pieces.—(*a*) Two bend test specimens shall be made. The specimens shall be rectangular in section and shall be cut transversely from the weld so as to have a width equal to one-and-a-half times the thickness of the specimens. The corners of the specimens shall be rounded to a radius not exceeding 10 per cent of the thickness of the specimen.

(*b*) Where plate thicknesses do not exceed, $1\frac{1}{4}$ in. the thickness of the specimen shall be equal to the full thickness of the test plate. Where the plate thickness exceeds $1\frac{1}{4}$ in. the specimen shall in all cases have a thickness of at least $1\frac{1}{4}$ in. 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 (*see* Fig. 20, Specimen A). 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 specimen thickness is obtained (*see* Fig. 20, Specimen B). Where the thickness of the plate permits, both specimens may be cut from the same piece of plate, the specimen being located in the plate one above the other (*see* Fig. 20, Specimen C).

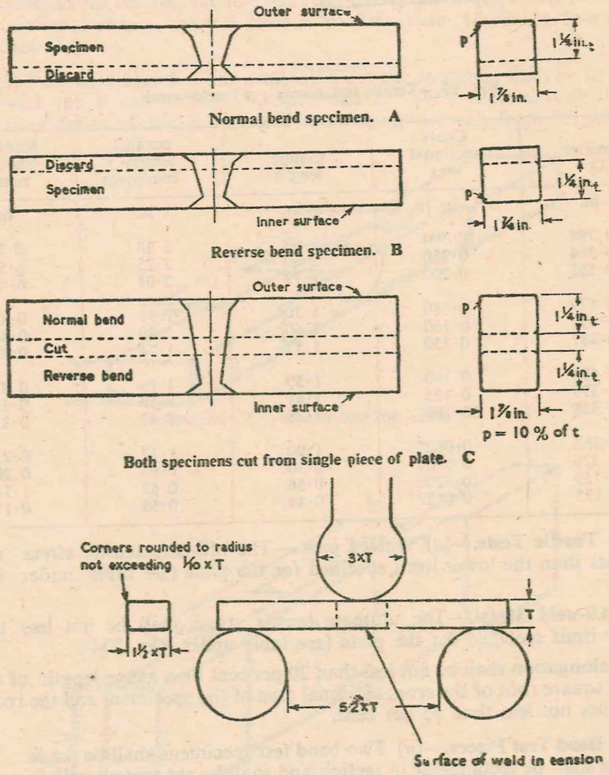


Fig. 20.—Specimen 3 Bend Test

262. Bend Tests.—One specimen shall be tested with the surface corresponding to the outer surface of the drum in tension and the other with the surface corresponding with the inner surface of the drum in tension. The specimens are to be mounted on supports the faces of which are apart by a distance not more than 5·2 times the thickness of the specimen, and shall be pushed through the supports by a former having a diameter equal to three times the thickness of the specimen.

On completion of the test no crack or defect on the outer surface of the specimen shall be greater than 1/16 in. measured across the specimen or 1/8 in.

measured along the length of specimen. Premature failures at the corners of the specimen shall not be considered cause for rejection.

263. Izod Impact Tests.—The dimensions of the two specimens shall be in accordance with Fig. 21, Specimens 4*a* and 5*b*.

One specimen shall have the notch cut at the middle of the outer surface of the weld and the other at the middle of the inner surface of the weld.

The tests shall show a minimum Izod impact test-value of 20 ft. lb.

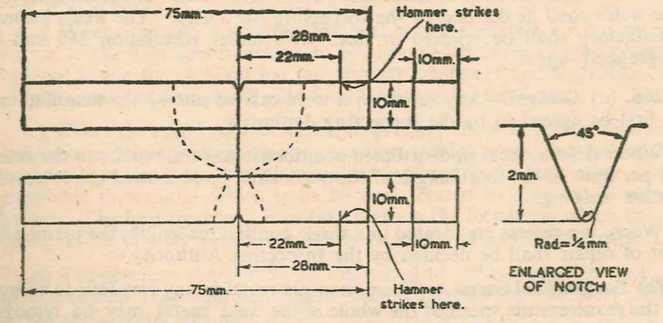


Fig. 21.—Specimens 4a and 4b Izod Impact test pieces.

264. Additional tests before rejection.—(*a*) Should any of the test specimens taken in accordance with Regs. 257 to 263 fail to meet the specified requirements one retest shall be allowed for each specimen that fails, provided the following minimum figures have been obtained :

(*i*) Reduction in area 30 per cent.

(*ii*) Any other test except the bend and impact tests, 90 per cent of the specified requirements.

(*b*) If a cold bend specimen should fail to meet the specified requirements, two re-tests shall be taken from the same test plate and these shall comply with the requirements of Regulations 261; and 262.

(*c*) If an Izod impact test fails to meet the specified requirements, two re-tests shall be taken from the test plate, one each side of the original specimen and separated from it by not more than 5 mm. Both retests shall show a minimum Izod impact test value of 20 ft. lb.

(*d*) If it be found there is insufficient metal to permit the preparation of specimens for retest from the remainder of the test plate from which the original specimen was taken the specimen for re-test may be cut from the test plate relating to the opposite end of the same longitudinal seam.

265. Non-Destructive Tests.—(*a*) **Micro and Macro Examination.**—A specimen, the full thickness of the plate and not less than half-an-inch wide may be taken from each set of test plates by the Inspecting Authority for the purpose of micro and macro examination.

(*b*) **Radiographical Examination.**—Every portion of the longitudinal and circumferential welded joints of the drum shall be subjected to radiographical examination.

The method employed in obtaining the radiographs shall be such as to show clearly defects having a magnitude equal to 2 per cent of the thickness of the welded joint. To determine whether this result is being obtained an indicator of approved form which includes a portion equivalent to not more than 2 per cent of the joint thickness, shall be placed in the vicinity of the weld so as to make a record on each radiograph.

Each section of every weld shall be marked so that the radiographs can be easily correlated to the particular part of the joint represented.

The examination shall be made from the original films and the acceptability of the welds shall be decided by the Inspecting Authority. The welds deemed unsatisfactory shall be rejected or dealt with under Regulation 266 and be radiographed again.

266. (*a*) **General.**—Any repair to a weld carried out by the manufacturer shall first be agreed to by the Inspecting Authority.

Where defects occur in distributed positions in a seam, repairs to the extent of 15 per cent. of the total length of the seam shall be permitted to replace the defective welding.

Where the defects are located in a single continuous length, the permissible extent of repair shall be decided by the Inspecting Authority.

(*b*) **Longitudinal Seams.**—Where the weld metal in any way fails to comply with the requirements specified the whole of the weld metal may be removed and the seam re-welded provided that :

(*i*) the original test plates are similarly treated, or

(*ii*) new test plates of the same thickness as the joint and of similar quality of material are attached to the end of the seam and re-welded with it.

In either case the plates shall be tested in accordance with Regulations 257 to 265 and the requirements for heat treatment shall be in accordance with Regulation 267.

(*c*) **Circumferential Seams.**—With regard to the extent of permissible repair and when agreed by the Inspecting Authority a circumferential seam shall be treated in the same manner as a longitudinal seam. The Inspecting Authority shall be entitled to call for representative tests for a re-welded circumferential seam.

(*d*) **Removal of Defects.**—Defects shall be cut out by chipping or machining only and not by burning out the defective part.

(*e*) **Examination before Re-welding.**—Where a defective part has been cut out, the Inspecting Authority shall be entitled to make an examination before re-welding.

(*f*) **Process used for Repairs.**—Only metallic arc welding shall be used for repairs.

(*g*) **Radiographical Examination after Repairs.**—All repaired areas shall be subjected to radiographical examination.

(*h*) **Specimen Representing Repairs.**—The Inspecting Authority shall be entitled to call for specimens representing any welded repair, for the purpose of examination and test.

(*i*) **Diagram of Welded Repairs.**—On completion of all welded repairs the manufacturers shall, if requested, supply for record purposes a detailed diagram showing the position, length, depth and width of all such repairs.

267. (*a*) **Heat Treatment.**—After the completion of the welding of the seams and the welding on of the stand pipes and including welding repairs but before the hydraulic test, each drum shall be heat treated for stress relieving; during this heat treatment the official test plates shall be lying inside the drum.

(*b*) Where the shell is subjected to a primary stress relieving treatment identical to the final heat treatment to be given to the drum, the test plates may be placed inside the shell during the primary treatment and thereafter cut up and tested without waiting for the final treatment of the drum.

(*c*) Where the shell is not subjected to primary stress relieving treatment or is subject to a primary stress relieving treatment which is not identical with the final heat treatment, the test plates may be placed inside any other drum of comparable dimensions which is to be heat treated in accordance with this Chapter. The heat treatment is to take place in the furnace in which the drum relating to the test plates will eventually be given its final heat treatment.

(*d*) Temperature charts shall be submitted to indicate that the test plates and the drums they represent have been subjected to identical heating, soaking and cooling treatment.

(*e*) For this heat treatment, the drum shall be placed in a furnace sufficiently large to accommodate the whole drum. The furnace shall have proper means of temperature measurement and control and shall be capable of heating the whole of the drum to a uniform temperature. It shall be so designed as to prevent direct impingement of a flame on the drum. The temperature of the furnace at the time the drum is placed in it, shall not be higher than 300° C. The furnace shall be slowly raised to a temperature between 600° C and 650° C and the drum shall remain until it has uniformly reached this temperature. Such temperature shall be sustained for a period of not less than $2\frac{1}{2}$ minutes per mm. plate thickness but shall, in no case, be less than 30 minutes. The drum may be allowed to cool in the furnace but, if withdrawn, shall be screened from draughts while cooling.

(*f*) Alternative procedure for the heat treatment of the drum may be submitted to the Inspecting Authority for approval.

(*g*) In special cases it may be permissible to heat treat the test plates separately from the drum, provided the Inspecting Authority is satisfied with the means adopted to ensure that the following factors will be the same for the drum as far the test plates.

Rate of heating.

Maximum temperature.

Time held at maximum temperature.

Conditions of cooling.

268. Hydraulic and Hammer Tests.—Each drum on completion of all welding and after heat treatment shall be subjected to a hydraulic test pressure of one-and-a-half times the boiler drum maximum permissible working pressure. This pressure shall be maintained for a length of time sufficient to enable an inspection to be made of all seams and connections, but for not less than half an hour. While the pressure is applied, the Inspecting Authority may

at its discretion, call for a thorough hammer test throughout the length of the welds, care being taken to avoid damage to the surface of the plates. In the case of drums of 'Composite' construction, *e.g.*, part riveted and part welded seams or seamless forged drum shells with ends attached by fusion welding, the test pressure shall be the same as that prescribed for fusion welded drum.

Should the hydraulic test reveal any defect in the welded seam it shall not be repaired unless agreed to by the Inspecting Authority.

On completion of agreed repairs to a drum which has previously been stress relieved by heat treatment, this treatment, if required by the Inspecting Authority, shall be repeated and the drums shall again be subjected to the hydraulic test.

INSPECTION AND TESTING

269. Inspection during Construction.—Inspection during construction and fees therefore shall be governed by the rules in Appendix 'J' and regulation 395A.

REGULATIONS FOR DETERMINING THE WORKING PRESSURE OF WATER TUBE BOILERS WITH FUSION WELDED AND SEAMLESS FORGED DRUMS

SHELLS

270. Shell of steam and water drums.—(*a*) The working pressure shall be determined by the following formula :—

$$\text{W.P.} = \frac{2fE\,(T - \cdot 03)}{D + T - \cdot 03} \qquad \text{Eqn. (72)}$$

where T = Thickness in inches.

D = Maximum internal diameter in inches.

W.P. = Working pressure in lb. per sq. inch.

f = Permissible working stress in lbs. per sq. inch at working metal temperature (*see* Reg. 271).

"E—the efficiency of ligaments between the tube holes or other openings in shell or the weld factor of the longitudinal joint (expressed as a fraction), whichever applies.

The weld factor shall not be taken as more than 0·95."

In the particular case of an unpirced wrapper plate of a fusion welded drum.

* E=1 and f = permissible stress on butt weld from the table in Reg. 271, column B.

(*b*) Irrespective of the thickness obtained by the use of the foregoing formula "T" shall not be less than :—

(*i*) For tube plates (where the tubes are expanded therein) the thickness shall be at least such as to allow a minimum parallel belt width of tube seat of 3/8 inch, this seating to be measured as explained below.

(*ii*) All tubes shall be carefully expanded into the holes in the tube plates. The tubes shall be belled of beaded to resist withdrawal and if belled they shall project through the parallel tube seat at least ¼ inch.

(*c*) The Belling shall be as shown in table below :—

TABLE

Outside diameter of tube	Amount of diameter of belling over diameter of the tube hole
	in.
Up to and including 1¼ in.	3/32
Over 1¼ in. upto and including 2 in.	4/32
Over 2 in. up to and including 3¼ in.	5/32
Over 3¼ in. up to and including 4 in.	6/32

(*d*) The tube holes in the tube plates of drums, pockets of headers shall be formed in such a way that the tubes can be effectively tightened in them. Where the tube ends are not normal to the tube plate, there shall be a neck or belt of parallel seating at right angles to the axis of the tube at least $\frac{1}{2}$ in. in depth measured in a plane containing the axis of the tube at the hole.

(*e*) Where the tubes are practically normal to the tube plate or the header this parallel seating shall, wherever practicable, be not less than 3/8 in. in depth.

* **271. Permissible working stresses for shells of Boiler and Integral Superheater Drums and Headers.**—The maximum permissible stress for drum shells and headers shall be the least of the values determined on the following basis :—

(*i*) For temperatures at or below 350°C(662°F), the smaller of the two values.

$$f = \frac{Et}{1{\cdot}6} \qquad \text{or} \qquad \frac{R}{3{\cdot}5}$$

(Note :—The ratio E/R shall not exceed 0·6 for Carbon Steels and 0·7 for Alloy Steels).

(*ii*) For temperatures above 350°C (662°F), the least of the following three values :—

(*a*) $\frac{Et}{1{\cdot}6}$ (*b*) $\frac{SR}{1{\cdot}6}$ and (*c*) Sc

Where,

t = Working metal temperature,

R = minimum specified tensile strength of the steel at room temperature.

E = minimum specified Yield point at room temperature.

Et = Yield Point (0·2% proof strees) at the temperature t.

Sc = The average stress to produce an elongation of 1% (creep) in 100,000 hours a temperature t.

SR = The average stress to produce rupture in 100,000 hours at the temperature 't' and in no case more than 1·33 times the lowest stress to produce rupture at the temperature t.

For fusion welded drums, when the wall thickness exceed 60 mm. (2 3/8") a deduction of 1 per cent in the value of "f" so determined shall be made for each increase of 5 mm. (3/16") in the thickness.

The working metal temperature shall be taken as :—

(*a*) For saturated steam, water and muddrums, the saturation tem perature corresponding to the pressure W. P. plus 50° F.

(*b*) For superheated drums the designed maximum steam temperature for that drum plus 50°° F.

Where the drums are adequately protected from the gases of combustion or swept by such gases in the third or subsequent pass of a boiler, the working metal temperature shall be taken as the saturation or designed maximum steam

temperature as defined above, whichever applies. A covering of refractory or insulating material which may be liable to become dislodged shall not be deemed adequate protection.

NOTE.—Where steels are for service at temperatures in excess of 700°F it shall be so stated as the silicon content shall be 0·10 per cent minimum or alternatively the material must pass the "Proof Test for Creep Quality of Carban Steel Plate of Boiler Plate Quality" as in the Appx. D.

272. The ligament efficiency of drum shells shall comply with Reg. 215.

273. Longitudinal Stress.—Notwithstanding the working pressure as calculated by equation 72, the thickness of drum or cylindrical header shells shall be such that in no case does the longitudinal stress resulting from the combination of stress arising from internal steam pressure, the self-weight of the drum or header and its contents and all externally applied loads, exceed the permissible working stress corresponding to the working metal temperature as prescribed in Regulation 271.

(*a*) The maximum direct longitudinal stress due to the internal steam pressure acting on the drum ends shall be calculated as follows :—

$$fd = \frac{PD^2}{1{\cdot}273A} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \text{ Eqn. (72}a\text{)}$$

where fd = Maximum direct longitudinal stress in pounds per square inch.

P = Design Pressure in pounds per square inch.

D = Internal diameter of the drum or header in inches.

A = Net cross-sectional area of the drum of header in square inches taken through the tube holes in a plane at right angles to its axis.

(*b*) The resultant bending moment M at any section shall be the algebraic sum of the bending moments due to the eccentricity of the end pressure and that due to the externally applied loads.

$$M_R = M_e + M_w \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \text{ Eqn. (72}b$$

The bending moment due to the eccentricity of end pressure shall be calculated as follows :—

$$M = \frac{PD^2_e}{1{\cdot}273} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \text{ Eqn. (72}c\text{)}$$

where M = Resultant bending moment due to eccentricity in pound-inches.

P = Design pressure in pounds per square inch.

D = Internal diameter of drum or header in inches.

E = Eccentricity of the nett cross section *i.e.*, the distance from the neutral axis of the nett section to the drum or header axis in inches.

The bending moment (M_w) due to externally applied loads shall be calculated by treating the drum or header as a beam carrying the externally applied loads, including the self-weight of the drum or header and its contents under working conditions.

(*c*) The stress due to bending shall be calculated as follows :—

$$fb = \frac{M_R Y}{I_a} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \text{ Eqn. (72}d\text{)}$$

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where fd=Stress due to bending in pounds per square inch.

M=Resultant bending moment at the section in pound-inches.

Y=Distance from the neutral axis of the nett cross section to the extreme fibre of the drum or header shell in inches.

I=moment of inertia of the nett cross section taken about its neutral axis in (inches^4).

The resultant longitudinal stress is the algebraic sum of the stresses given under (*a*) and (*c*).

(*d*) In calculating the longitudinal stress due to bending in a drum supported at or near its ends and connected to a lower drum by a bank of tubes (so arranged as to form substantial struts between the drums) the value of the moment of inertia I_a used in the formula in sub-regulation (*c*) shall be :

Moment of inertia of upper drum (I_b) plus a proportion (S) of the moment of inertia of lower drum (I_c).

Where $S=1-\frac{\alpha^2}{240}$ .. .. Eqn. (72*e*)

Where α =The angle in degrees between the vertical and the line joining the centres of the upper and lower drums. Where α is equal to or greater than 15½°., S shall be taken as O. In no case shall the actual value of I_a used in Equation 72*d* be taken as more than 1·33 times the moment of inertia of the upper drum (1b).

In the foregoing, unless otherwise agreed the term "bank of tubes" shall be defined as consisting of four or more rows of tubes extending over at least three quarters of the drum length between supports, and pitched longitudinally at not greater than an average pitch of four tube diameters.

274. Intermediate Boiler Drum Supports.—Where a boiler drum is supported at intermediate points in its length at a distance greater than one internal diameter from the end of the parallel portion of the drum shell, the shell shall be thickened locally to the supports or so designed that when the local stress set up by the supports in the drum shell are added, algebraically to those caused by the internal steam pressure and supported loads, the maximum resultant stress does not exceed the permissible working stress at the working metal temperature.

END PLATES

275. Shape of Dished End Plate.—When an end plate is dished to semi-ellipsoidal, partial spherical or hemispherical form, it shall comply with the following : (*see* Fig. 23) :

(*a*) For ends of partial spherical form the inside radius of dishing R shall not be greater than the outside diameter D of the end plate and the inside corner radius r shall not be less than four times the thickness of the end plate or 2½ inches or 12·5 per cent of the inside diameter of shell, whichever is the greatest.

(*b*) For ends of semi-ellipsoidal form the ratio of the major axis to the minor axis shall not be greater than 2.

276. General.—The thickness T specified in equation 74 of Regulation 278 is the thickness of the end plate after manufacture and is applicable over the whole area of the end plate 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 maximum of 10 per cent. of the thickness T at the point where the corner radius joins the straight portion of flanged end plate. A similar gradual thinning is permissible for end plates of semi-ellipsoidal shape. This permissible reduction in thickness applies also to the flange for the manhole opening. In no case, however, when the end plate is but welded to the drum shell, shall the thickness of the edge of the flange for connection to the shell be less than the thickness of an unpierced seamless shell of the same diameter and material, determined by equation 72.

277. End plate with Manhole.—When an end plate has a flanged-in-manhole the depth of the flange forming the access opening measured from the outer surface of the plate at the minor axis of the opening shall be not less than

$\sqrt{T \times W}$ .. .. Eqn. (73)

where T=Thickness of the end plate in inches;

W=Minor axis of the manhole in inches.

NOTE.—The corner radius of the manhole flange rm shall be not less than 1" (*see* Fig. 23).

278. End Plate subject to pressure on the concave side.—The maximum working pressure of unstayed Dished End Plates subject to pressure on the concave side shall be determined by the following formula :

$$W.P. = \frac{2f(T-C)}{DFK} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad \text{Eqn. (74)}$$

where W.P.=Working pressure.

f=permissible stress at working metal temperature of the drum-end plate (to be calculated on the basis prescribed under Regulation 271);

The working metal temperature for the drum ends of saturated seam, steam and water drums and mud drums, the saturation temperature corresponding to the working pressure of the boiler.

For drum ends of Superheater drums the maximum steam temperature of the drum.

T=Thickness of the plate.

D=Outside diameter of the end plate.

C=0·25 centimeter (0·1 inches).

F=1 for end plates without holes, or having unreinforced widely spaced holes not exceeding four times the plate thickness or 6·4 centimeter (2½ inches) whichever is the less.

=1·15 for end plates having a central flanged in-hole or hand hole (complying with Eqn. 73)

=a constant whose value is more than 1·15 for end plates having unreinforced hole of dimensions greater than 6·4 centimeter (2½ inches) or four times the thickness of the plate.

End plates should not have large unreinforced holes eccentric flanged manholes or hand-holes wherever practicable and in those cases the Chief Inspector of Boilers may in his discretion use such values of F as would meet the circumstances, dependent upon the size, shape and position of these openings in the end plate.

K = A factor dependent upon the ratio $\frac{h}{D}$ where h is the external height, and generally obtained from the curve shown in Fig. 22.

In no case shall K be taken as less than $1{\cdot}15\ \frac{R}{D}$ or $0{\cdot}12\frac{D}{r}$ (*see* Fig. 23).

NOTE 1.—The external height of dishing h may for ends of partial spherical form, be determined as follows—(*see* Fig. 23) :—

$$h = R_2 - \sqrt{\left(R2 - \frac{D}{2}\right) \times \left(R2 + \frac{D}{2} - 2r_2\right)} \qquad \text{Eqn. (75)}$$

NOTE 2.—Where the above rules are applied to small drum ends with manhole openings, the dimensions "rm" and "r" (*see* Fig. 23) apply only to the section of the end containing the minor axis of the opening *i.e.*, "r" and "rm" need not apply throughout the whole periphery of such ends.

STANDPIPES OR BLOCKS

* **279.** (*a*) **Welded construction.**—Where standpipes are secured by welding, adequate compensation for the hole cut for the standpipe shall be provided. Compensation shall be considered adequate when the sectional area X to be compensated is less than the compensating area Y (*see* Fig. 25B).

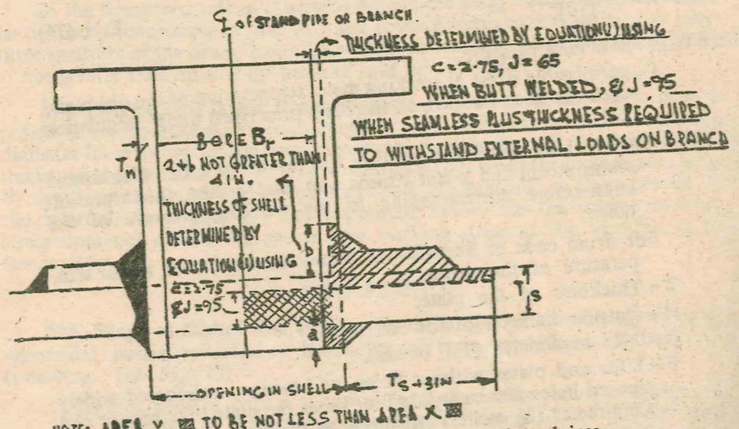


Fig. 25 B—Compensation for welded standpipes.

Area to be compensated and corresponding area allowable for compensation.

The sectional area X shall be calculated as follows :—

The product of the outside diameter of the standpipe (calculated by equation 72) and the thickness of an equivalent drum shell (*see* note at the end of the clause).

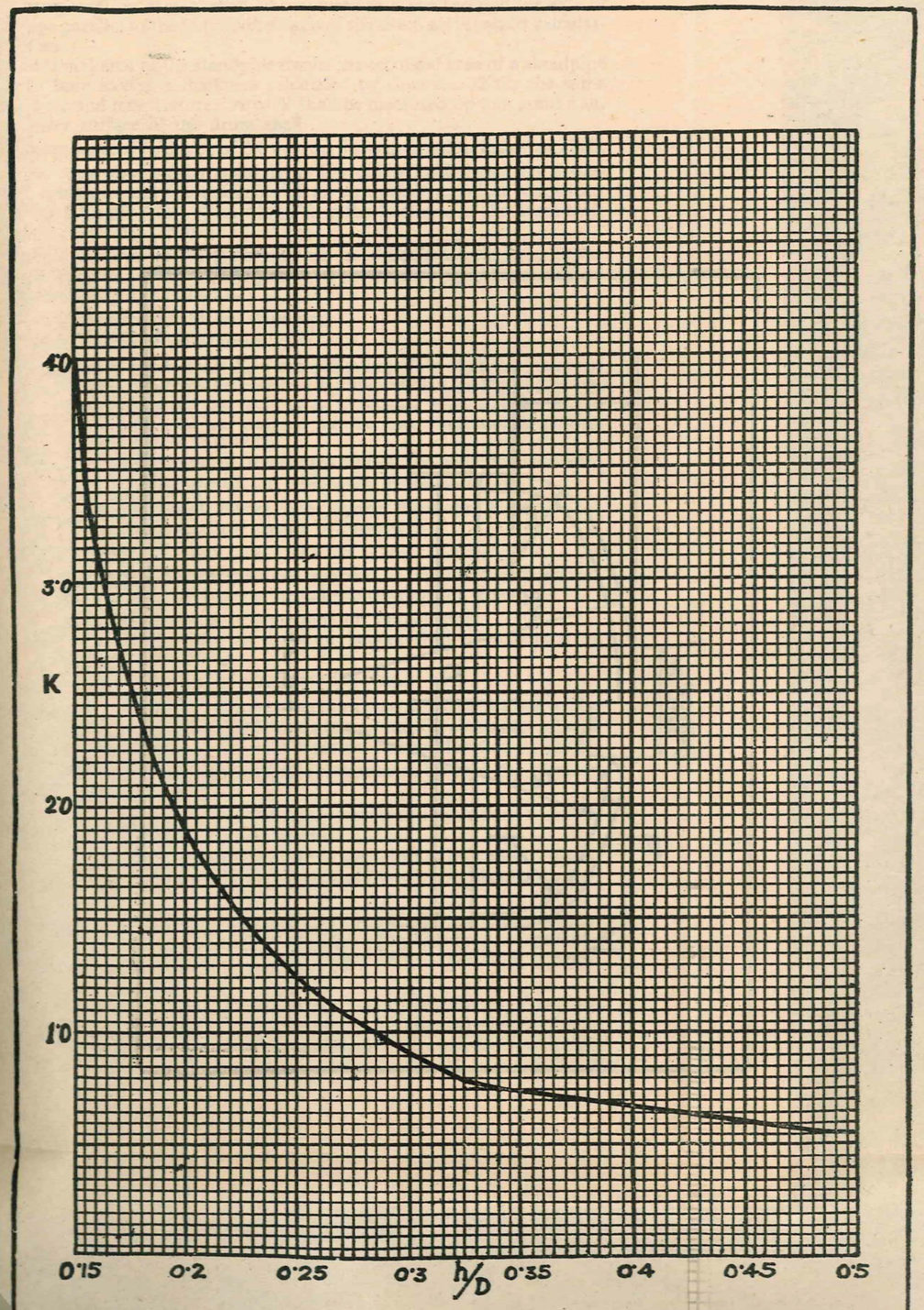


FIG. 22
K = A FACTOR FOR USE IN EQUATION 74 REGULATION 278

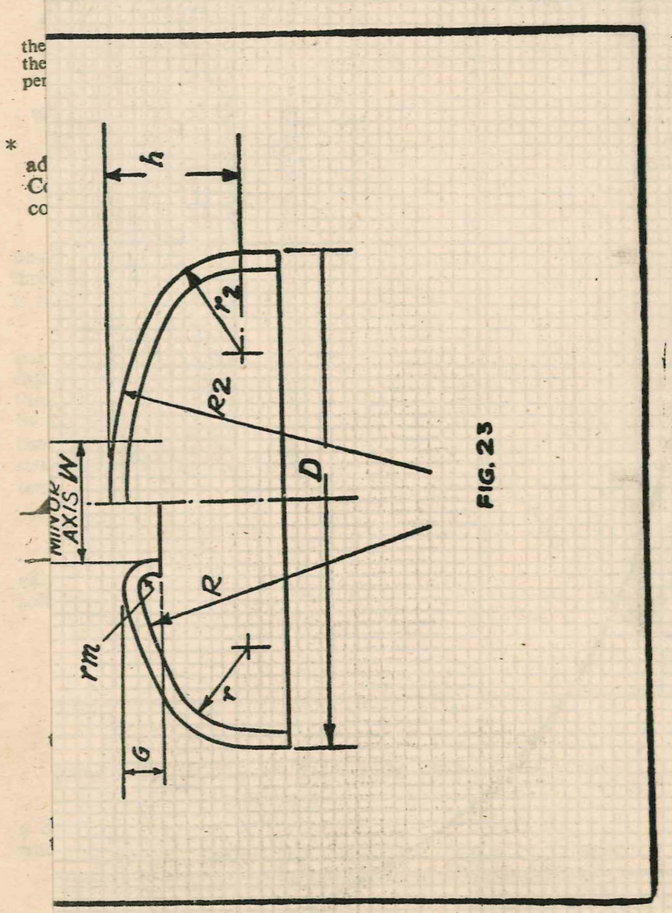


FIG. 23

The compensation area Y shall be measured in plane through the axis of the standpipe parallel to the longitudinal axis of the drum and shall be calculated as follows :—

The sectional area of the standpipe minus the sectional area of a standpipe of the same bore having a thickness calculated by equation 72 for the same design pressure and temperature. Area Y shall be measured up to a point 4 in. from the outer surface of the drum shell.

Plus the cross-sectional area of the welding fillets external to the drum shell.

Plus the area obtained by multiplying the difference between the actual drum shell thickness and the thickness of an equivalent seamless unpierced drum shell by a length 2(Ts+3) in. where Ts is the thickness of the drum shell plate in inches (*see* Fig. 25B).

Where the material of the standpipe has an ultimate tensile stress lower than that of the drum shell, the compensating sectional area of the standpipe shall be multiplied by the ratio :—

$$\frac{\text{Ultimate tensile stress of the standpipe}}{\text{Ultimate tensile stress of drum shell}}$$

In cases where Y is less than X, a compensating plate shall be fitted to the drum shell at the standpipe and secured by fillet welds (*see* Fig. 25B).

NOTE.—An equivalent drum shell shall mean a seamless drum shell of similar material unpierced by tube holes and designed for the same conditions of pressure and temperature as the drum shell in question.

(*b*) The minimum thickness of the flanges and of the body of standpipes shall be in accordance with the table under Regulation 156.

280. Attachment of Stand Blocks and Branch Pipes by Welding.—(*a*) Typical methods of attachment are shown in Figures :—

24A, 24B, 24C, 24D, 26A, 26B, 26C, 26D, 26E, 27A and 27B.

All weld dimensions shown shall be regarded as minimum dimensions those defining the grooves refer to the actual preparation for welding.

t_n = Specified thickness of standpipe or branch pipe.
t_s = Specified thickness of drum or header shell at standpipe or branch connection.
t_c = Actual thickness of compensating ring.

The application of certain of the constructions illustrated may be limited by consideration of design pressure and temperature or size (in combination) and although certain dimensions are given, each case must be considered on its merits.

Other methods may be adopted subject to agreement between the Inspecting Authority and manufacturer.

(*b*) Electrodes shall comply with the requirements of Regulations 94 to 98 (Covered Electrodes for Metal Arc Welding).

(*c*) Not less than two runs of metal shall be deposited at each weld. Each run of weld metal shall be thoroughly cleaned and freed from slag before the next run is deposited.

Where one side of a double V Weld has been completed, the under surface of the original run of metal shall be removed by grinding, chipping or machining to give a clean metallic surface before welding on the other side is commenced.

(*d*) The final finish of the weld shall be such that the change of section from drum to standpipe, or from flange to standpipe is gradual and free from sharp notches. After completion of welding (except in the case of seal welds the drum shall be stress-relieved by heat treatment.

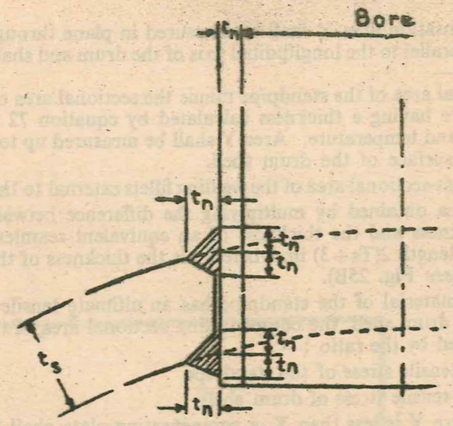


Fig. 24A Welded-in standpipe or branch
For standpipes and branches up to and including 4 in. bore.

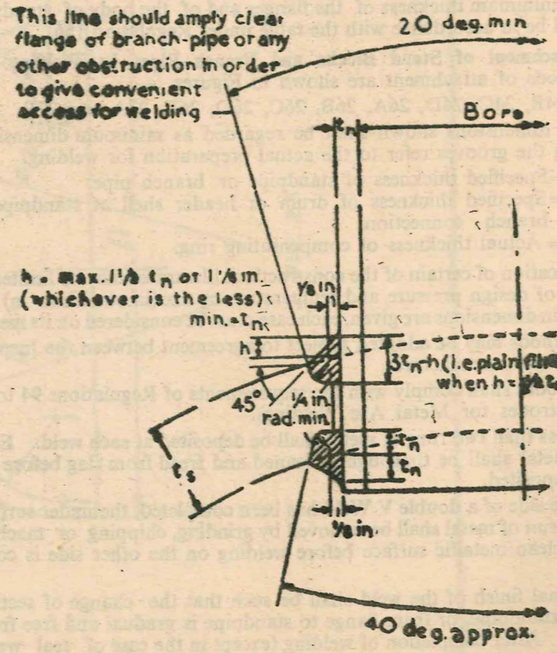
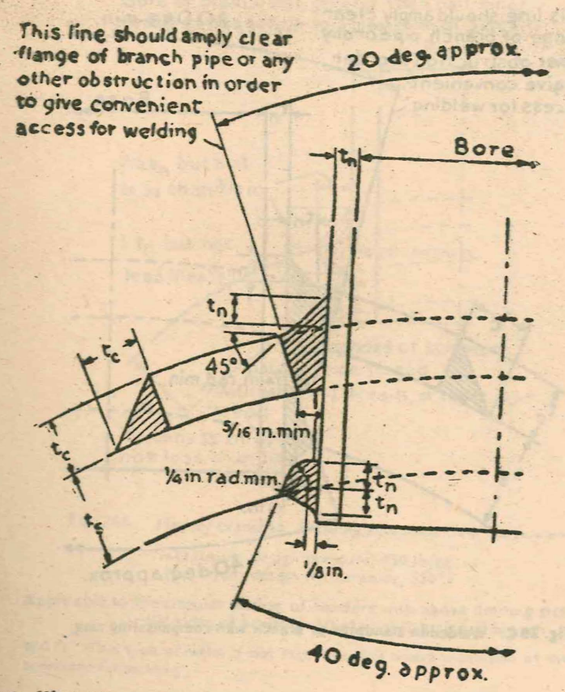


FIG 248 Welded to standpipe or branch for standpipe or branches up to and including 4 in. bore.



24C Welded-in standpipe or branch with compensating ring for standpipes or branches up to and including 4 in. bore.

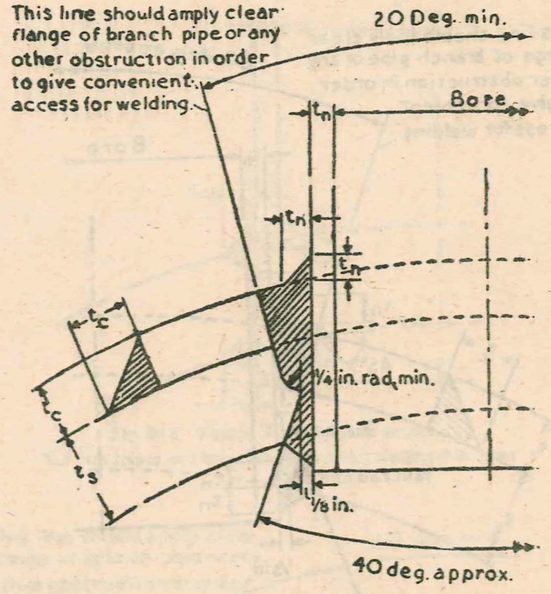


Fig. 26C. Welded-in standpipe or branch with compensating ring

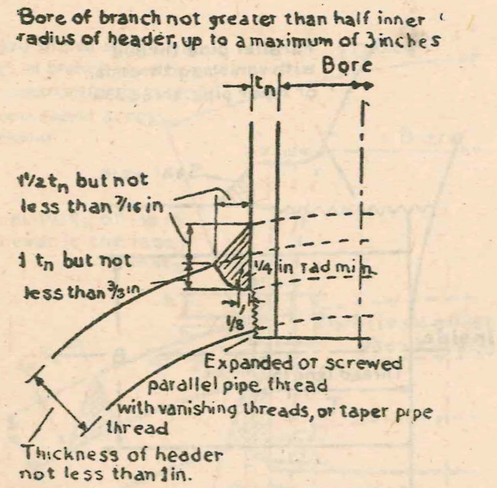
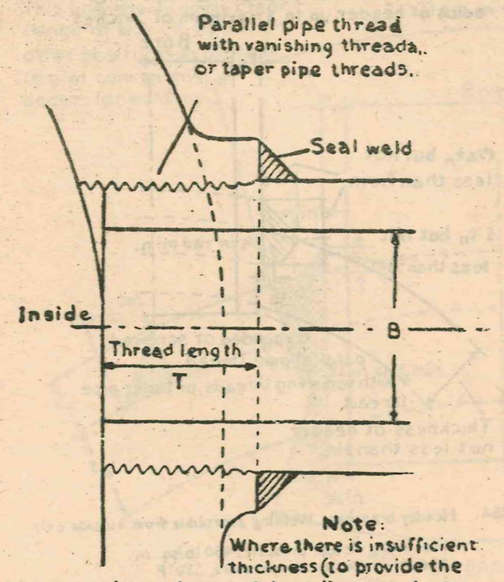


Fig. 26A. Header branches Welding accessible from outside only

Maximum design pressure, 450 lb/sq. in
Maximum design temperature, 550° F

Applicable to the circular section of headers with above limiting size of branch or flat sides of headers without limiting size of branch

NOTE This type of weld is not recommended where the inside of the header is accessible for welding



Note:
Where there is insufficient thickness (to provide the minimum length of thread) a boss, built up of weld metal, may be added

Nominal bore of pipe B	Total length of thread (Minimum) (T)
in.	in
1½ and 1¼	1
1	⅞
¾	¾
½ and below	⅝

Fig. 26B. Screwed and seal welded connection

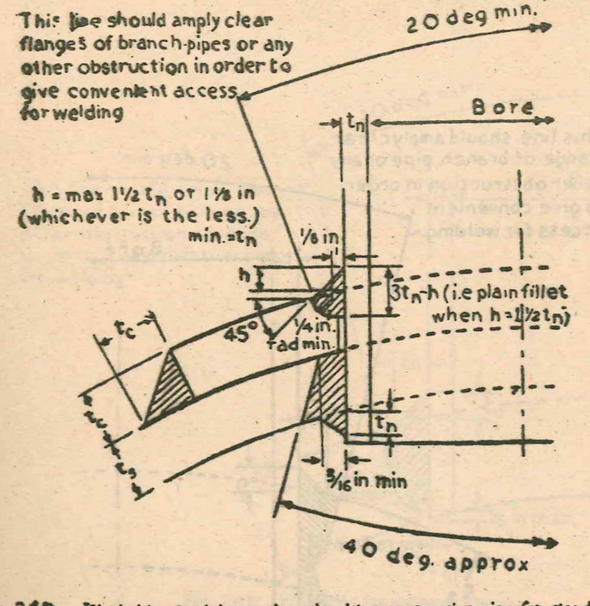


Fig 24D Welded-in standpipe or branch with compensating ring for standpipes and branches up to and including 4 in. bore.

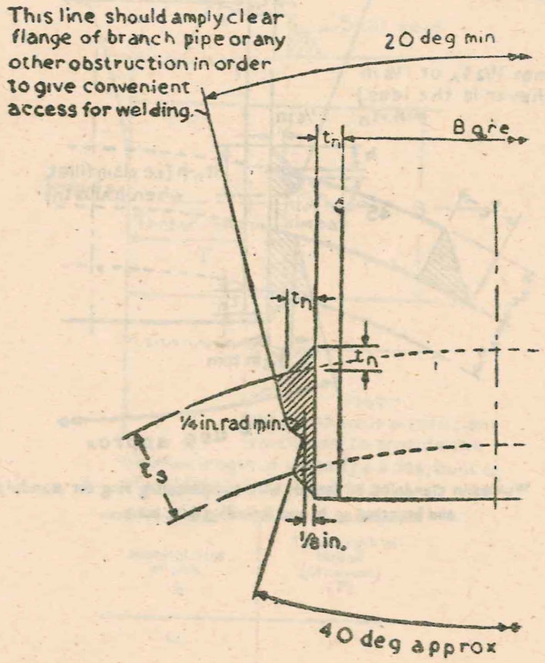


Fig. 26 D Welded-in standpipe or branch

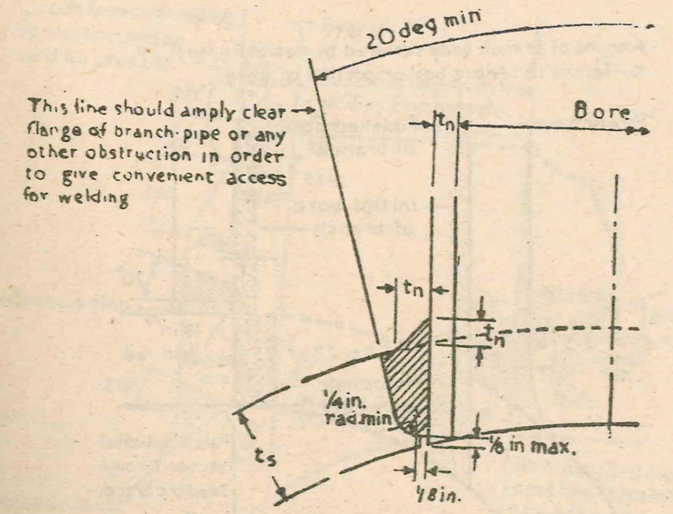


Fig. 26 E. Welded-in standpipe or branch

This type of weld is not recommended where the inside of header or drum is accessible for welding.

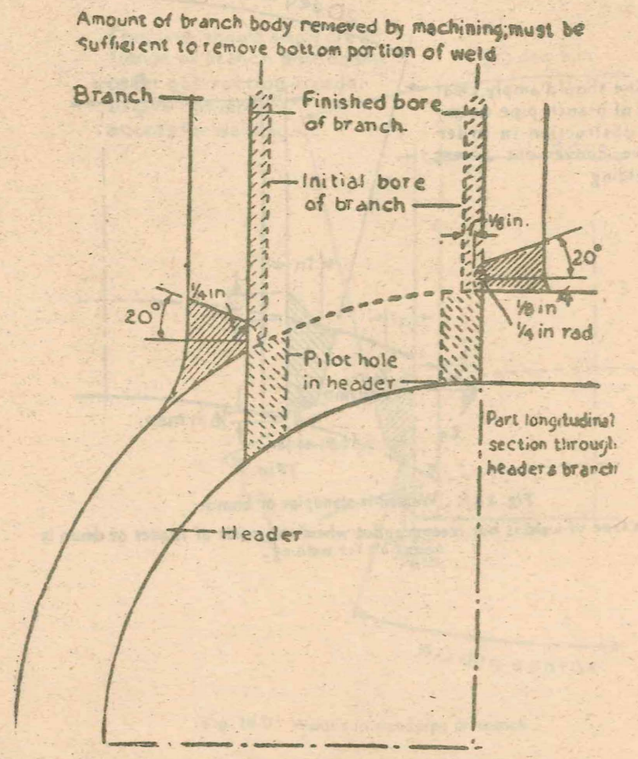


Fig 27A Branch welded-on header with internal machin.

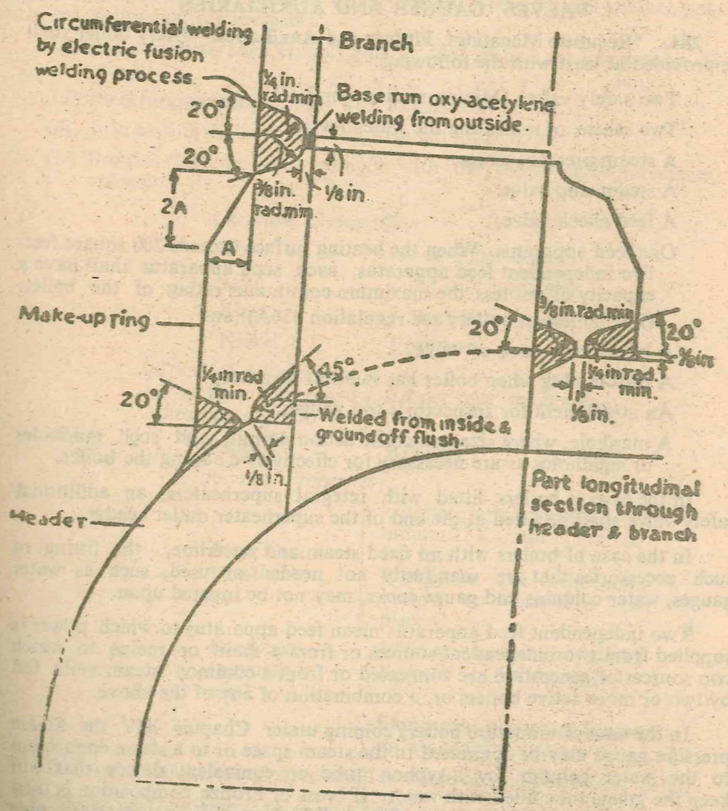


Fig 27B. Branch with make-up ring welded on header