CHAPTER II

MATERIALS OF CONSTRUCTION

STEEL PLATES, RIVETS, SECTION AND BARS

* **9. Process of manufacture.**—Structural steel for boilers shall be made by the Open Hearth or an Electric Process, acid or basic.

* **10. Chemical Analysis.**—(*a*) The steel shall contain not more than 0.05 per cent of sulphur or of phosphorus.

(*b*) A sulphur print test shall be taken from the material of each charge used for rivet bars for the purpose of ensuring that sulphur segregates are not concentrated in the core. The stage in manufacture at which this test is made shall be at the option of the Steel-Maker.

(*c*) When the material is required for flame cutting and/or welding, the carbon content shall not exceed 0.30% and special precautions shall be taken wnen the carbon content exceeds 0.26%

When steels are intended for service temperatures over 700°F the silicon content shall be not less than 0.10% or alternatively, the material shall pass the proof test for creep quality of carbon steel plates of boiler quality.

11. Freedom from Defect etc.—The finished material shall be sound, free from cracks, surface flaws, lamination or inclusion or any cavities due to gas bubbles in ingot. The homogenity of the material shall be proved to the satisfaction of the Inspecting Authority. Hammer dressing, patching or welding is prohibited; but this does not prevent the removal of slight scales or shall by the use of chisel, file, buff or shot blast, providing the material is not reduced to under the specified thickness.

12. Rolling Margin.—No plate or rolled section shall be under the specified thickness at any part, nor more than 5 per cent over the calculated weight, except that in the case of thin plates and wide plates the weight tolerances shall be as set out in the table below :

Schedule of percentage of Rolling weight tolerances for boiler plates

Thickness	Width in inches								
	Under 48	48 to under 60	60 to under 72	72 to under 84	84 to under 96	96 to under 108	108 to under 120	120 to under 132	132 and over
in.	%	%	%	%	%	%	%	%	%
1/4 to under 5/16 ..	5	5	5	7	9	12	—	—	—
5/16 to under 3/8 ..	5	5	5	6	7·5	10	11	12	—
3/8 to under 7/16 ..	5	5	5	6	6	8	9	11	15
7/16 to under 1/2 ..	5	5	5	5	6	7·5	8	9	12
1/2 to under 5/8 ..	5	5	5	5	6	6	7·5	9	10
5/8 to under 3/4 ..	5	5	5	5	5	5	7	8	9
3/4 to under 1	5	5	5	5	5	5	6	7	8
1 to under 2	5	5	5	5	5	5	5	9	7

All the above margins will be taken over nett theoretical weight.

13. Testing and Inspecting.—The following tests and inspections shall be made at the place of manufacture prior to despatch; but in the event of any of the material proving unsatisfactory in the course of being worked into boilers, such material shall be rejected, not withstanding any previous certificate of satisfactory testing, and such further tests of the material from the same charge shall be made as the Inspecting Officer in attendance may consider desirable.

14. Selection of test pieces.—All test pieces shall be selected by the Inspecting Officer and tested in his presence, and he shall satisfy himself that the conditions herein described are fulfilled.

15. (*a*) **Tensile test pieces.**—The tensile strength and ductility shall be determined from standard test pieces (*see* App. B) cut lengthwise or crosswise from the rolled material. When material is annealed or otherwise treated before despatch, the test pieces shall be similarly and simultaneously treated with the material before testing.

(*b*) (*i*) **Plates, Angles and Tees.**—Wherever practicable, the rolled surface shall be retained on two opposite sides of the test piece. The ultimate tensile stress and percentage of elongation on 8 in. gauge length shall be determined on standard test piece A (*see* App. 8) and for plates over 2 in. in thickness, standard test piece B shall be used.

(*ii*) **Round Bars.**—Round bars may be tested full size as rolled, or they may be turned down to a convenient size.

If tested 1 inch diameter or under, test piece B (*see* App. B) shall be used. The sectional area of the test piece shall not be less than 1/4 square inch.

Where the test piece is over 1 inch diameter, test piece B (*see* App. B) may be used.

Any straightening of the test pieces which may be required shall be done cold.

16. Tensile Tests.—The ultimate tensile stress and elongation of the various classes of materials shall be between the limits shown in the table below but a range of not more than 4 tons in each class of material shall be permitted.

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 plate or bar.

Description	Ultimate tensile stress Tons/ sq. in.	Minimum Elongation* per cent			Bend Test
		Test piece A 8 in. gauge length	Test Piece B	Test piece	Radius of bend T—Thickness or diameter
Plates for shell, but straps, gussets and stays.	26—36	23 for 26—30 tons/sq. in. 20 for 28—32 tons/sq. in. 20 for 30—36 tons/sq. in.	21 for 26—30 tons/sq. in. 18 for 28—32 tons/sq. in. 18 for 30—36 tons/sq. in.	—	1 T for 26—30 tons/sq. in. 1 1/4 T for 28—32 tons/sq. in. 1/2 T for 30—36 tons/sq. in.
Plates for flanging and for furnaces.	24—32	23 for 24—30 tons/sq. ib. 20 for 28—32 tons/sq. in.	21 for 24—30 tons/sq. in. 18 for 28—32 tons/sq. in.	—	IT for 24—30 tons/sq. in. 1 1/2 T for 28—32 tons/sq. in.
Plates for forge welding.	24—30	3 for 24—30 tons/sq. in.	21	—	IT for 24—30 tons/sq. in.

Description	Ultimate tensile stress tons/sq. in.	Minimum Elongation* per cent			Bend Test
		Test piece A 8 in. gauge length	Test Piece B†	Test piece B_1	Radius of bend T=Thickness or diameter
Sections ..	26—30 or 28—33	26 for 26—30 tons/sq. in. 20 for 28—33 tons/sq. in.	—	—	1T for 26—30 tons/sq. in. 1½ T for 28-33 tons/sq. in.
Bars for bar stays	26—36	—	25 for 26—30 tons/sq. in. 22 for 30—36 tons/sq. in.	30 for 26—30 tons/ sq. in. 27 for 30—36 tons/ sq. in.	1½ T.
Bars for Screwed Stays	24—28 or 26—30	—	25	30	1T
Bars for rivets ..	24—28 or 26—30	—	25	30	—

*For material under 3/8 inch. in thickness reduce minimum percentage elongation value by 3.
† Machined in the case of plate.

17. Number of Tensile Tests.—(*a*) **Plates.**—For shell plates, butt straps and gusset plates one tensile test piece shall be cut from each end of every plate as rolled.

(*b*) For other plates such as end plates, furnace and flanging plates, etc., one tensile test piece shall be cut from one end of every plate as rolled.

(*c*) **Angle, tee, rivet, and stay bars.**—One tensile test shall be made from each 15 or part of 15 bars rolled of each section or diameter from the same charge, but not less than two tensile tests shall be made unless the total number of bars rolled from the same charge is 8 or less than 8 and the bars of the same section or diameter, in which case one tensile test shall suffice. For round bars of 1¾ inches diameter and under, the numbers 50 and 20 shall be substituted for 15 and 8 respectively for determining the number of tests required.

18. Dump Tests.—Short lengths equal to twice their diameter cut from the rivet bars shall, when cold, withstand without fracture being compressed to half their length. A dump test shall be made for each Tensile Test.

19. Bend Tests.—Cold Bends.—(*a*) Test pieces shall be sheared lengthwise or crosswise from plates or bars, and shall not be less than 1½ inches wide, but for small bars the whole section may be used. For rivet bars bend tests are not required.

(*b*) In all cold bend tests, on samples 0.5 inch in thickness and above, the rough edge or arris caused by shearing may be removed by filing or grinding, and samples 1 inch in thickness and above may have the edges machined, but the test pieces shall receive no other preparation. The test pieces shall

not be annealed unless the material from which they are cut is similarly annealed in which case the test piece shall be similarly and simultaneously treated with the material before testing.

(*c*) For cold bend tests the test piece shall withstand, without fracture, being doubled over until the internal radius is equal to that shown in table under regulation 16 and the limbs are parallel.

(*d*) For small sectional material these bend tests may be made from the flattened bar.

(*e*) Bend tests may be made either by pressure or by blows.

20. Number of Bend Tests.—(*a*) **Plates.**—A bend test shall be taken from each plate as rolled. For plates exceeding 2½ tons in weight one bend test shall be taken from each end. The bend tests from shell plates, butt straps and other plates which have not to be flanged or worked in the fire or which when in use are not to be exposed to flame shall be cold bend tests.

(*b*) **Angle Bars.**—A cold bend test shall be made from each angle bar rolled.

(*c*) **Stay Bars.**—A cold bend test shall be made from every 15 stay bars as rolled from each charge.

21. Manufactured Rivets.—(*a*) **Quality of Material.**—Rivets shall be manufactured from steel complying with the aforementioned requirements of this Chapter in respect of rivet bars.

(*b*) **Tests.**—(*i*) The rivet shanks shall be bent cold, and hammered until two parts of the sank touch, without fracture on the outside of the bend.

(*ii*) The rivet heads shall be flattened while hot, without cracking at the edges until their diameter is 2½ times the diameter of the shank.

(*c*) **Number of Tests.**—Up to half per cent of rivets of each size shall be selected by the Inspector or Inspecting Officer from bulk for the above tests.

22. Additional tests before rejection.—Should the test pieces first selected by the Inspector or Inspecting Officer not fulfil the test requirements, two further tests of the same kind may be made, but should either of these fail, the plates or bars from which test pieces were cut shall be rejected. In all such cases further tests shall be made before any material from the same charge can be accepted.

23. Branding.—Every plate, section and bar shall be clearly and distinctly marked by the maker in two places with the number of identification mark by which they can be traced to the charge from which the material was made. As an alternative the rivet bars may be bundled and tabbed to enable the material to be traced to the cast of steel from which they are made.

24. Defacing of rejected material.—In the event of the material failing in any case to withstand the prescribed tests, the identification mark of the Inspecting Officer which has been stamped on the material, shall be defaced by punch marks extending beyond the identification mark, in the form of a cross, thus denoting that the material has failed.

25. Facilities for inspection.—The maker shall adopt a system of making the ingots, billets, slabs, plates, bars, etc. which will enable all finished material to be traced to the original charge, and the Inspector or Inspecting Officer shall be given every facility for tracing all plates and bars to their respective charges, and for witnessing the required tests. When he is satisfied with the

material and with the results of the tests, he shall be furnished with two copies of the advice notes of the material for his signature.

* **26. Steel not produced where rolled.**—Where steel is not produced in the works at which it is rolled, a certificate in Form IV shall be supplied to the Inspecting Officer deputed to witness the testing of the material, stating the Open Hearth or Electric Process by which it was made, the name of the Steel-Maker who supplied it, also the numbers of the charges for reference to the books of the Steel-Maker. The number of the charge shall be marked on each plate or bar for the purpose of identification.

* **27. Maker's certificate.**—Before the mill sheets are signed, the maker shall furnish the Inspecting Officer with a certificate in Form IV guaranteeing that the material has been made by the Open Hearth or an Electric Process, acid or basic, and that it has been subjected to, and has withstood satisfactorily the test above described in the presence of the Inspecting Officer.

WROUGHT IRON STAY AND RIVET BARS

28. Rivet Bars.—The tensile breaking strength shall be between 21 and 25 tons with an elongation of not less than 25 per cent measured on the standard Test Piece B (as rolled) or 30 per cent measured on the Standard Test Piece B_1 (as rolled).

29. Manufactured Rivets Tests.—To comply with Regulation 21.

30. Stay Bars.—The tensile breaking strength shall be between 21 and 25 tons with an elongation of not less than 22 per cent measured on the Standard Test Piece B or 27 per cent measured on the Standard Test Piece B_1.

31. Stay Bars.—Bend Tests.—To comply with Regulation 19

32. Special Iron for Screw Stays for Fire-boxes and Combustion Chambers.—In order that iron screw stays may be approved of the same size as would be required for mild steel, the iron must withstand the following tests:—

(*a*) **Tensile Tests.**—The tensile breaking strength shall not be less than 21½ tons per square inch, with an elongation of not less than 25 per cent measured on the Standard Test Piece B or 30 per cent measured on the Standard Test Piece B_1.

(*b*) **Bend Tests.**—Test pieces either of the bar as rolled, or turned down to 1 inch diameter, shall stand bending cold until the sides are parallel and the space between the two sides is not greater than the diameter of the test piece.

(*c*) **Number of Tensile Tests.**—The bars as rolled shall be placed in batches of twenty, and one tensile test shall be taken from each batch. If this is unsatisfactory two other bars shall be selected for test, and should either of these fail the batch shall be rejected.

(*d*) **Number of Bend Tests.**—One ordinary bend test shall be taken from each batch, and a similar test piece from each batch shall be lightly and evenly nicked on one side with a sharp cutting tool and bent back at this point through an angle of 180 degrees by pressure or by a succession of light blows. The fracture must be clean, fibrous,

free from slag or dirt or any coarse crystalline structure. If either of these is unsatisfactory, two other bars shall be selected for test, and should either of these fail the batch shall be rejected.

(*e*) In all cases the selection of the test pieces shall be made by the Inspector or the Inspecting Officer.

COPPER PLATES, STAY AND RIVET BARS

33. Plates.—(*a*) **Process.**—The copper shall be fire-refined or electrolytic and hot-rolled from suitable cakes.

(*b*) **Chemical Composition.**—The chemical composition of the plates shall be as follows:—

	Per cent
Copper	99.2 minimum
Arsenic	.30 to .50
Antimony	0.05 maximum
Bismuth	0.05 maximum
Oxygen	0.10 maximum

(*c*) **Freedom from defects.**—The plates shall be clean, smooth and free from defects and shall have a workmanlike finish. They shall be thoroughly annealed.

(*d*) **Rolling Margin.**—No plate shall be under the specified thickness at any part, not more than 5% over the calculated weight. The scrap margin, partly sheared and left attached, shall be not less than 3 inches at the ends and 1½ inches at each side.

(*e*) **Tensile Tests.**—One tensile test shall be taken from each plate as rolled.

The tensile breaking strength, from Standard Test Piece A, shall not be less than 14 tons per sq. in. with an elongation of not less than 35%.

(*f*) **Hot and Cold Bend tests.**—One hot (temperature between 1200° F and 1400° F) and one cold bend test shall be taken from each plate as rolled.

For either hot or cold bend tests, the test piece shall withstand being doubled over without fracture until the sides are touching and parallel.

34. Stay and Rivet Bars.—(*a*) **Process.**—To comply with Regulation 33 (*a*).

(*b*) **Chemical Composition.**—To comply with Regulation 33 (*b*).

(*c*) **Freedom from Defects.**—To comply with Regulation 33(*c*).

(*d*) **Rolling Margin.**—The bars in any part shall not be more than 1% over or more than ½% under the specified diameter.

(*e*) **Tensile Tests.**—The materials shall have the tensile properties shown in the following table:—

Tensile properties

	Unturned rods (rods up to 1¼ in. dia.)	Turned rods (rods above 1¼ in. dia.)
Minimum tensile strength lb. per sq. in.	32,400	32,400
Elongation, minimum per cent in 2 in. gauge length	40	45

(*f*) **Bend Tests.**—To comply with Regulation 33(*f*).

(*g*) **Dump Tests.**—A piece of rod 1 in. long shall be placed on end and hammered or crushed down cold to a thickness of 3/8 in. without showing either crack or flaw on the circumference of the resulting disc.

(*h*) **Number of Tests.**—One bar, from which the required test specimens shall be taken, shall be selected at random from each batch of 50 (or part thereof) bars of each size from each melt. From each bar selected, one tensile test, one cold bend test, one hot bend test and one dump test shall be made.

COPPER AND BRASS TUBES

35. (1) **Copper Tubes.**—(*a*) **Process.**—The copper shall be fire-refined or electrolytic and shall be made into tubes either by the hot rolling or cold drawing process. The tubes shall be finished by cold drawing.

(*b*) **Chemical Composition.**—To comply with Regulation 33(*b*).

(*c*) **Freedom from Defects.**—The finished tubes, both externally and internally shall be sound, clean, smooth, well finished and free from surface defects and longitudinal grooving, and the ends must be clean and square.

(*d*) **Tolerance.**—The actual weight of each tube shall not be more than 5% above the calculated weight. Unless, otherwise specified, they shall be straight cylindrical, of uniform thickness and external diameter throughout.

(*e*) **Tensile Tests.**—Tensile tests shall be made on pieces of tubes or strips cut from the tube. If the tensile test is made on a piece of tube, the ultimate tensile stress shall be not less than 14·50 tons (32,480 lbs.) per sq. in. with an elongation of not less than 50 per cent on 2 in.

If the tensile test is made on strip cut from the tube, the ultimate tensile stress shall be not less than 14 tons (31,360 lbs.) per sq. in. with an elongation of not less than 40 per cent on a test piece having a gauge length of four times the square root of the area.

The results obtained from a batch shall be uniform, and should a variation of more than one ton (2,240 lbs.) per sq. in. be found between any number of tubes tested, the batch shall be liable to rejection. A batch shall not consist of more than 500 tubes.

(*f*) **Bulging or Drifting Test.**—The test piece shall stand bulging or drifting cold (*see* Diagrams 1 and 2 respectively) without showing either crack or flaw, until, the outside diameter of the bulged or drifted end measures not less than 25 per cent more than the original diameter of the tube.

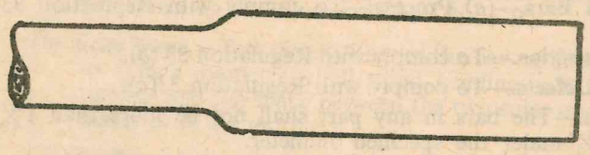


DIAGRAM 1

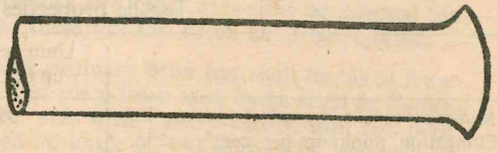


DIAGRAM 2

(*g*) **Flanging Test.**—The test piece shall stand flanging cold (*see* Diagram 3 without showing either crack or flaw until the diameter of the flange measures not less than 40 per cent more than the original diameter of the tube

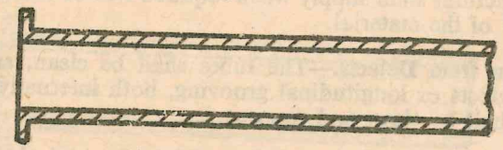


DIAGRAM 3

(*h*) **Flattening and Doubling over Test.**—The test piece shall stand the following test, both cold and at a red heat, without showing either crack or flaw. The test piece shall be flattened down until the interior surfaces of the tube meet and then be doubled over on itself, that is bend through an angle of 180° (*see* Diagram 4) the bend being at right angles to the direction of the length of the tube.



DIAGRAM 4

(*i*) **Hydraulic Test.**—Each tube shall be tested, before the tubes are presented for inspection by an internal hydraulic pressure of 750 lbs. per sq. in. or by such internal hydraulic pressure as may have been specified by the Inspecting Authority and the Inspector may re-test 5 per cent or more as he may deem necessary.

The tubes shall withstand the test without showing any signs of weeping or any evidence of defects.

(*j*) **Treatment of Test Specimens.**—All test material, if not already in an annealed condition, shall be annealed before testing and shall comply with the mechanical tests without further heat or mechanical treatment.

35. (2) **Brass Tubes.**—(*a*) **Composition.**—Brass for boiler tubes may be of either 70/30 alloy or 2/1 alloys as specified.

(*b*) **Chemical analysis.**—The tubes shall consist of an alloy of copper and zinc, and shall contain:—

70/30 alloy. Not less than 70 per cent of copper and not more than a total of 0·75 per cent of materials other than copper and zinc.

2/1 alloy. Not less than 66·70 per cent of copper and not more than a total of 0·75 per cent of materials other than copper and zinc.

The manufacturer shall supply when required free of charge, a copy of his works analysis* of the material.

(*c*) **Freedom from Defects.**—The tubes shall be clean, smooth and free from surface defects or longitudinal grooving, both internally and externally, and the ends shall be clean and square.

(*d*) **Tolerances.**—The tubes shall be solid drawn and shall be concentric within the working margins for thickness given below. The tubes shall be straight and unless otherwise ordered they shall be of uniform diameter throughout.

The working margins shall be as follows:—

On length±1/16 in.

On thickness±half the difference between the Standard Wire Gauge (S.W.G.) specified and the next Standard Wire Gauge thicker.

On external diameter±0·005 in.

(*e*) All test material shall be annealed before testing and shall comply with the following mechanical tests:—

(*i*) *Bulging or Drifting Test.*—The test piece shall stand bulging or drifting cold (*see* Diagrams 1 and 2 respectively) without showing either crack or flaw, until the diameter of the bulged or drifted end measures not less than 25 per cent more than the original diameter of the tube.

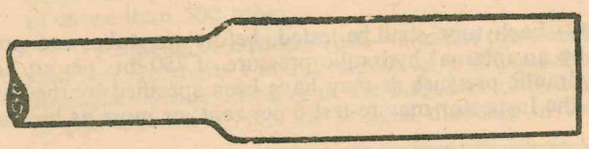


DIAGRAM 1

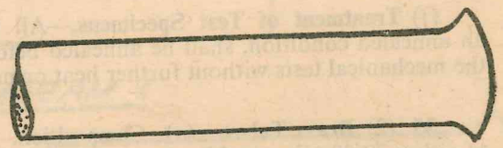


DIAGRAM 2

(*ii*) *Flanging Test.*—The test piece shall stand flanging cold (*see* Diagram 3) without showing either crack or flaw until the diameter of the

*A Works analysis is defined as the routine analysis taken by or for the manufacturer in order to control the quality of the material.

flange measures not less than 25 per cent more than the original diameter of the tube.

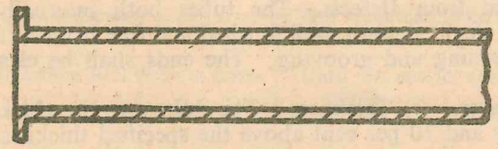


DIAGRAM 3

(*iii*) *Flattening and Doubling over Test.*—The test piece shall stand the following test when cold without showing either crack or flaw. The rest piece shall be flattened down until the interior surfaces of the tube meet and then be doubled over on itself, that is, bent through an angle of 180° (*see* Diagram 4), the bend being at right angles to the direction of the length of the tube.



DIAGRAM 4

(*f*) **Hydraulic Test.**—Each tube shall be tested, before the tubes are presented for inspection, by an internal hydraulic pressure of 750 lbs. per sq. in. or by such internal hydraulic pressure as may have been specified by the Inspecting Authority and the Inspector may re-test 5 per cent or more as he may deem necessary.

The tubes shall withstand the test without showing any signs of weeping.

COLD DRAWN SEAMLESS STEEL BOILER AND SUPERHEATER TUBES FOR DESIGN METAL TEMPERATURES NOT EXCEEDING 427 DEGREE C (800 DEGREE F)

* **36.** (*a*) **Material.**—The tubes shall be seamless and made of steel produced by an Open Hearth or Electric Process, acid or basic, and shall be certified as such by the makers of the steel and tubes. The material of the tubes shall show on analysis not more than 0·05 per cent of sulphur and 0·05 per cent phosphorus and the manufacturer shall supply a certificate of the analysis when required to do so.

NOTE.—Where the materials used for designed temperatur above 750° F (399° C) the steel shall be of non-segregated or fully killed type.

HOT FINISHED SEAMLESS CARBON STEEL BOILER AND SUPERHEATER TUBES FOR DESIGN METAL TEMPERATURES NOT EXCEEDING 427 DEGREE C (800 DEGREE F)

* 43. (*a*) **Material.**—The tubes shall be seamless and made of steel produced by an Open Health or Electric Process, acid or basic, and shall be certified as such by the maker. The chemical composition of the material of the tubes shall conform to the following analysis:—

Chemical Composition (*ladle analysis*)

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

These provisions cover two quality group of steels, namely, grade 1 and grade 2 depending on their tensile properties.

(*b*) **Annealing.**—The ends of all tubes shall be carefully annealed to a length not less than 6" if they have been submitted to a process of swelling or reducing the end dimensions.

(*c*) **Freedom from defects.**—To comply with Regulation 36(*c*).

(*d*) **Tolerances.**—The tubes shall be of the dimensions specified, straight, cylindrical, of uniform thickness and external diameter throughout, subject to the working margins given in the table below :—

(*i*) **Diameter.**—The external diameter of the tubes measured at any point shall be within the following tolerances of diameter specified :—

Outside diameter of tubes	Tolerance
Up to and including 2½ in.	+1/64" —1/32"
Over 2½ in.	+1%

(*ii*) **Thickness.**—The thickness of the tubes shall be within the following tolerances:—

Outside diameter of tubes	Tolerance
Up to and including 2½ in.	+17½% —7½%
Over 2½ in.	+15% —5%

Where the ends of the tubes are swelled or reduced the thickness at the ends may be decreased below or increased above the nominal thickness of the tubes by an amount in proportion to the percentage of such swelling or reduction and, in addition to this allowance, the tolerances relating to thickness shall also apply.

(*iii*) **Length.**—The tubes shall be not less than the nominal length but may exceed it by the amount given below :—

Up to and including 30 ft.	⅛ in.
Over 30 ft.	¼ in.

(*e*) **Selection of tubes for test.**—To comply with Regulation 37.

44 (*a*) **Tensile test.**—Test pieces cut from the ends of annealed portion removed from the ends of the selected tubes shall comply with the following requirements:—

The test may be carried out on test peices cut out from the tube in the longitudinal direction, which shall not be further heat treated nor straightened within the gauge length. As an alternative, tubes may be tested on full cross section.

Kind of steel	Tensile strength minimum		*Elongation on $L_o = 5d_o$ or $L_o = 5{\cdot}65\sqrt{A_o}$, %minimum
	kg./mm.	tons/sq. in.	
Grade 1 . .	31.5	20	25
Grade 2 . .	42	27	21

*(*i*)

L_o = original gauge length ;

d_o = original diameter ; and

A_o = original area of cross section.

**(*ii*)

A carbon content not exceeding 0.35% may be permitted subject to the approval of the Inspecting Authority.

(*b*) **Flattening Test.**—A ring not less than 2 inches in length cut from the annealed portions removed from the ends of the selected tubes shall be flattened between two parallel flat surfaces, the width of which shall be not less than 1½ times the outside diameter of the tube. When the pressure is released, the interior surfaces of the test piece at the middle shall remain at a distance apart of not more than three times the thickness of the tube and the test piece shall then show no sign of crack or flaw.

The flattening test carried out in accordance with any other standard code may be accepted in which case the Code adopted shall be specified.

(*c*) **Expanding Tests.**—The annealed tube ends shall withstand expanding by a drift expander having a total included angle of between 40° and 60° (20° to 30° per side) to the following increase in external diameter without showing crack or flaw :—

Thickness of Tube	Increase in Diameter per cent
6 S.W.G. and thinner . . .	15
Thicker than 6. S. W. G. upto and including 3 S. W. G.	12
Thicker than 3. S.W.G. . . .	9·5

The expanding test carried out in accordance with any other Standard Code may be accepted in which case the Code adopted shall be specified.

45. (*a*) **Additional tests before rejection.**—Should tube selected for testing purposes show definite signs of failure in any one or more of the tests specified in Regulations 44(*a*), 44(*b*) and 44(*c*), two further tests of the same kind may be made at the option of the manufacturer from two additional tubes selected from same batch.

(*b*) If the repeat tests are satisfactory the tubes shall be accepted provided that in all other respects they fulfil the conditions of this Standard. Should either of the tubes fail in any test, the batch of tubes represented may be re-heat-treated in accordance with Regulation 43(*b*) and then retested in accordance with Regulations 44(*a*), 44(*b*) and 44(*c*), but employing twice the number of test pieces. If these second repeat tests are satisfactory, the tubes shall be accepted provided that in all other respects they fulfil the conditions of this Standard; but if definite defects are again shown, the batch of tubes which the tests pieces represent shall be rejected.

46. Hydraulic Test.—Each tube shall be tested at the Makers' Works and shall withstand a hydraulic pressure of 1½ times the design pressure, subject to a minimum of 70 kg./sq.cm. (1000 lbs. per sq. inch).

SEAMLESS MOLYBDENUM STEEL BOILER AND SUPERHEATER TUBES FOR DESIGN METAL TEMPERATURES NOT EXCEEDING 510 DEGREE C. (950 DEGREE F.)

47. General.—These Regulations cover both hot finished and cold drawn seamless boiler and superheater tubes which shall conform in all respects with the requirements herein specified.

48. (*a*) **Material.**—The tubes shall be manufactured from steel produced by the Open Hearth or Electric processes and shall conform to the following limits of chemical composition:—

Chemical Composition (*ladle analysis*)

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%

The steelmaker shall prove to the satisfaction of the Inspecting Authority that the quality of the steel is of the required high temperature creep strength.

* (*b*) **Heat Treatment.**—The tubes shall be normalised at a temperature between 1688° F (920° C) and 1760° F (960° C).

(*c*) **Workmanship and tolerance.**—The tubes shall be well finished, clean and free from harmful defects. They shall be reasonably straight, smooth, cylindrical and subject to the following tolerances before bending:—

(*i*) **Diameter.**—The external diameter of the tubes measured at any point shall be within the following tolerances of the diameter specified:—

Type of Tube	Outside Diameter of Tube	Tolerance
Hot finished	Up to and including 2½ in.	+1/64 in. —1/32 in.
	Over 2½ in.	+1%
Cold drawn	All sizes	+0% —1%

(*ii*) **Thickness.**—The thickness of the tubes shall be within the following tolerances:—

Type of Tube	Outside Diameter of Tube	Tolerance
Hot finished	Up to and including 2½ in.	+17½% — 7½%
	Over 2½ in.	+15% — 5%
Cold drawn	All sizes	+10% — 5%

Where the ends of the tubes are swelled or reduced the thickness at the ends may be decreased below or increased above the nominal thickness of the tubes by an amount in proportion to the percentage of such swelling or reduction and, in addition to this allowance, the tolerances relating to thickness shall also apply. Swelling or reduction shall be carried out before the heat treatment specified in Regulation 48(*b*).

(*iii*) **Length.**—The tubes shall be not less than the nominal length but may exceed it by the amount given below:—

Up to and including 30 ft.	.. 1/8 in.
Over 30 ft.	.. 1/4 in.

(*d*) **Selection of tubes for testing.**—After heat treatment the tubes shall be presented for mechanical testing in accordance with Regulations 49(*a*), 49 (*b*) and 49(*c*) in batches of not more than 100 of the same nominal diameter and thickness. The manufacturer shall provide at his own expense extra tubes at the rate of 2 per cent of each diameter and thickness of tubes specified and the Inspecting Officer shall select for test such of the tubes as he may think proper to the extent of the percentage mentioned. Should the number of tubes ordered of any one nominal size exceed 400 then, for every 100 tubes or part thereof above that number, one additional tube shall be provided. The samples for testing shall not be heat treated after selection.

Selection of specimens for testing may be in accordance with any other standard code in which case the code adopted shall be specified.

49. (*a*) **Tensile Test.**—Test pieces cut from the ends of the selected tubes shall comply with the following requirements. The test may be carried out on the test pieces cut out from the tube in the longitudinal direction which shall not be further heat treated not straightened with in the gauge length. As an alternative, tubes may be tested on full cross-section.

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.	
Molybdenum Steels	37·5	24	22

**Note*

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

(*b*) **Flattening Test.**—A ring not less than 2 inches in length cut from on. end of each selected tube shall be flattened between two parallel flat surfaces the width of which shall be not less than 1½ times the diameter of the tube Where the pressure is released, the interior surfaces of the test piece (at the middle) shall remain at a distance apart of not more than three times the specified thickness of the tube and the test piece shall then show no sign of crack of flaw.

The flattening test carried out in accordance with any other standard Code may be accepted in which case the Code adopted shall be specified.

(*c*) **Expanding Tests.**—The tubes shall withstand expanding by a drift expander having a total included angle of betwen 40° and 60° (20° to 30° each side) to the following increases in external diameter without showing crack or flaw:—

Thickness of Tube	Increase in diameter per cent
10 S.W.G. and thinner	12 ½
Thicker than 10 S.W.G.up to and including 6 S.W.G. ..	9 ½
Thicker than 6 S.W.G.	6 ½

In lieu of the expanding test, the flaring test carried out in accordance with any other standard code may be accepted in which case the Code adopted shall be specified.

50. Additional tests before rejection.—Should a tube selected for testing purposes show definite signs of failure in any one or more of the tests specified in Regulations 49(*a*), 49(*b*) and 49(*c*), two further tests of the same kind may be made at the option of the manufacturer from two additional tubes selected from the same batch. If the repeat tests are satisfactory the tubes shall be accepted provided that in all other respects they fulfil the conditions of this standard. Should either of the tubes fail in any tests, the batch of tubes represented may be re-heat-treated in accordance with Regulation 48(*b*) and then retested in accordance with Regulations 49(*a*), 49(*b*) and 49(*c*), but employing twice the number of tests pieces. If these second repeat tests are satisfactory, the tubes shall be accepted provided that in all other respects they fulfil the conditions of this standard; but if definite defects are again shown, the batch of tubes which the test pieces represent shall be rejected.

51. Hydraulic Test.—Each tube shall be tested at the Makers' works and shall withstand a hydraulic pressure of 1½ times the design pressure, subject to a minimum of 70 kg/sq. cm². (1000 lbs. per sq. inch).

SEAMLESS CHROMIUM-MOLYBDENUM STEEL BOILER AND SUPERHEATER TUBES FOR DESIGN METAL TEMPERATURES NOT EXCEEDING 538 DEGREE C. (1,000 DEGREE F.)

52. General.—These Regulations cover both Hot Finished and Cold Drawn Seamless Boiler and Superheater Tubes which shall conform in all respects with the requirements herein specified.

53. (*a*) Material.—The tubes shall be manufactured from steel produced by the Open Hearth or Electric processes and shall conform to the following limits of chemical composition:—

Chemical composition (ladle analysis)

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%

The Steelmaker shall prove to the satisfaction of the Inspecting Authority that the quality of the steel is of the required high temperature creep strength.

(*b*) **Heat treatment.**—The tubes shall be fully annealed or normalised and tempered, at a temperature approved by the Inspecting Authority.

(*c*) **Workmanship and tolerance.**—The tubes shall be well finished, clean and free from harmful defects. They shall be reasonably straight, smooth, cylindrical and subject to the following tolerances before bending:—

(*i*) **Diameter.**—The external diameter of the tubes measured at any point shall be with in the following tolerances of the diameter specified:—

Type of Tube	Outside Diameter of Tube	Tolerance
Hot finished	Up to and including 2 ½ in.	+1/64″ —1/32″
	Over 2 ½ in.	+1% —1%
Cold drawn	All sizes	+0% —1%

(*ii*) **Thickness.**—The thickness of the tubes shall be within the following tolerances:—

Type of Tube	Outside Diameter of Tube	Tolerance
Hot finished	Up to and including 2 1/2 in.	+17 ½% —7 ½%
	Over 2 ½ in.	+15% —5%
Cold drawn	All sizes	+10% —5%

Where the ends of the tubes are swelled or reduced, the thickness at the ends may be decreased below or increased above the nominal thickness of the tubes by an amount in proportion to the percentage of such swelling or reduction

and, in addition to this allowance, the tolerances relating to thickness shall also apply. Swelling or reduction shall be carried out before the heat-treatment specified in Regulation 53(*b*).

(*iii*) **Length.**—The length of the tubes shall be not less than the nominal length, but may exceed it by the amount given below:—

Up to and including 30 ft.....1/8 in.
Over 30 ft.....1/4 in.

(*d*) **Selection of Tubes for testing.**—After heat-treatment, the tubes shall be presented for mechanical testing in accordance with Regulations 54(*a*), 54(*b*) and 54(*c*) in batches of not more than 100 of the same nominal diameter and thickness. The manufacturer shall provide at his own expense extra tubes at the rate of 2 per cent of each diameter and thickness of tube specified and the Inspecting Officer shall select for test such of the tube as he may think proper to the extent of the percentage mentioned. Should the number of tubes specified of any one nominal size exceed 400, then, for every 100 tubes or part thereof above that number, one additional tube shall be provided. The samples for testing shall not be heat-treated after selection.

54. (*a*) Tensile Test.—Test pieces cut from the end of the selected tubes shall comply with the following requirements. The test may be carried out on the test pieces cut out from the tube in the longitudinal direction which shall not be further heat-treated nor straightened within the gauge length. As an alternative, tubes may be tested on full cross section.

Kind of Steel	Tensile Strength minimum		*Elongation on $L_o = 5\ d_o$ or $L_o = 5{\cdot}65\ \sqrt{A_o}$ % minimum
	Kg/mm².	tons/sq. in.	
Caromium-Molybdenum Steels	39	25	20

Note
L_o = original gauge length
d_o = original diamter
A_o = original area of cross section

(*b*) **Flattening Test.**—A ring not less than 2 inches in length cut from on end of each selected tube shall be flattened between two parallel flat surfaces the width of which shall be not less than 1½ times the diameter of the tube. When the pressure is released, the interior surfaces of the test pieces at the middle shall remain at a distance apart of not more than three times the specified thickness of the tube and the test piece shall then show no sign of crack or flaw.

The flattening test carried out in accordance with any other standard code may be accepted in which case the Code adopted shall be specified.

(*c*) **Expanding Tests.**—The tubes shall withstand expanding by a drift expander having a total included angle of between 40° and 60° (20° and 30° per side) to the following increases in external diameter without showing crack or flow :—

Thickness of Tube	Increase in Diameter per cent
10 S W.G. and thinner	12 ½
Thicker than 10 S.W.G. up to and including 6 S.W.G.	9 ½
Thicker than 6	6 ½

In lieu of the expanding test, the flaring test carried out in accordance with any other standard code may be accepted in which case the Code adopted shall be specified.

55. Additional tests before rejection.—Should a tube selected for testing purposes show definite signs of failure in any one or more of the tests specified in Regulations 54(*a*), 54(*b*) and 54(*c*), two further tests of the same kind may be made at the option of the manufacturer from two additional selected that tubes. If the repeat tests are satisfactory the tubes shall be accepted provided in all other respects they fulfil the conditions of this standard. Should either of the tubes fail in any test, the batch of tubes represented may be re-heat-treated in accordance with Regulation 53(*b*) and then retested in accordance with Regulations 54(*a*), 54(*b*) and 54(*c*) but employing twice the number of test pieces.

If these second repeat tests are satisfactory, the tubes shall be accepted provided that in all other respects they fulfil the conditions of this standard; but if definite defects are again shown, the batch of tubes which the test pieces represent shall be rejected.

56. Hydraulic Test.—Each tube shall be tested at the Makers' works and shall withstand a hydraulic pressure of 1½ times the design pressure, subject to a minimum of 70.kg/sq. cm². (1000 lbs. per sq. inch).

56. A: Seamless Chromium-Molybdenum Steel Boiler and Superheater Tubes for Design Metal Temperatures not Exceeding 577°C. (1070° F).

(*i*) **General.**—The provisions of this regulation apply to both Hot Finished and Cold Drawn Seamless Boiler and Superheated Tubes which shall conform in all respects with the requirements herein specified.

(*ii*) **Material.**—The tubes shall be maufactured from steel produced by the Open Hearth or Electric processes and shall conform to the following limits of chemical composition:—

Carbon	0·15% maximum
Manganese	0·30 to 0·70%
Silicon	0·1 to 0·50%
Phosphorus	0·04% maximum
Sulphur	0·04% maximum
Chromium	1·90 to 2·6%
Molybdenum	0·87 to 1·2%

The Steelmaker shall prove to the satisfaction of the Inspecting Authority that the quality of the steel is of the required high temperature Creep Strength.

(*iii*) **Heat Treatment.**—The tubes shall be fully annealed or normalised and tempered, at a temperature approved by the Inspecting Authority.

(*iv*) **Workmanship and tolerance.**—The tubes shall be well finished, clean and free from harmful defects. They shall be reasonably straight, smooth, cylindrical and subject to the following tolerance before bending.

(a) **Diameter**—The external diameter of the tubes measured at any point shall be within the following tolerances of the diameter specified:—

Type of Tube	Outside Diameter of Tube	Tolerance
Hot finished	Up to including 64 mm. (2½ in.)	+0·4mm. (1/64″) −0·8mm. (1/32″)
Hot finished	Over 64 mm. (2½ in.)	+1% −1%
Cold drawn	All sizes	+0% −1%

(*b*) **Thickness.**—The thickness of the tubes shall be within the following tolerances:—

Type of Tube	Outside Diameter of Tube	Tolerance
Hot finished	Up to and including 64mm. (2½″)	+17½% − 7½%
	Over 64 mm. (2½″)	+15% − 5%
Cold drawn	All sizes	+10% −5%

Where the ends of the tubes are swelled or reduced, the thickness at the ends may be decreased below or increased above the nominal thickness of the tubes by an amount in proportion to the percentage of such swelling or reduction, and in addition to this allowance, the tolerances relating to thickness shall also apply. Swelling or reduction shall be carried out before the heat-treatment specified in Regulation 56A (*iii*).

(*c*) **Length.**—The tubes shall be not less than the nominal length but may exceed it by the amount given below:—

Up to and including 9 meters (30 ft.) ..	3 mm. (1/8″)
Over 9 meters (30 ft.)	6 mm. (1/4″)

(*v*) **Selection of tubes for testing.**—After heat-treatment, the tubes shall be presented for mechanical testing in accordance with the Regulations 56A(*vi*), 56A(*vii*) and 56A (*viii*), in batches of not more than 100 of the same nominal diameter and thickness. The manufacturer shall provide at his own expense extra tube at the rate of 2 per cent. of each diameter and thickness of tube specified and the Inspecting Officer shall select for test such of the tubes as he may think proper to the extent of the percentage mentioned. Should the number of tubes specified of any one nominal size exceed 400, then, for every 100 tubes or part thereof above that number, one additional tube shall be provided. The samples for testing shall not be heat treated after selection.

(*vi*) **Tensile Test.**—Test pieces cut from the ends of the selected tubes shall comply with the following requirements:—

The tests may be carried out on test pieces cut out from the tube in the longitudinal direction which shall not be further heat-treated nor straightened within the gauge length. As an alternative, tubes may be tested on full cross section.

Kind of Steel	Tensile strength minimum		*Elongation on $L_o = 5d_o$ or $L_o = 5{\cdot}65\sqrt{A}$ % minimum
	Kg/mm².	Tons/sq. in.	
Chromium Molybdenum Steel ..	39	25	20

Notes :

L_o = original gauge length
d_o = original diameter and
A_o = original area of cross section

(*vii*) **Flattening Test.**—A ring not less than 51 mm. (2 inches) in length cut from one end of each selected tube shall be flattened between two parallel flat surfaces, the width of which shall be not less than 1½ times the diameter of the tube. When the pressure is released, the interior surfaces of the test pieces (at the middle) shall remain at a distance apart of not more than three times the specified thickness of the tube and the test piece shall then show no sign of crack or flaw.

Flattening test carried out in accordance with any other standard code may be accepted in which case, the Code adopted shall be specified.

(*viii*) **Expanding Tests.**—The tubes shall withstand expanding by a drift expander having a total included angle of between 40° and 60° (20° and 30° per side) to the following increases in external diameter without showing crack or flaw :—

Thickness of Tube	Increase in Diameter per cent
3 mm. (0·128″) and thinner..	12½
Thicker than 3 mm. (0·128″) upto and including 5 mm. (0·92″)	9½
Thicker than 5 mm. (0·192″)	6½

In lieu of expanding test as above, flaring test carried out in accordance with any other standard code may be accepted in which case, the Code adopted shall be specified.

(*ix*) **Additional tests before rejection.**—Should a tube selected for testing purposes show definite signs of failure in any one or more of the tests specified in clauses (*vi*), (*vii*) and (*viii*) two further tests of the same kind may be made at the option of the manufacturer from two additional selected tubes. If the repeat tests are satisfactory, the tubes shall be accepted provided that in all other respects they fulfil the conditions of these Regulations. Should either of the tubes fail in any test, the batch of tubes represented may be re-heat-treated in accordance with clause (*iii*) and then re-tested in accordance with clauses (*vi*), (*vii*) and (*viii*) but employing twice the number of test pieces.

If the second repeat tests are satisfactory, the tubes shall be accepted provided that in all other respects they fulfil the conditions of this standard; but if definite defects are again shown, the batch of tubes which the test pieces represent shall be rejected.

(*x*) Each tube shall be tested at the Makers' works and shall withstand a hydraulic pressure of 1½ times the design pressure, subject to a minimum of 70 kg/sq. cm². (1000 lbs. per square inch).

ELECTRIC-RESISTANCE-WELDED STEEL BOILER AND SUPER-HEATER TUBES FOR DESIGN METAL TEMPERATURES NOT EXCEEDING 454° C (850° F)

57. General.—These Regulations cover electric-resistance-welded tubes made of steel and intended for boiler tubes.

* **58.** (*a*) **Material—Process.**—The material shall be made either or both of the following processes: Open Hearth or Electric Furnace.

(*b*) **Manufacture.**—Tubes shall be made by electric-resistance-welding and shall be normalised at a temperature above the upper critical temperature.

(*c*) **Chemical Composition.**—The sulphur and phosphorus contents shall not exceed 0·05 per cent. If rimming steel is used, the strips shall be rolled in single widths and not slit longitudinally.

Chemical requirements

	Type A Low Carbon Steel	Type C Medium Carbon Steel
Carbon, per cent	0·08 to 0·18	0·35 max.
Manganese, per cent	0·30 to 0·60	0·80 max.
Phosph rus, max. per cent	0·05	0·05
Sulphur, max. per cent	0·05	0·05

Where the temperatue is below 390°C (750°F) either 'rimming' or 'killed' steel may be used. If 'rimming' steel is used, the strips shall be rolled in single widths and not slit longitudinally.

The steel used for design steam temperature above 390°C (750° F) but not exceeding 454°C (850°F) shall be of the fully 'killed' type. The question of the high temperature creep strength of the material shall be the subject of agreement between the manufacturer and the Inspecting Authority.

(*d*) **Thickness.**—The thickness of each tube shall conform to the specified thickness excluding the weld within the limits of plus 10 and minus 5 per cent.

(*e*) **Diameter.**—The outside diameter of each tube measured at any position shall conform to the specified outside diameter within the limits of plus 0 and minus 1 per cent.

(*f*) **Length.**—The length of each tube shall be not less than the nominal length, but may exceed it by the following amounts:—

	Nominal length ft.	Tolerance in.
Up to and including	30	1/8
Over	30	1/4

59. (*a*) **Flattening Test.**—(*i*) A section of the tube not less then 31 mm. (1 1/4.) length shall be flattened cold between parallel plates the width of which shall not be less then one and a half times the outside diameter of the tubes, until the opposite walls of the tube meet. No cracks or breaks in the mental shall occur until the distanc between the plates is less then 5 times the nominal thickness of the tube. Evidence of laminations or burnt material or incomplete penetration of the weld shall not develop during the process.

(*ii*) The weld shall be placed 90 degrees from the line of direction of the applied force.

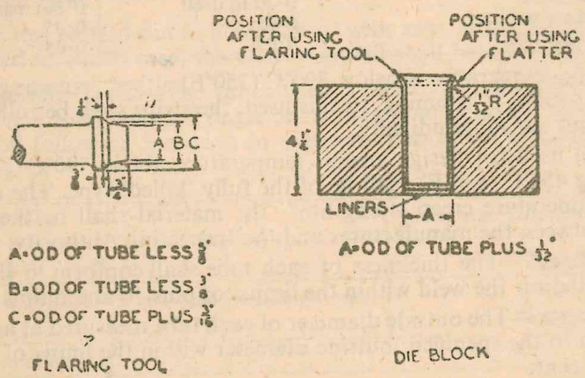
(*iii*) Superficial ruptures as a result of minor surface imperfections shall not be cause for rejection.

(*iv*) Flattening test carried out in accordance with any other standard code may be accepted in which case the Code adopted shall be specified.

(*b*) **Flange Test.**—A section of the tube not less than 4 inch in length shall be capable of having a flange turn over at a right angle to the body of the tube without cracking or showing flaws. This flange, as measured from the outside of the tube, shall not be less than $\frac{1}{8}$ in. nor more than $\frac{1}{2}$ in. Within these limits, the width of the flange shall be not less than the following :

Outside diameter of Tube	Width of Flange
64 mm. (2 $\frac{1}{2}$ in.) and under ..	15% of outside diameter
Over 64 mm. to 95 mm (3 $\frac{3}{4}$ in.) ..	10 mm. ($\frac{3}{8}$ in.)
Over 95 mm. to 127 (5 in.)	10% of outside diameter

In making the flange test, it is recommended that the flaring tool and die block shown in Fig. below be used.



(*c*) **Crush Test.**—When required by the Inspecting Authority, crushing test shall be made on sections of tube 2½ in. in length which shall stand crushing longitudinally, without cracking, splitting or opening at the weld, as follows:—

Wall thickness of Tubes	Height of crushed Section
3·4 mm. (0·135 in.) and under ..	19 mm. ($\frac{3}{4}$ in.) or until outside folds are in contact.
Over 3·4 mm. (0·135 in.)	32 mm. (1$\frac{1}{4}$ in.) or until outside folds are in contact.

Slight surface checks shall not be cause for rejection.

(*d*) **Reverse Flattening Test.**—As an alternative to flange test a reverse flattening test may be carried out as follows:—

A section 102 mm (4 in.) in length shall be taken every 457 metres (1500 ft.) of finished welded tubing to be split longitudinally 180 dg. from the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlapse resulting from flash removal in the weld.

* **60. Tensile test.**—The tube shall conform to the following requirements:—

Tensile Strength

Minimum	31·5 kg/mm² (20 tons/sq. in.)
Maximum	44 kg/mm² (28 tons/sq. in.)

Percentage Elongation

On a test piece $L_o = 5{\cdot}65\sqrt{A_o}$ .....7 Minimum 21% where L_o is the original gauge length of the test piece and A_o is the original area of cross section of the test piece.

61. (*a*) **Hydraulic Test.**—Each tube shall be tested at the Makers' works and shall withstand a hydraulic test pressure of one-and-a-half times the design pressure, subject to a minimum of 70 kg/cm² (1000 lbs/sq. in.).

(*b*) Tube shall be struck near both ends while under the test pressure with a 2 lb. steel hammer or its equivalent.

62. Test Specimens.—(*a*) Test specimens required for the flattening and flange test specified in Regulations 59(*a*) and 59(*b*) shall be taken from the ends of finished tubes prior to up-setting swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws.

(*b*) If desirable and practicable, tension tests may be made on full section of the tubes up to the capacity of the testing machine. For large size tubes, the tension test specimen shall consist of strip cut longitudinally from the tube and not flattened between gauge marks. The sides of the specimens shall be parallel between gauge marks; the width, irrespective of the thickness, shall be 1 in.

(*c*) All specimens shall be tested at room temperatures.

63. Number of Tests.—(*a*) Tests specified in Regulation 50 shall be made from each lot of 250 tubes or 610 meters (2,000 feet), or fraction thereof;

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If any one or more tests specified in these regulations should fail two further tests of the same kind, may be made on two other tubes of the same batch. If any of these retests fails the batch of tubes represented may be given a further heat-treatment and the entire set of tests shall be repeated.

If the repeat tests are satisfactory, the tubes shall be accepted. If any failure in the tests should occur the entire batch of tubes shall be rejected.

(*d*) Each tube shall be subjected to the hydraulic test specified in Regulation 61.

134/2/M. of Industry/69-70-3

COLD DRAWN ELECTRIC-RESISTANCE-WELDED STEEL BOILER AND SUPERHEATER TUBES FOR DESIGN METAL TEMPERATURES NOT EXCEEDING 454°C (850°F)

63. (*a*) (*i*) **Material.**—Material and chemical composition for these Tubes shall be in accordance with the appropriate clause in Regulation 58.

(*ii*) **Manufacture.**—These tubes shall be manufactured as prescribed in Regulation 58(*b*) and subsequently cold drawn.

(*iii*) **Tolerances.**—The tolerance on thickness, diameter and length shall conform to Regulation 58.

(*iv*) **Heat treatment.**—The tubes for design metal temperatures up to and including 427°C (800°F) shall be suitably annealed throughout their length. Tubes for higher temperatures shall be normalised. The ends which are subjected to cold working operations may however be annealed.

(*v*) **Tests.**—(*a*) **Tensile test**—This test shall comply with the provisions of Regulation 60.

(*b*) **Flattening test.**—This test shall comply with the provisions of Regulation 59(*a*) except that in the case of tubes of higher wall thickness than 3·25 mm. (0·128 in.) the distance between the flat plates mentioned therein shall not be more than four times the thickness of the tubes for tubes of lesser thickness the finer surfaces of the tube shall meet at the middle.

(*c*) **Flange test.**—This shall comply with the requirements of Regulation 59(*b*).

(*d*) **Reverse flattening test.**—This shall comply with the requirements of Regulation 59(*d*).

(*e*) **Crush test.**—This shall comply with the requirements of Regulation 59(*c*).

(*vi*) **Hydraulic Test.**—This shall comply with the provisions of Regulation 61.

(*vii*) **Test Specimens.**—These shall comply with the provisions of Regulation 62.

(*viii*) **Number of tests.**—These shall comply with the provisions of Regulation 63.

LAPWELDED STEEL BOILER TUBES (FOR EXTERNAL PRESSURE)

64. (*a*) **Material.**—The tube shall be made from steel which shall show on analysis not more than 0·05 per cent of sulphur or phosphorus. The manufacturer shall supply a certificate of the analysis when required to do so.

(*b*) **Annealing.**—The ends of all tubes shall be carefully annealed.

(*c*) **Freedom from defects.**—To comply with Regulation 36(*c*).

(*d*) **Tolerances.**—The tubes shall be of the dimensions specified, straight cylindrical, of uniform thickness and external diameter throughout, subject to the working margins given in table below:

Outside diameter of tube	On diameter		On thickness		On length	
	Plus	Minus	Plus	Minus	Plus	Minus
	Inch	Inch	Per cent	Per cent.	Inch	Inch
Under 2½ inch	1/64	1/32	10	10	1/8	0
2½ inch and over	Per cent 1	Per cent. 1				

(*e*) **Selection of tubes for test.**—To comply with Regulation 37.

65. Tensile test.—(*a*) To comply with Regulation 44 (*a*).

(*b*) **Flattening test.**—To comply with Regulation 44(*b*), the weld being placed 45° from the horizontal.

(*c*) **Expanding test.**—The selected tubes shall, when cold, withstand being, expanded by a drift or a roller expander to the following increases in diameter without showing crack or flaw:—

Thickness of tube S.W.G.	Increase in diameter per cent
Up to 10	9·5
Above 10 to 6	7·5
Above 6	5

66. Additional Tests.—Should a tube selected for testing purposes in accordance with Regulation 37 fail to satisfy the requirements of any one or more of the tests specified in Regulations 65 (*a*), 65 (*b*), 65 (*c*), if so desired by the manufacturer, the tube represented shall be re-annealed and then retested in accordance with these Regulations and if the repeat tests are satisfactory the tubes shall be accepted provided that in other respects, they fulfil the conditions of these Regulations but if the tube again fails to satisfy the requirements, the tubes which the test pieces represent shall be rejected.

67. Hydraulic test.—Every tube shall be tested at the Makers' works by hydraulic pressure to not less then 1,000 lbs. per sq. in. Any tubes failing to withstand this test shall be rejected.

WROUGHT IRON LAPWELDED BOILER TUBES (FOR EXTERNAL PRESSURE)

68. (*a*) **Material.**—The tubes shall be made from wrought iron which shall show on analysis not more than 0·10% manganese and 0·03% sulphur.

(*b*) **Annealing.**—The end of all tubes shall be carefully annealed.

(*c*) **Freedom from defects.**—To comply with Regulation 36 (*c*).

(*d*) **Tolerance.**—The tubes shall be of the dimensions specified subject to working margins given below. They shall be straight and cylindrical, of uniform thickness, concentric and unless otherwise specified, of uniform external diameter throughout.

The working margin shall be as follows:—

On thickness—plus or minus 10%.

On external dia. for tubes under 2½—plus 1/64″ and minus 1/32″.

On external dia. for tubes 2½ and larger—plus or minus 1 per cent.

(*e*) **Selection of tubes for test.**—To comply with Regulation 37.

69. (*a*) **Tensile Test.**—Lengths or strips cut from the selected tubes shall comply with the following requirements:—

	Ultimate Tensile Strength in tons/sq.in.		Elongation per cent on 8 in.
	Not less than	Not more than	
Strips cut from the tubes clear of the welds and tested in their curved condition	20	24	10
Tested length taken from finished tubes (ends of tubes to be plugged for grips)	20	24	12½

(*b*) **Flattening Test.**—To comply with Regulation 39.

70. Expanding Test.—The selected tubes shall, when cold, withstand being expanded by a drift or roller expander to the following increases in diameter without showing crack or flaw:—

Thickness of Tubes S.W.G.	Increase in Diameter per cent
Up to 6	2½
Above 6	1½

71. Crushing Test.—A ring 2 in. in length cut from one end of each selected tube shall withstand, without showing crack or flaw, being crushed on end by hammering or pressure when cold, until the length is reduced to 1⅛ in.

72. Hydraulic Test.—Every tube shall be tested by internal hydraulic pressure to not less than 1,000 lbs./sq. in. Any tube failing to withstand this test shall be rejected.

STEEL CASTING

73. Scope.—The steel castings shall be of the following grades.:—

Grade	ULTIMATE TENSILE STRES Tons/sq. in. min.
A	28
B	32
C	35

* 74.(*a*) **Process of manufacture.**—Steel for castings shall be ma le by the Open Hearth or an Electric Process, acid or basic.

* (*b*) **Chemical analysis.**—The steel shall contain:—

Element	Grade A	Grade B	Grade C
	Per cent Max.	Per cent Max.	Per cent Max.
Carbon	0·25	0·35	0·45
Silicon	0·60	0·60	0·60
Manganese	1·00	1·00	1·00
Sulphur	0·06	0·06	0·06
Phosphorus	0·06	0·06	0·06

The manufacturer shall supply a certificate of analysis of each melt when requested.

(*c*) **Heat Treatment.**—All castings shall be supplied in the heat-treated condition. The heat-treatment shall consist of annealing, annealing and normalising, normalising, normalising and tempering, or hardening and tempering, either at the discretion of the manufacturer or the Inspecting Officer and shall be carried out at suitable temperatures to give the mechanical properties specified in Regulation 77.

(*d*) **Fettling and Dressing.**—All castings shall be properly fettled and dressed and all surfaces shall be satisfactorily cleaned for inspection purposes.

(*e*) **Freedom from Defects.**—All castings shall be free from injurious defects. In the event of any casting proving defective in the course of preparation, machining or erection, such casting may be rejected notwithstanding any previous certification of satisfactory testing.

75. Repairs to defective castings.—Castings shall not be repaired or welded without the specific sanction of the Inspecting Officer. If required the castings shall be suitably re-heat-treated to remove internal stresses. Should a defect impair the strength of the casting, repair by welding or otherwise shall not be permitted.

76. Number of tests—Provision of test samples.—Tensile and bend test pieces shall be prepared from test samples representative of each melt or heat-treatment batch as follows:—

(*a*) The test samples shall be cast attached to or separate from the castings as agreed between the manufacturer and the Inspecting Officer. The agreement for attached test samples shall include the precise location and method of attachment. If the Inspecting Officer does not make such an agreement with the manufacturer, the decision as to the manner of providing test samples shall rest with the manufacturer. The descretion of the manufacturer shall not, however, apply to the testing of castings made from more than one melt as indicated in clause (*d*) below.

(*b*) If the test samples are attached to the castings, at least one tensile test, and when required one bend test, shall be made from each melt. Such test samples shall not be detached from the castings until heat-treatment of the castings has been completed and they have been stamped by the Inspecting Officer. Test samples shall be stamped by the Inspecting Officer after the heat-treatment process.

(*c*) If the test samples are cast separately, they shall be provided to the extent of 2 per cent of the number of castings from each melt, but in no case shall there be less than 2 samples per melt, except by agreement between the manufacturer and the Inspecting Officer. The test samples shall be cast in moulds of the same material as is used for the castings and shall be made at the same time as the castings, and run from the same ladle. The samples shall be stamped by the Inspecting Officer so as to identify the castings to which they relate.

(*d*) When a casting is made from more than one melt, at least four tensile tests, and where required four bends tests, shall be made from test samples situated as far apart as possible on the casting. Some of the test samples shall be taken from as near the top and others near from the bottom of the casting as is practicable.

(*e*) Test samples shall be heat-treated with the castings they represent.

77. (*a*) Tensile tests.—The mechanical properties obtained from the test pieces selected and prepared as specified in Regulation 76 shall comply with the requirements of the following table:—

	Grade		
	A	B	C
Ultimate tensile stress tons/sq. in. not less than	28	32	35
Yield stress, or 0·5% proof stress, tons/sq. in. not less than	14	16	17·5
Elongation, per cent not less than	22	20	15

NOTE.—Should a tensile test piece break outside the middle half of its gauge length, the test may, at the manufacturer's option be discarded and another representative test made.

(*b*) The tensile test shall be carried out on test pieces conforming to the dimensions of Standard test piece C, or to those of one of the subsidiary round test pieces as shown in Appendix B.

If, however, the tensile tests are carried out on specimens conforming to any other standard, the material will be accepted provided the tensile strength and elongation computed on the basis of the dimensions of the test pieces under the Regulation conform to the above requirements.

78. Bend tests.—Cold bend tests shall be made upon test pieces having rectangular section of one inch wide by ¾ inch thick. The test pieces shall be machined and the edges rounded to a radius of 1/16 inch. The test pieces shall be bent over the thinner section.

Bend tests may be made by pressure or by blows, and the test pieces shall without fracture withstand being bent round a former having a radius of 1 inch through an angle not less than that given in the following table:—

Grade of Casting	Angle of Bend minimum
A	120°
B	90°
C	No test

79. (*a*) Additional tests before rejection.—Should any of the original test pieces fail to pass the mechanical tests, two further samples which represent the same casting or castings shall be selected and tested in the same manner. The manufacturer shall have the right, if he so desires to re-heat-treat the castings before the two further samples are selected.

Should the two further tests satisfy the requirements of this standard, castings represented by them shall be accepted. Should either of the re-tests fail, the castings represented shall be liable to rejection.

(*b*) **Hardness test after heat treatment.**—The Inspecting Officer may call for hardness testing of the heat-treated castings.

(*c*) **Non-destructive tests.**—The Inspecting Officer may call for radiographic examination or other non-destructive testing of the castings.

Castings found to be unsound may be treated in accordance with Regulation 75. If the welding repairs are sanctioned by the Inspecting Officer, they shall be carried out in accordance with Regulation 80.

80. Procedure for Welding.—In order to maintain a high standard of workmanship in the practice of arc-welding to steel castings, the following general principles should be followed, but the precise technique will of necessity vary according to the circumstances.

Surface condition.—The surfaces of the steel, it is intended to weld should be cleaned and freed from all foreign matter, otherwise poor penetration and unsound weld metal may result.

The preparation for the welding of cracks should be of the U or V types. When the latter is used, the included angle should be not less than 70°. Where cracks extend through the section of the casting, the choice between single and double preparation, U or V will be governed by (*i*) the thickness of the casting; (*ii*) the location of the defect. In double preparation, U or V the root of the U or V should be sufficiently open to ensure complete penetration.

Electrodes.—The electrodes shall comply with Regulations 94 to 98 for Grade A castings. Electrodes for Grades B and C castings should be agreed between the manufacturer and the Inspecting Officer.

The electrode manufacturer's recommendations for the use of the electrode should be strictly followed.

Pre-heating.—Variations in composition, mass design, and the extent of welding required make it impossible to lay down specific rules to establish conditions under which pre-heating should be applied.

When after consideration of each casting in the light of the above variables it is deemed necessary to pre-heat, such pre-heating should be carried out at a temperature of 150—300° C (302—572° F).

Stress-relieving treatment.—When the welding is carried out after the casting has received its normal heat treatment, a further heat treatment may be considered necessary. This treatment need be applied only in cases where welding has been such as to induce either internal stresses which would be detrimental to the casting, or locally hardened areas which would cause difficulty in machining. Where this further heat treatment is applied, the casting, where possible, should not be allowed to go cold after welding, but should be charged into a warm furnace and re-heated to a suitable tempering temperature which in general should be not less than 550° C (1022° F).

When considering the advisability of applying this further treatment, its effect on the physical properties of the castings should be borne in mind. If the treatment, or the welding itself is such that the physical properties will be adversely affected, the full heat treatment required to produce satisfactory qualities should be substituted.

STEEL FORGINGS AND SOLID DRAWN HEADERS
(Other Than Seamless Drums)

* **81.** (*a*) **Process of manufacture.**—Steel for forgings shall be made by the Open Hearth or an Electric Process, acid or basic.

* (*b*) **Chemical analysis.**—The steel shall contain not more than 0·05 per cent of sulphur or of phosphorus.

(*c*) **Freedom from defects.**—The forgings shall be free from defects of any kind and shall be finished to the prescribed dimensions. Defects in forgings shall not be repaired without the previous sanction of the Inspecting Officer.

(*d*) **Heat treatment.**—Each forging shall be efficiently heat-treated unless during the last stage of manufacture it has been finished at such a temperature as to ensure that the material of the forging will have satisfactory mechanical properties.

82. Selection of test pieces.—Sufficient material shall be left on each forging for test pieces. In the case of a number of small forgings, not less than two per cent, of the total or not less than 2 forgings form each cast.

83. Tensile Tests.—The ultimate tensile stress and elongation shall be between the limits of 24 and 38 tons per sq. inch and 33 and 19 per cent respectively determined on Standard Test piece or subsidiary round test piece (Appendix B).

In no case shall the sum of ultimate tensile stress in tons per square inch and corresponding percentage elongation be less than 57.

Should a tensile test piece break outside the middle half of the test gauge length, the test may, at the manufacturer's option be discarded and another test be made of the same forging.

84. Bend Tests.—(*a*) Bend test pieces shall be of rectangular cross section machined to a finished size of 1 inch wide by $\frac{3}{4}$ inch thick. In the case of headers, bend test pieces may be cut transversely $1\frac{1}{2}$ T wide by T thick where T is the thickness of the header. The edges shall be rounded to a radius of 1/16 inch. The test pieces shall be bent over the thinner section.

(*b*) Test pieces shall be bent when cold through an angle of 180° without fracture, the internal radius of the bend being not greater than that specified in table below for the 1 inch wide by $\frac{3}{4}$ inch thick test piece and not more than $1\frac{1}{2}$ T for the full thickness test piece.

Ultimate tensile stress	Internal radius of bend
Tons/sq. in.	inch
Upto 32	$\frac{1}{4}$
Above 32 and up to 36	$\frac{3}{8}$
Above 36 and up to 38	$\frac{5}{8}$

Bend tests may be made by pressure or by blows.

85. Additional tests before rejection.—Should either a tensile or a bend test fail, two further tests of the type which failed may be made on test pieces cut from the same forging. If the results obtained from these retests are satisfactory, the forgings shall be accepted, provided that in other respects they fulfil the conditions laid down above for steel forgings. If these retests do not give satisfactory results the forgings represented may be re-heat-treated together with the remainder of the test blocks and presented for further testings.

In all cases where final retests do not give satisfactory results, the forgings represented by the test pieces which fail shall be rejected.

GENERAL GREY IRON CASTINGS (GRADE A)

86. (*a*) **Process of manufacture.**—The castings shall be cast from metal melted or refined in any metallurgical plant other than an iron ore smelting furnace, for the use of which furnace permission in writing must be received from the Inspecting Authority

(*b*) **Chemical Composition.**—The composition of the iron as cast shall be left to the discretion of the manufacturer but the maximum percentage of phosphorus or sulphur or both may be specified by the Inspecting Authority, if he so desires.

(*c*) **Moulding.**—The castings shall be accurately moulded in accordance with the pattern or working drawings supplied by the Inspecting Authority with the addition of such letters, figures or marks as may be specified and the drawings shall include the tolerances specified in the Regulations.

Freedom from defects.—The castings shall be sound, clean out of twist and free from blow holes distortion and all surface and other defects. They shall be well dressed or fettled and shall be machinable by normal methods.

87. Provision of test bars.—The Inspecting Authority shall state at the time of enquiry whether he requires tensile or transvere tests, or both, and he may also specify cast-on bars where the design of the casting and method of running permit.

When the test bars are cast separately they shall be poured at the same time and from the same ladle, or metal as the casting or castings they represent. The number of test bars specified in Regulation 92 shall be applicable to all castings of each melt.

When the bars are cast-on, the mould for the casting and the mould for the test piece shall be joined together in such a manner that the liquid metal fills both moulds at the same operation.

All test bars shall be cast in green sand or dry sand or in loam moulds according as to whether the casting or castings they represent are moulded in green sand, or in loam or dry sand, respectively.

The test bars shall not be subjected to any heat treatment after leaving the moulds.

88. Dimension of test bars—(*a*) **Transverse Test Bars.**—The transverse test bars of the diameter specified by the Inspecting Authority according

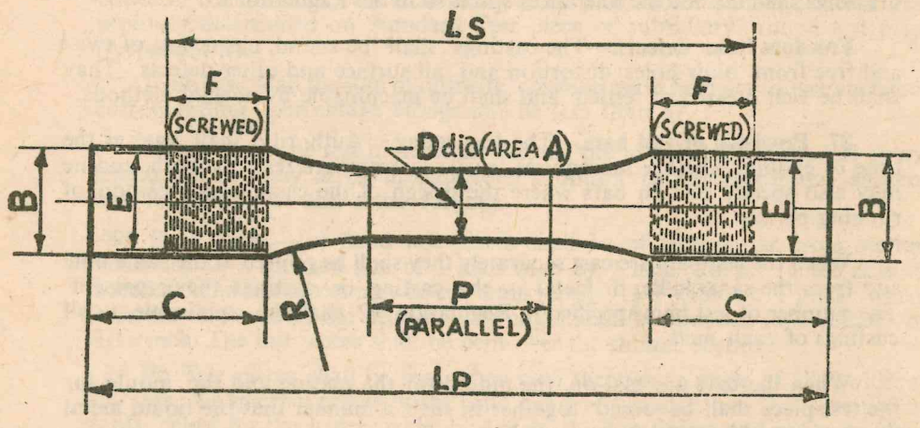
to the main cross sectional thickness of the casting represented, shall conform to the following dimensions:

Diameter of test Bar	Limits on Diameter	Over all length	Main cross-sectional thickness of casting represented
in.	in.	in.	in.
0·6	±0·045	10	Not exceeding $\frac{3}{8}$
0·875	±0·065	15	Over $\frac{3}{8}$ and not exceeding $\frac{3}{4}$
1·2	±0·090	21	Over $\frac{3}{4}$ and not exceeding $1\frac{1}{8}$
1·6	±0·10	21	Over $1\frac{1}{8}$ and not exceeding $1\frac{5}{8}$
2·1	±0·10	27	Over $1\frac{5}{8}$

Bars cast to a size in excess of the limits given above may be machined to a diameter within the specified limits. Bars cast within these limits of diameter may also be machined before the transverse test is made, providing that the finished diameter falls within these limits.

(*b*) **Tensile Test Bars.**—The tensile test bars of the diameter specified by the Inspecting Authority, according to the main cross-sectional thickness of the casting represented shall conform to the dimensions shown in the following table. Bars may be tested with either plain or screwed ends.

DIAGRAM



TABLE

Diameter as Cast	Gauge diameter	Area	Min. parallel length	Min. radius	Min. length of plain ends	Screwed ends			Main cross-sectional thickness of casting represented	Approximate minimum overall length,	
						Size		Min. length		Plain ends	Screwed ends
B	D	A	P	R	C	E		F		LP	LS
in.	in.	sq. in.	in.	in.	in.	in.		in.	in.	in.	in.
0·6	0·399	0·125	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{1}{4}$ S.P.	9/16 S.F. 9/16 S.W.	9/16	Not exceeding $\frac{3}{8}$	$4\frac{1}{2}$	3
0·875	0·564	0·25	2	$3\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{4}$S.F.	7/8S.W.	$\frac{3}{4}$	Over $\frac{3}{8}$ and not exceeding $\frac{3}{4}$	7-1/16	4-13/16
1·2	0·798	0·50	2	$3\frac{1}{2}$	2	$1\frac{1}{8}$ S.F.	$1\frac{1}{8}$ S.W.	$1\frac{1}{8}$	Over $\frac{3}{4}$ and not exceeding $1\frac{1}{8}$	$8\frac{1}{4}$	5-7/8
1·6	1·128	1·00	2	$3\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{1}{4}$ S.F.	$1\frac{1}{4}$ S.W.	$1\frac{1}{2}$	Over $1\frac{1}{8}$ and not exceeding $1\frac{5}{8}$	9-1/32	$7\frac{1}{4}$ $7\frac{1}{4}$
2·1	1·596	2·00	2	$3\frac{1}{2}$	$3\frac{1}{4}$	2 S.F.		2	Over $1\frac{5}{8}$	$11\frac{1}{8}$	$8\frac{1}{4}$

The test bars shall be cast as parallel bars of the diameters given in column B and then machined to the dimensions C and P in the above table.

(*c*) For castings over 2 inches in thickness a test bar of larger diameter than 2·1 inches may be used by agreement between the manufacturer and the Inspecting Authority. For diagram and table *see* under clause (*b*) of this Regulation.

89. Mechanical test.—The casting must comply with the transverse and tensile tests specified in Regulations 90 and 91. All test pieces shall be selected by the Inspector and tested in his presence and to his satisfaction.

90. Transverse test.—A transverse test bar cast in accordance with Regulation 88(*a*) must when placed on supports set at the distance shown in column 2 of the following table sustain a load applied at the centre of not less than that shown in column 3 and must show before rupture a deflection not less than that shown in column 4. The supports and the point of application of the load shall be rounded to a radius of not less than $\frac{1}{8}$ inch.

Diameter of test bar 1	Distance between Support 2	Minimum breaking load—Grade A 3	Minimum defection —Grade A 4
in.	in.	lbs.	a
0·6	9	530	0·07
0·875	12	1,185	0·10
1·2	18	1,950	0·15
1·6	18	4,280	0·12
2·1	24	6,660	0·15

If the diameter of a transverse test bar as cast varies within the limits specified in Regulation 88(*a*) the equivalent breaking load for the test bar of standard diameter shall be calculated in accordance with the factors given in Appendix F.

91. Tensile test.—A tensile test bar machined to the dimensions shown in Regulation 88(*b*) and tested with either plain or screwed ends must show a breaking strength of not less than that shown in the following table:—

Diameter of test bar	Minimum ultimate tensile stress—Grade A
in.	Tons per sq. in.
0·6	12·5
0·875	12
1·2	11
1·6	10·5
2·1	10

NOTE.—Self-aligning grips to ensure axial loading are recommended.

92. Number of transverse and tensile tests.—The number of tests required for each batch of castings shall be in accordance with the following table, the various classes of castings being divided into four representative groups. One test shall refer to one transverse and one tensile test, whether taken from one or two test bars as cast.

Group	Weight of castings	Test requirements
1	Up to 28 lbs.	One test for each 30 cwt. of castings or part thereof.
2	Over 28 lbs. and up to 1 cwt. ..	One test for each 2 tons of castings or part thereof.
3	Over 1 cwt. and up to one ton ..	One test for each 4 tons of castings or part thereof.

In the above Groups, 1, 2 and 3, all castings represented by one test must be poured from the same ladle or same heat as the bar or bars provided for the test.

4	Over 1 ton and important castings where mutually agreed upon.	One test for each 4 tons of castings or part thereof or for each casting weighing 4 tons or more.

93. Additional Tests.—The additional tests to be carried out before a casting or batch of castings is rejected shall be in accordance with the following table:—

Test piece	Event	Conditions
1st. ..	If this fails	The second test piece shall be tested.
2nd ..	If this passes	The batch or separate casting represented shall be accepted.
	If this fails	The batch or separate casting represented may be rejected.

Provided always that in the case of failure of both test pieces if either show obvious defects a third test piece may be taken from a broken casting or a piece may be cut from a usable casting for further testing as follows:—

3rd. ..	.. If this passes	The batch or separate casting represented shall be accepted.
	If this fails	The batch or separate casting represented may be registered.

COVERED ELECTRODES FOR METAL ARC WELDING OF MILD STEEL

94. General requirements.—(1) **Application.**—The following Regulations apply to electrodes of sizes 3/32 inch (12 S.W.G.) and larger in diameter for metal arc welding of carbon steels having ultimate tensile strength not exceeding 33 tons per square inch and Sulphur and Phosphorus contents not greater than 0·06 per cent each. Electrodes less than 3/32 inch in diameter shall not be used in boilers.

The electrode shall comply with the requirements of physical tests prescribed for each class.

Their characteristics and behaviour under ordinary working conditions shall be such that satisfactory weld deposits can be made by a welder of average skill and experience and that the following characteristics are also obtained:—

(*a*) a relative ease in the control of the slag and weld metal during welding ;
(*b*) a good degree of stability of the arc and of the fusing of the covering;
(*c*) no undue degree of spatter;
(*d*) a fair rate of deposition and depth of penetration;
(*e*) easy removability of the slag;
(*f*) no undue tendency to under-cut;
(*g*) a fair contour of the weld deposits; and
(*h*) a low internal porosity of the weld metal.

(2) **Classification.**—The electrodes shall be classified into:

(*a*) normal penetration electrodes for use in one or more welding positions, and
(*b*) deep penetration electrodes for close unprepared butt-welding in the flat position and/or fillet welding, in the flat and horizontal—vertical positions.

(3) **Manufacture.**—Electrodes may be made by any method that shall yield a product conforming to the requirements of these Regulations.

(4) **Size of Electrodes.**—The nominal size of the electrodes shall refer to the diameter of the core wire and the length shall not exceed 18 inches. Provision shall be made for end or centre gripping.

The tolerances on the specified diameter of the core wire of the electrodes shall be plus or minus 0·002 inch.

(5) **Covering.**—The flux covering shall be sufficiently robust to withstand the normal conditions of transport, storage, handling and use, without damage and shall be uniform in thickness all over so that it fuses evenly. The variation in the thickness shall not exceed 3 per cent.

(6) (*a*) **Packing and storage.**—Electrodes shall be suitably packed to guard against damage during transportation. When stored, the electrodes shall be kept in their original bundles or packings in a dry store room and under such conditions, the electrodes shall for a period of at least six months be capable or giving results similar to those which they would have given on the date of their despatch from the manufacturer.

(*b*) **Marking.**—Each package shall be marked with the following information:—

Name of the Manufacturer.
Trade name of the Electrodes.

Size and quantity of Electrodes.
Batch number.
Recommended current range.
Classification as per Indian Boiler Regulations.

(7) **Tests.**—The electrodes shall be subjected to Initial tests, Periodic check tests and Production control to ensure that the requirements of these Regulations are fulfilled.

Electrodes intended for use with more than one type of current or polarity shall be tested using each type of current and polarity.

Where any test specimen fails to satisfy the requirements of any particular test, two further test specimens shall be prepared using the electrodes from the same batch and submitted to the same test.

The batch of electrodes shall be accepted as having passed the test provided that the tests of both the additional specimens are satisfactory.

(8) **Test Certificates.**—The manufacturers shall, when called upon, produce the results of the most recent Periodic check tests carried out within the preceding 12 months, on electrodes representative of the electrodes supplied.

95. Requirements for Normal Penetration Electrodes—Initial Tests.—The following initial tests on each brand of electrodes shall be carried out:—

(*a*) **All Weld-Metal Tensile Test.**—Three all-weld-metal tensile test specimens, one each using the smallest, 6 S.W.G., and the largest diameter electrodes manufactured in this grade shall be prepared, and tested in accordance with the method described in *Appendix H*-1. The ultimate tensile stress of each test specimen shall be not less than 26 tons per square inch and yield stress not less than 20 tons per square inch. The elongation shall be not less than 25 per cent and the minimum reduction of area shall be not less than 35 per cent.

(*b*) **Fillet Weld H t Cracking Test.**—One fillet weld hot cracking test shall be carried out as specified in *Appendix H*-1. The electrodes shall be deemed to be satisfactory provided no hot cracking occurs under the conditions of test. Greater cracks may be neglected provided they do not run into the full Section of the weld.

(*c*) **Transverse Tensile Test.**—One transverse tensile test shall be carried out for each welding position for which the electrode is recommended by the manufacturer except that two tests shall be required for the flat position. For electrode recommended for all positions, a test in the inclined position is not required.

The ultimate tensile stress shall be not less than 28 tons square inch. The nethod of preparation of the test pieces is specified in *Appendix H*-1.

(*d*) **Transverse Bend Test.**—Two bend tests one with the face and the other with the root in tension shall be carried out for each welding position for which the electrode is recommended by the manufacturer, except that two in each shall be carried out for those intended for flat position only. For electrodes recommended for all positions a test in the inclined position is not required. The method of preparation and carrying out the test shall be in accordance with *Appendix H*-1. The electrode shall be deemed to be satisfactory provided that on completion of the test, no crack or defect at the outer surface is greater than $\frac{1}{8}$ inch measured across the specimen or 1/16 inch measured along its length. Premature failures at corners of the test specimen shall not be considered a cause for rejection.

(*e*) **Cruciform Fillet Weld Tensile Test.**—One Curuciform fillet weld tensile test shall be carried out for each welding position for which the electrode is recommended by the manufacturer, except that when the electrode is recommended for both the flat and the horizontal—vertical positions, a test in the flat position shall not be required. The method of preparation of the test pieces and of carrying out the tests shall be as specified in *Appendix H*-1. These test pieces shall be capable of withstanding an ultimate tensile load of not less than $36{\cdot}5 \times W \times C$ tons: where W is the width of the test piece and C is the average throat thickness of the welds, both in inches. C shall be taken as $0{\cdot}7\times$ the average leg length or as the actual mean throat thickness, whichever is the greater.

(*f*) **All-Weld Metal Impact Test.**—Three Izod impact test specimens, one each using the smallest size manufactured, 6 S.W.G., and the largest size manufactured electrodes respectively, shall be prepared and tested in accordance with the method specified in *Appendix H*-1. The average of the three impact values for each test specimen shall be not less than 30 ft. lbs.

96. Requirements for Deep Penetration Butt-Welding Electrodes—Initial Test.—For electrodes recommended for deep penetration butt-welding, the following initial tests shall be carried out:—

(1) Transverse Tensile Test.—Three transverse tensile test specimens, one each from test pieces shall be prepared according to Table 3 in *Appendix H*-2 and tested as specified in *Appendix H*-2. If the diameter of the largest size of electrode manufactured is less than $\frac{1}{4}$ inch only two specimens need be prepared. The ultimate tensile stress of each specimen shall be not less than 28 tons per square inch.

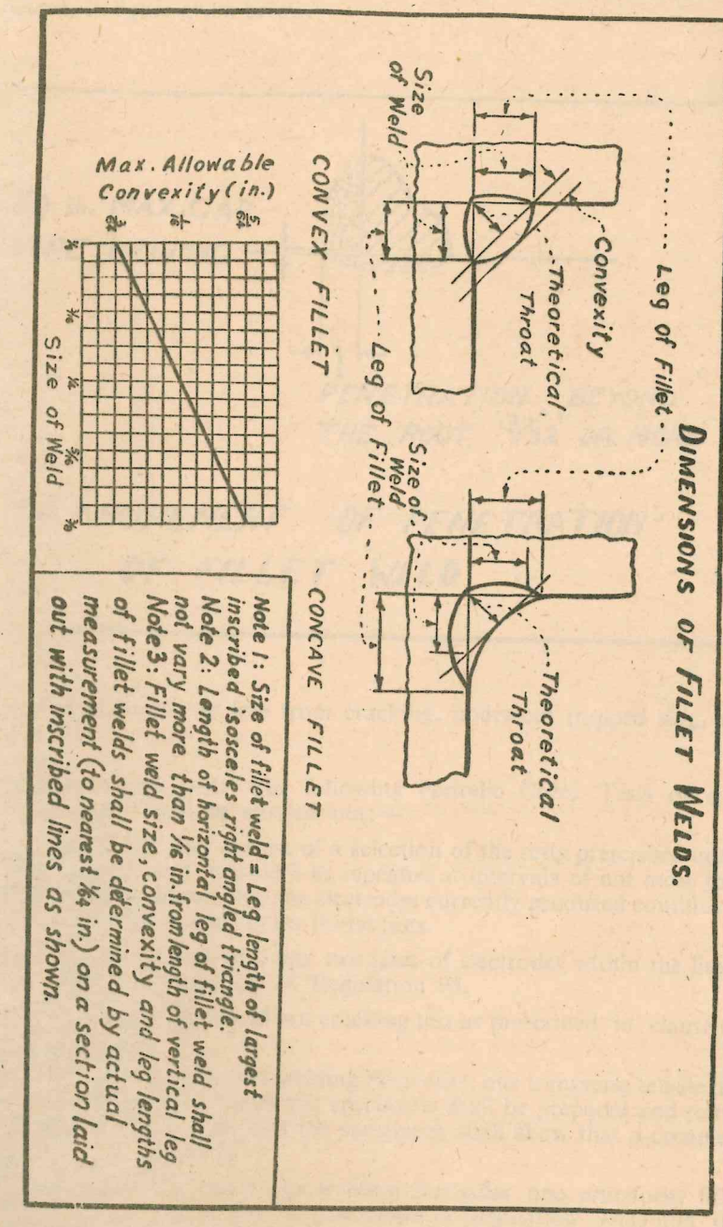
(2) Transverse Bend Test.—Six bend test specimens, two each from test pieces, prepared according to the Table 3 in *Appendix H*-2 shall be tested in accordance with the method specified in *Appendix H-2*. If the diameter of the largest size of the electrode manufactured be less than $\frac{1}{4}$ inch, only 4 specimens will be required. Of each pair of specimens, one shall be tested with the side first welded in tension and one with the other side in tension. The electrode shall be deemed to be satisfactory if on completion of the test no crack or defect at the outer surface of the specimen is greater than $\frac{1}{8}$ inch measured across it or 1/16 inch measured along its length. Premature failure at corners shall not be considered cause for rejection.

(3) Butt-Weld Penetration Test.—Examination of the inner edges of the outer discards from the butt-weld test pieces prepared as specified in *Appendix H*-2 shall show that complete penetration has been achieved.

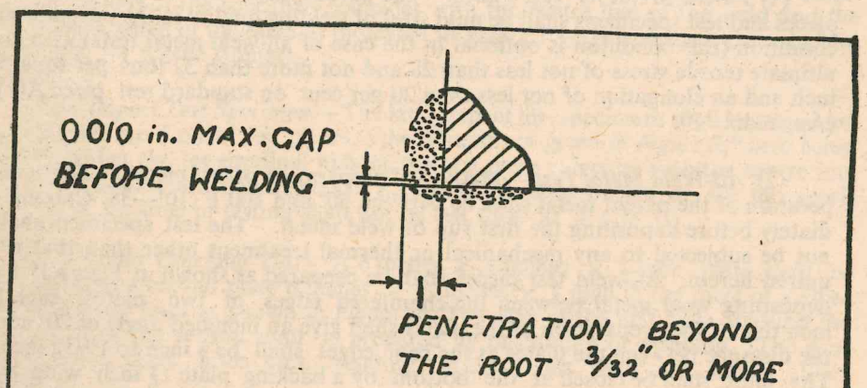
97. Requirements for Deep Penetration Fillet Welding Electrodes—Initial Test.—The following initial tests on each brand of electrodes shall be carried out:

(1) Cruciform Fillet Weld Tensile Test.—Three test specimens one eace from test pieces prepared according to the procedures laid down in *Appendix H*-2 shall be tested in accordance with the method specified therein. If the diameter of the largest size of electrode manufactured is less than $\frac{1}{4}$ inch then two specimens only are required. Each specimen shall withstand an ultimate tensile load of not less than $36{\cdot}5 \times W \times C$ tons; where W is the width of the test specimen and C is the effective size of the welds, both in inches. For the purpose of calculating the test load, the effective size of deep penetration fillet welds shall be taken either as $0{\cdot}7\times$ (the average leg length plus 3/32 inch) or as the actual mean throat thickness plus 1/17 inch whichever is the greater.

(2) (a) *Fillet Weld Penetration Test*—Both legs of each fillet weld deposited shall be of equal length within 1/16 inch and the convexity shall be within the maximum allowable limits shown in the figure given below.



(*b*) The outer discards from the cruciform fillet weld test pieces prepared as above shall show a minimum penetration beyond the root of not less than 3/32 inch as shown in figure given below.



MEASUREMENT OF PENETRATION OF FILLET WELD

The weld shall also be free from cracking, under-cut trapped slag, and porosity.

98. Periodic Check Test.—The following Periodic Check Tests on each brand of electrodes shall be carried out:—

(*a*) Periodic check tests consist of a selection of the tests prescribed under Regulations 95 to 97 and they shall be repeated at intervals of not more than 6 months to provide evidence that the electrodes currently produced continue to possess the properties recorded in the initial tests.

(1) All-weld tensile test with any two sizes of electrodes within the limits prescribed in clause (*a*) of Regulation 95.

(2) One Tee joint fillet weld hot cracking test as prescribed in clause (*b*) of Regulation 95.

(*b*) For deep penetration butt-welding electrodes, one transverse tensile test specimen and two transverse bend test specimens shall be prepared and tested as prescribed in Regulation 96 and the specimens shall show that a complete penetration has been achieved.

(*c*) For deep penetration fillet welding electrodes one cruciform fillet weld tensile test shall be taken as prescribed in Regulation 97(1) and the two outer discards from the test pieces shall show a minimum penetration beyond the root as required under Regulation 97(2).

134/2/M. of Industry/69-70-4

APPENDIX H—1

(*See* Regulation 95)

(1) *Parent Metal for Test Plates.*—The parent metal used in preparing test pieces and test specimens shall be mild steel of welding quality in the normalized condition (this condition is optional in the case of all-weld metal tests) with an ultimate tensile stress of not less than 28 and not more than 32 tons per square inch and an elongation of not less than 20 per cent on standard test piece A(1) (Appendix B).

(2) *All-Weld Metal Test.*—Method of preparation of test pieces. The temperature of the parent metal shall be between 50° and 100 F (10°—38 °C) immediately before depositing the first run of weld metal. The test specimen shall not be subjected to any mechanical or thermal treatment other than that required herein. All-weld test pieces shall be prepared as shown in *Figure* 1* by depositing weld metal between the chamfered edges of two plates, each $\frac{7}{8}$ inch thick. The preparation of the plates shall give an included angle of 20° and the distance between the plates at the root edges shall be $\frac{1}{2}$ inch to 17/32 inch. The joint shall be closed at the bottom by a backing plate $1\frac{1}{4}$ inch wide by $\frac{1}{4}$ inch thick. The two plates shall be 7 inches long and the dimension B from square edge to root edge of each side plate shall be between:

2 inches minimum and 3 inches maximum when testing 12 S.W.G. (3/32) inch electrodes.

3 inches minimum and 4 inches maximum when testing 10 S.W.G. or 8 S.W.G. electrodes.

4 inches minimum and 5 inches maximum when testing 6 S.W.G. electrodes.

5 inches minimum and 6 inches maximum when testing $\frac{1}{4}$ inch or 5/16 inch electrodes.

The assembly shall be welded together with these plates pre-set so that the gap at the top between the chamfered edges of the plates is 1 inch and the plates may be approximately level when the butt-weld is completed.

The weld metal shall be deposited in single or multi-run layers and the direction of deposition of each layer shall be alternatively from each end of the specimen. Each run of weld metal shall not be less than 1/16 inch and not more than $\frac{1}{8}$ inch thick. The time interval between the completion of one run and the commencement of deposition of the succeeding run shall be not less than 5 minutes. The assembly shall not be quenched between the deposition of individual runs. The welding current used shall be within the appropriate range given by the manufacturer. The welding position for the assembly shall be flat, unless this is contrary to the recommended position for the electrode, in which case the position of weld shall be as recommended by the manufacturer.

On completion of the weld the specimen shall be allowed to cool in still air. The portion including the weld shall then be removed by cutting away the excess plate at the places indicated in *Figure* 1.

*As shown in this Appendix.

The all-weld test piece shall be heat-treated by raising to a uniform temperature of 1112° to 1202° F (600° to 650° C) and maintained at that temperature for one hour and then allowed to cool slowly outside the furnace, protected from draughts and chilling. A tensile test specimen shall be machined from the test piece to the dimensions given in *Figure* 1 (*a*)* taking care that the longitudinal axis of the specimen coincides with the centre line of the weld and the mid-thickness of the plate as indicated in *Figure* 1. The specimen then shall be tested for tensile strength.

(3) *Impact Test Specimen.*—The Izod impact test specimens shall be machined from the weld metal test pieces to the dimensions given in *Figure* 2,* care being taken that the longitudinal axis of the test piece coincides with the centre line of the weld and mid-thickness of the plate. The temperature of the test specimen at the time of testing shall not be less than 50° F (10° C).

(4) *Hot Cracking Test.*—A 6 inches × 3 inches × $\frac{1}{2}$ inch plate shall be welded to a second plate 6 inches × 6 inches × $\frac{1}{2}$ inch in the form of a close square Tee joint as shown in *Figure* 3*. The edge of the first plate abutting the surface of the second shall be prepared by machining or grinding. The gaps between parts after tack welding at the ends shall not exceed 0·01 inch.

Two fillet welds 5 inches long and $\frac{1}{4}$ inch in leg length shall be deposited in the flat position with a single 6 S.W.G.(or 0·2 inch) electrode,using the maximum current of the range recommended by the manufacturer. The test piece shall be so positioned that the slope and the rotation of the weld are zero. The second weld shall be started at that end where the first run was finished after time interval of 4 to 5 seconds. The slage shall be removed after the test piece is cooled in still air to the room temperature. The surfaces of the weld shall be visually examined for cracks.

The second plate shall be slit and the welds broken open as shown in *Figure* 4*. The weld shall not show any evidence of hot cracking as indicated by oxidation or temper colouring of the surface of the fractures.

(5) *Transverse Tensile and Bend Tests.*—The transverse tensile and bend test pieces shall be made as shown in *Figure* 5* by butt-welding together two $\frac{1}{2}$ inch plates of suitable length and not less than 6 inches in width. The Plate edges shall be prepared to form a single Vee joint the details of which shall be as follows:—

(*See Figure* 5*a*)*

Angle between fusion faces 60° —70°.

Root face $\frac{1}{8}$ inch.

Maximum gap $\frac{1}{8}$ inch.

The plate edges shall be prepared as per *Figure* 5(*a*)*, and pre-set to allow for slight distortion after welding.

*As shown in this Appendix.

The welding procedure in making out the test pieces shall be according to the position of welding as in Table 1 below:—

TABLE 1

Welding procedure for preparation of transverse tensile test and bendtest pieces

Welding position for test pieces (all angles±5°) as shown in Table-5 below	Welding Procedure
FLAT Weld slope 0° Weld rotation 0°	1. All runs made with 8 S.W.G. electrodes. 2. First run—6 S.W.G. electrodes. Subsequent runs —5/16 inch diameter electrodes (or largest size manufactured)
INCLINED Weld slope 30° Weld rotation 45°	First run—8 S.W.G. electrodes. Subsequent runs—6 S.W.G. electrodes.
HORIZONTAL—VERTICAL Weld slope 0° Weld rotation 90°	First run—8 S.W.G. electrodes. Subsequent runs—6 S.W.G. electrodes.
VERTICAL Weld slope 90°	All runs made with 8 S.W.G. electrodes.
OVERHEAD Weld slope 0° Weld rotation 180°	All runs made with 8 S.W.G. electrodes.

In all cases a backing run shall be made with 8 S.W.G. electrodes in the welding position applicable to the test piece, after cutting out a groove of $\frac{1}{8}$ inch deep if considered necessary, as in *Figure* 5(*a*)*.

The test pieces for the inclined and vertical positions shall be welded using the 'upwards' method unless the electrodes manufacturer specifically recommends that only the 'downwards' method shall be used. If both methods are recommended, test pieces welded by each method shall be made.

After welding, the test pieces shall be cut by sawing or machining to form one transverse tensile, one face-bend and one root-bend test specimen, as indicated in *Figure* 5*.

(6) *Transverse Tensile Test*.—Transverse tensile test specimens shall conform to the dimensions given in *Figure* 6*. The upper and lower surfaces of the weld shall be filed, ground or machined level with the respective original surfaces of the plates. Where the surfaces of the plates are not level with each other the metal may be cut away to bring them approximately level, provided that the thickness of the plate is not reduced by more than a total of 0·04 inch.

The test specimens shall then be tested for tensile test as in Appendix B.

(7) *Transverse Bend Test*.—The bend test specimens shall be $1\frac{1}{2}$ inches in width. The upper and lower surfaces of the weld shall be filed, ground or machined level with the respective original surfaces of the plates, with the proviso as in item (6) above. Tool marks should be avoided as they lead to location of stress and may cause premature failure. For this reason the direction of machining of the surfaces should be along the specimens and transverse to the weld. The sharp corners of test specimens shall be rounded to a radius not exceeding $\frac{1}{10}$ inch.

*As shown in this Appendix.

The test specimens shall be bent through an angle of 180° over a former having a diameter equal to three times the thickness of the specimen, as shown in *Figure* 7*. One test specimen shall be tested with the face of the weld in tension and one with the root of the weld in tension.

(8) *Cruciform Fillet Weld Tensile Test*.—Normal Penetration Electrodes.

The specimens shall be prepared as shown in *Figure* 8* Care shall be taken that the centre lines of two vertical plates are in the same plane. The parent metal used shall be at a temperature between 50°—100° F (10°—38° C) immediately before depositing the first run of weld metal. The test specimens shall not be subjected to any mechanical or thermal treatment, other than what is given in this appendix. The plates shall be so placed that each weld shall be deposited in the appropriate welding position, using the procedure specified in Table 2 below:—

TABLE 2

Welding procedures for preparation of Cruciform fillet weld tensile test pieces for normal penetration electrodes

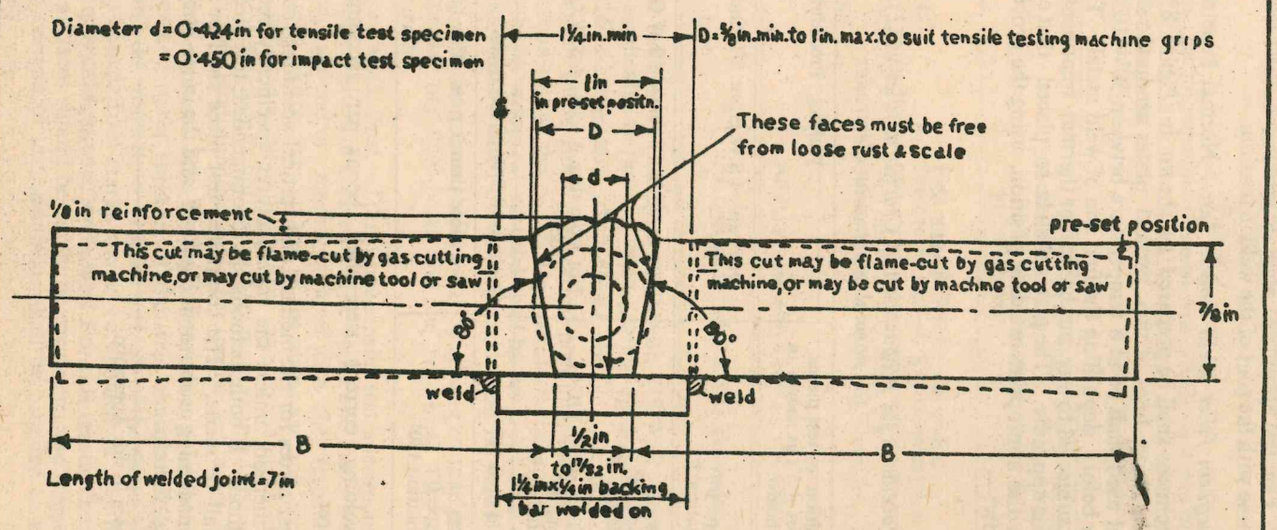
Welding position for test pieces. (All angles ±5°) as shown in Table 5 below.	Welding Procedure
FLAT Weld slope 0° Weld rotation 0°	One run—4 S.W.G. or 5/16 inches diameter electrodes.
INCLINED Weld slope 30° Weld rotation 90°	Not more than 3 runs—8 S.W.G. electrodes.
HORIZONTAL—VERTICAL Weld slope 0° Weld rotation 45°	Not more than 3 runs—6 S.W.G. or 4 S.W.G. electrodes.
Vertical Weld slope 90°	One run—8 S.W.G. electrodes.
OVERHEAD Weld slope 0° Weld rotation 180°	Not more than 3 runs—8 or 6 S.W.G. electrodes.

The welding current used shall be as per recommendation of the manufacturer.

The test pieces for the inclined and vertical positions shall be welded using 'upwards' method, unless the manufacturer specifically recommends 'downwards' method. If both methods are recommended, test pieces welded by each method shall be made. The completed test piece shall be cut into strips by sawing or machining as shown in *Figure* 8* and the inner strip tested in tension as indicated therein.

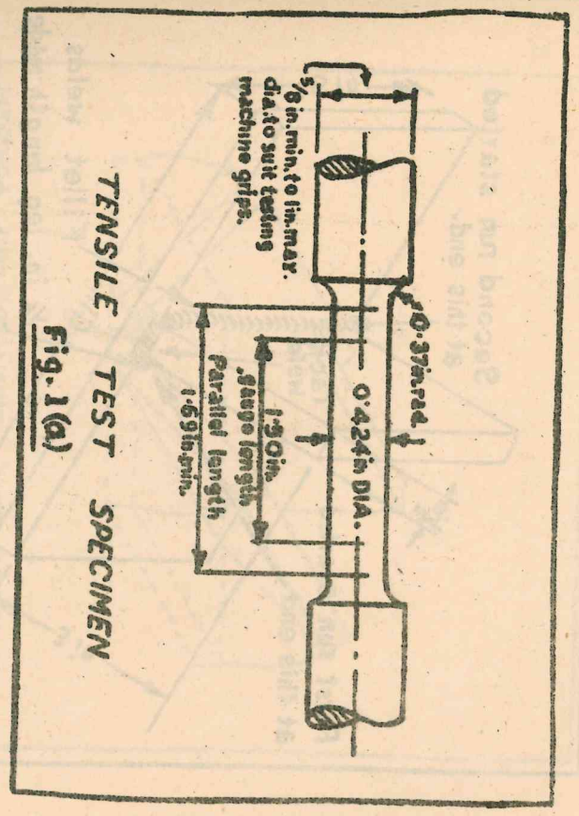
*As shown in this Appendix.

APPENDIX-H1



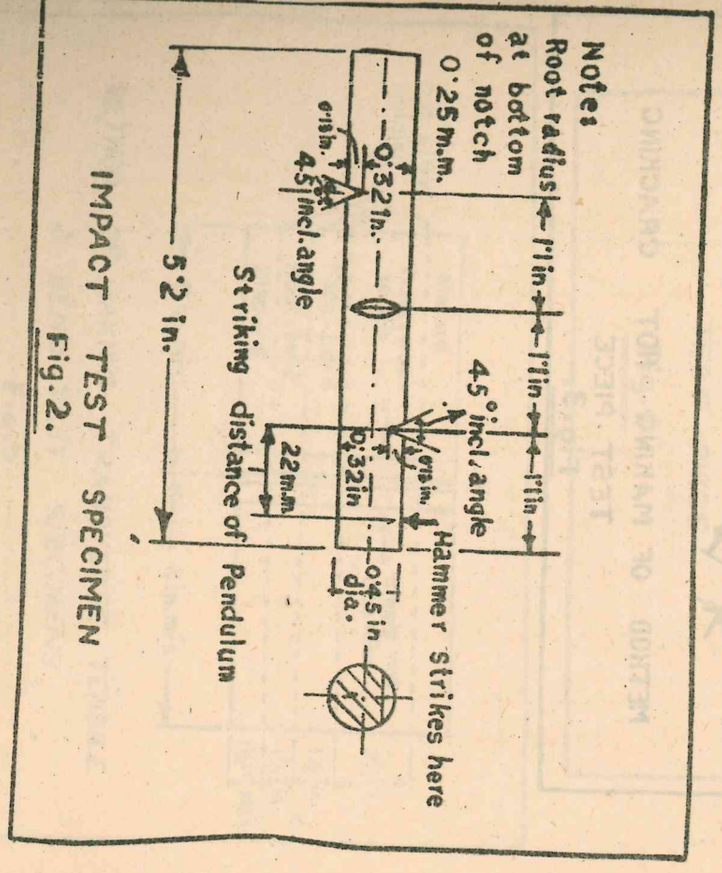
METHOD OF PREPARATION OF ALL-WELD-METAL TEST SPECIMEN

Fig.1



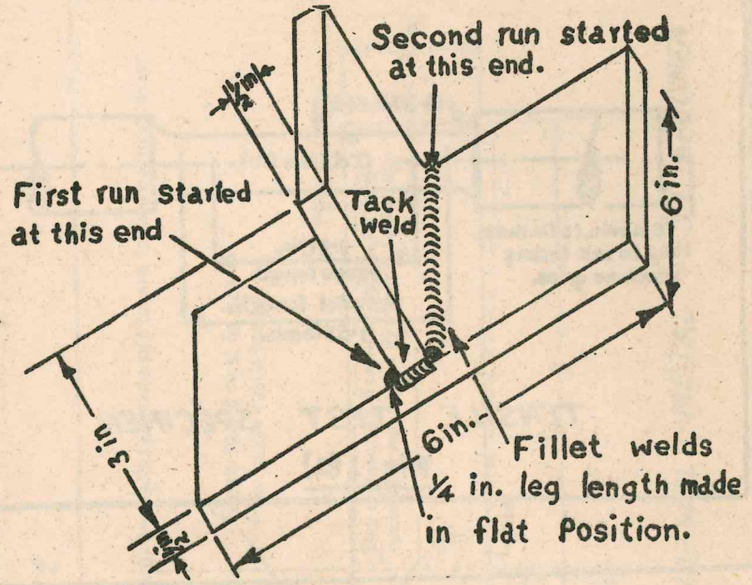
TENSILE TEST SPECIMEN

Fig.1(a)



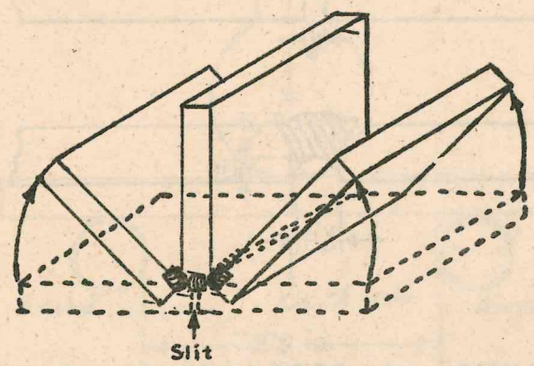
IMPACT TEST SPECIMEN

Fig.2.



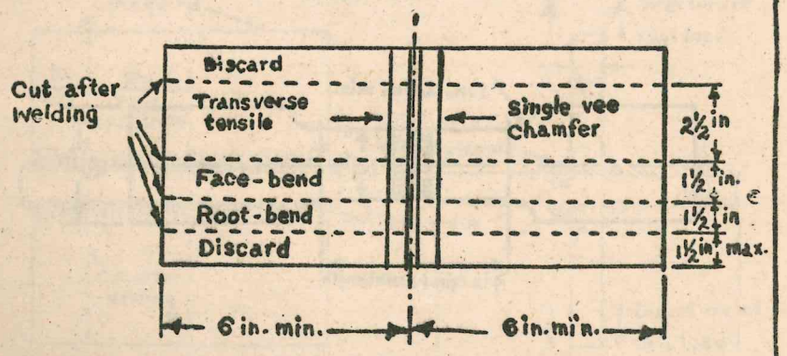
METHOD OF MAKING HOT CRACKING TEST PIECE

Fig.3.



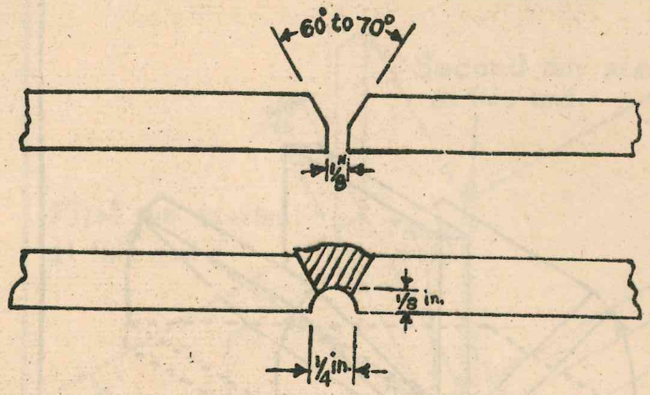
METHOD OF BREAKING HOT CRACKING TEST PIECE

Fig.4.



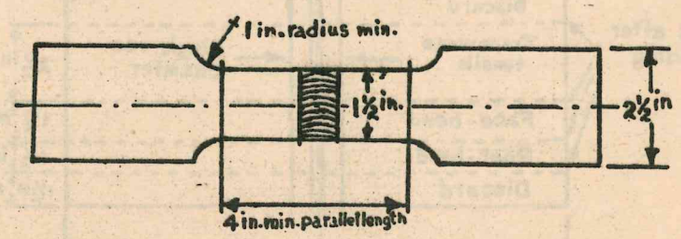
METHOD OF MAKING TRANSVERSE TENSILE & BEND TEST SPECIMENS

Fig.5.



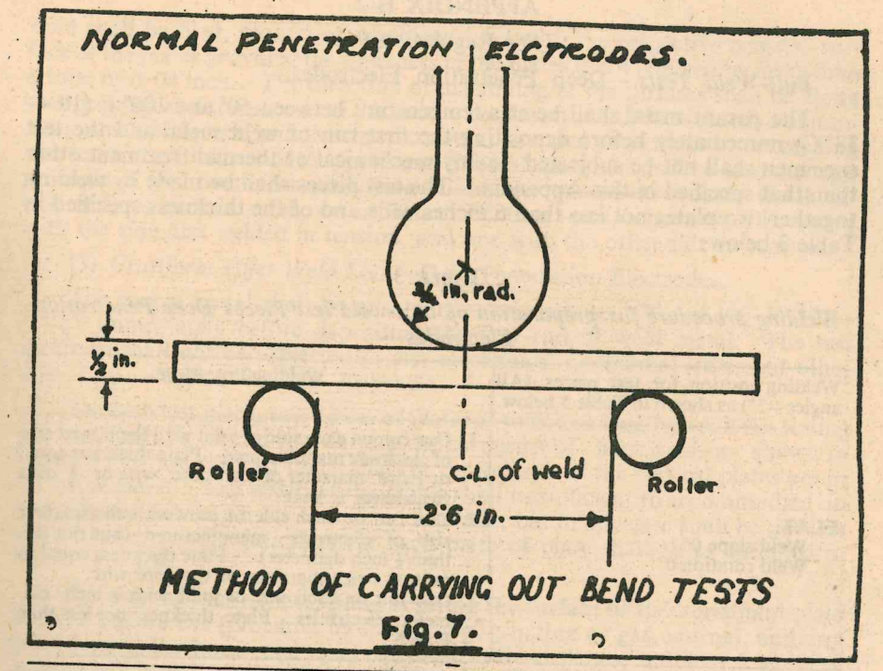
GROOVING IN PREPARATION FOR DEPOSITION OF BACKING RUN

Fig. 5 (a).



DIMENSIONS OF TRANSVERSE TENSILE TEST SPECIMEN

Fig. 6.



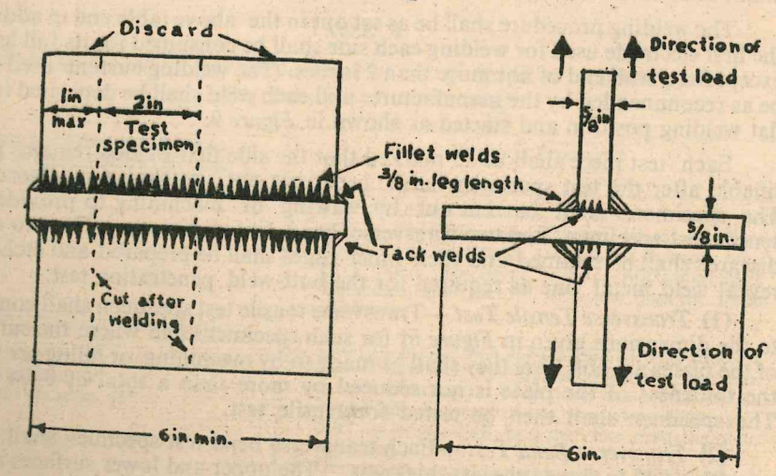
METHOD OF CARRYING OUT BEND TESTS

Fig. 7.

APPENDIX-H1

NORMAL PENETRATION ELCTRODES.

Fig. 8.



METHOD OF MAKING CRUCIFORM FILLET WELD TEST SPECIMENS

APPENDIX H-2

(*See* Regulation 96)

Butt-Weld Tests.—Deep Penetration Electrodes.

The parant metal shall be at a temperature between 50° and 100° F (10 — 38° C) immediately before depositing the first run of weld metal and the test specimen shall not be subjected to any mechanical or thermal treatment other than that specified in this Appendix. The test pieces shall be made by welding together two plates not less than 6 inches wide and of the thickness specified in Table 3 below:

TABLE 3

Welding procedure for preparation of butt-weld test Pieces Deep Penetration Electrodes

Welding position for test pieces (All angles ± 5°) as shown in Table 5 below	Welding Procedure
FLAT Weld slope 0° Weld rotation 0°	1. One run on each side of joint with the largest size of electrode manufactured. Plate thickness equal to twice diameter of the core wire or ½ inch (whichever is less). 2. One run on each side of joint with the smallest size of electrode manufactured (but not less than ¼ inch diameter). Plate thickness equal to at least twice diameter of the core wire. 3. One run on each side of joint with ¼ inch diameter electrodes. Plate thickness not less than ½ inch.

The length of the plates shall be sufficient to accommodate on one side the run length of a complete electrode, but in any case shall not be less than 10 inches.

The joint edges of the plates shall be square cut and any gap between the plates after tack welding at the ends shall not exceed 0·010 inch.

The welding procedure shall be as set out in the above table and in addition the first electrode used for welding each side shall be consumed for its full length except for a stub end of not more than 2 inches. The welding current used shall be as recommended by the manufacturer and each weld shall be deposited in the flat welding position and started as shown in *Figure* 9.*

Each test piece shall be so marked that the side first welded remains identifiable after the test specimens have been cut out, as shown in *Figure* 9*. The specimens shall be cut out by sawing or machining to provide one tensile test specimen and two transverse bend test specimens. The two outer discards shall be retained and their inner edges shall be prepared and etched to reveal weld metal one as required for the butt-weld penetration test.

(1) *Transverse Tensile Test.*—Transverse tensile test specimen shall conform to the dimensions given in *Figure* 6† for such specimens and where the surfaces of the plates are not, level they shall be made so by machining or filling provided the thickness of the plate is not reduced by more than a total of 0·04 inch. The specimen shall then be tested for tensile test.

(2) *Transverse Bend Test.*—Each transverse bend test specimen shall be of a width equal to three times its thickness. The upper and lower surfaces of the

*As shown in this Appendix.
†As shown in Appendix H-1.

weld shall be filed, ground or machined level with the respective original surface of the plates provided the thickness of the plates is not reduced by more than a total of 0·04 inch. The direction of machining of the surfaces shall be along the specimen and transverse to the weld. Tool marks shall be avoided to eliminate premature failure, and the sharp corners rounded to a radius not exceeding one-tenth the thickness of the specimen. The test specimen shall be bent through an angle of 180° over a former having a diameter equal to three times the thickness of the specimen as shown in *Figure* 10*. One test specimen shall be tested with the side first welded in tension, and one with the other side in tension.

(3) *Crusiform Fillet Weld Test.*—Deep Penetration Electrodes.

The parent metal shall be at a temperature between 50° and 100° F (10°—38° C) immediately before depositing the first run of weld metal. The test specimen shall not be subjected to any mechanical or thermal treatment other than that specified in this Appendix.

For each test piece, two pieces of plate, of sufficient length to suit the testing machine shall be welded to a third plate by means of fillet welds as shown in *Figure* 11*. Care shall be taken that the centre lines of the vertical plates are in the same plane. The width of the plates shall be sufficient to accommodate on one side the run length of complete electrode, but in any case shall be not less than 10 inches. The thickness of each piece of plate shall be as specified in Table 4 below.

The edge of each vertical plate abutting the surface of the horizontal plate shall be square cut (prepared by machining, grinding or gas cutting), and any gap between the horizontal plate and the vertical plates, after tack welding at the ends in preparation for welding shall not exceed 0·01 inch.

The welding procedure followed in making the test pieces shall be as set ou in Table 4 below with the addition that the first electrode used for welding each fillet shall be consumed for its full length except for a stub end of not more than 2 inches.

TABLE 4

Welding procedure for preparation of cruciform fillet weld test pieces (deep penetration electrodes)

Welding position for test pieces (as shown in table 5 below) all angle ± 5°	Welding Procedure
HORIZONTAL –VERTICAL Weld slope 0° Weld rotation 45°	1. One run on each side of each joint with the largest size of electrode manufactured. Plate thi ckness equal to at least twice diameter of the core wire or ¼ inch. (whichever is less). Maximum fillet leg length shall be 1/8 inch less than the plate thickness. 2. One run on each side of each joint with the smallest size of electrode manufactured (but not less than ¼ inch diameter). Plate thickness equal to at least twice diameter of the core wire. Maximum fillet leg length shall be ⅛ inch less than the plate thickness. 3. One run on each side joint with ¼ inch diameter electrodes. Plate thickness not less than ½ inch and fillet leg length not to exceed ⅜ inch.

*As shown in this Appendix.

The welding current used shall be within the appropriate range recommended by the manufacturer and each weld shall be deposited in the horizontal-vertical position.

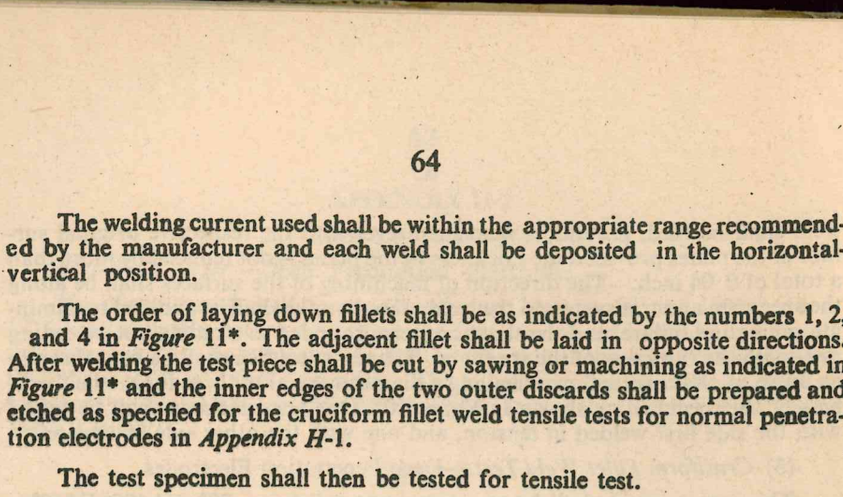
The order of laying down fillets shall be as indicated by the numbers 1, 2, and 4 in *Figure* 11*. The adjacent fillet shall be laid in opposite directions. After welding the test piece shall be cut by sawing or machining as indicated in *Figure* 11* and the inner edges of the two outer discards shall be prepared and etched as specified for the cruciform fillet weld tensile tests for normal penetration electrodes in *Appendix H*-1.

The test specimen shall then be tested for tensile test.

*As shown in this Appendix.

APPENDIX-H2.

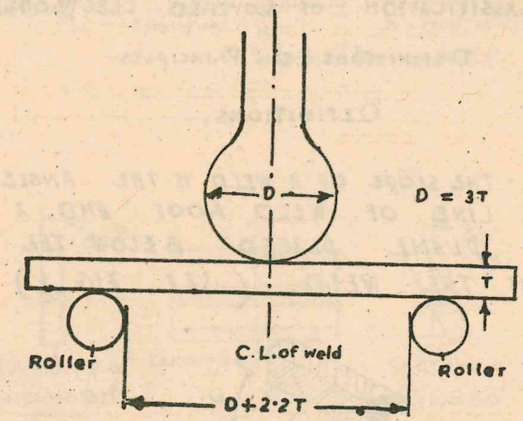
Fig.9.



METHOD OF MAKING BUTT WELD TEST SPECIMENS

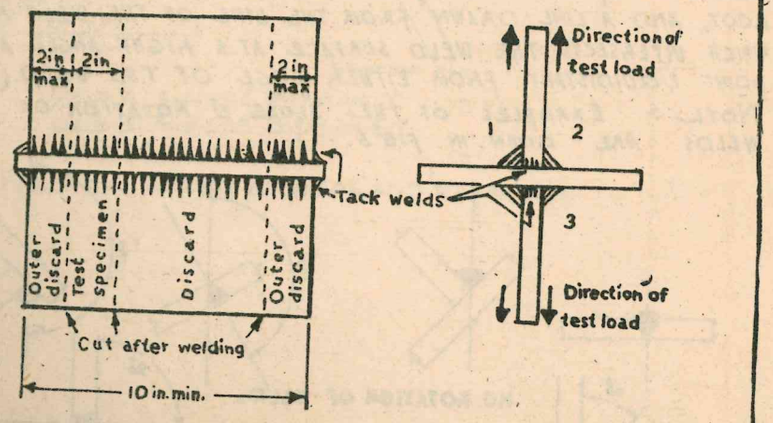
Fig.10.

TRANSVERSE BEND TEST ON BUTT WELD SPECIMENS



DEEP PENETRATION ELECTRODES.

Fig.11.



METHOD OF MAKING CRUCIFORM FILLET WELD TEST SPECIMENS

TABLE 5

(See Appendix H1 & Appendix H2)

Definition of Welding terms

CLASSIFICATION OF COVERED ELECTRODES.

DEFINITIONS & PRINCIPLES

DEFINITIONS.

WELD SLOPE. THE SLOPE OF A WELD IS THE ANGLE FORMED BETWEEN THE LINE OF WELD ROOT AND A HORIZONTAL REFERENCE PLANE PLACED BELOW THE LOWEST PORTION OF THE WELD. (SEE FIG.1)

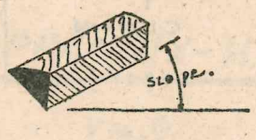


FIG. 1. DIAGRAM TO ILLUSTRATE WELD SLOPE.

WELD ROTATION. THE ROTATION OF WELD IS THE ANGLE FORMED BETWEEN THE UPPER PORTION OF VERTICAL REFERENCE PLANE WHICH PASSES THROUGH THE LINE OF THE WELD ROOT, AND A LINE DRAWN FROM THE LINE OF THE WELD ROOT WHICH INTERSECTS THE WELD SURFACE AT A RIGHT ANGLE AND A POINT EQUIDISTANT FROM EITHER EDGE OF THE WELD. (SEE FIG 2)

NOTE :- EXAMPLES OF THE SLOPE & ROTATION OF VARIOUS WELDS ARE GIVEN IN FIG 3.

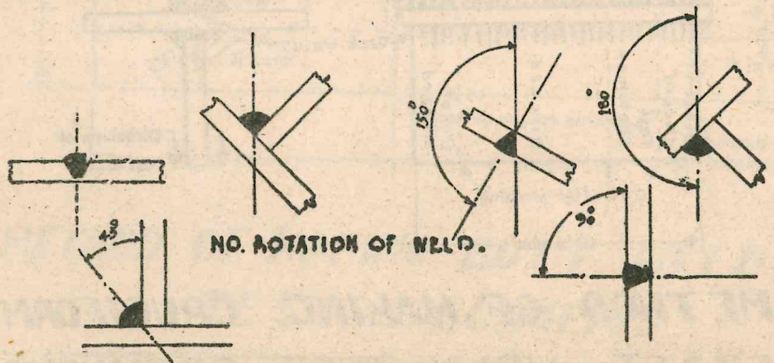
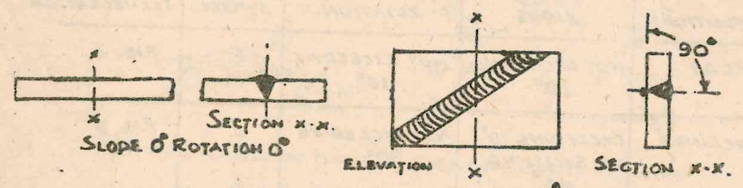
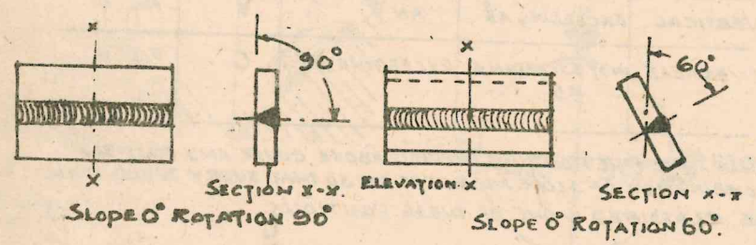
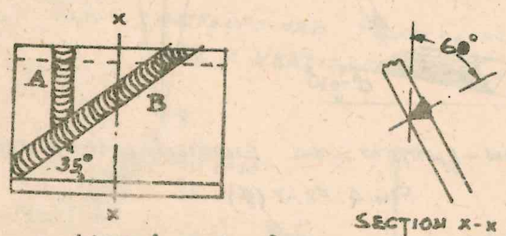


FIG 2. DIAGRAMS TO ILLUSTRATE WELD ROTATION







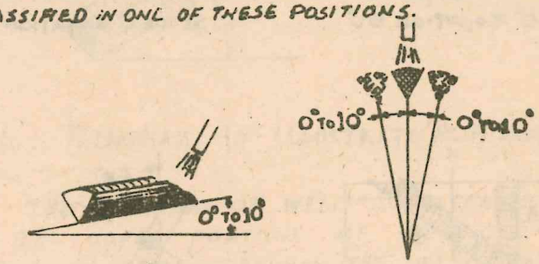
WELD A: SLOPE 60° ROTATION 0°
WELD B: SLOPE 35° ROTATION 60°

FIG. 3 EXAMPLES OF 'SLOPE' AND 'ROTATION

WELDING POSITIONS. WELDING POSITIONS ARE DEFINED AS FOLLOWS.

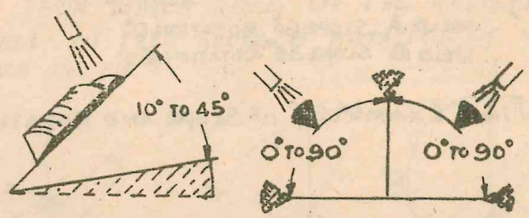
POSITIONS	SLOPE	ROTATION	SYMBOL	ILLUSTRATION
FLAT	NOT EXCEEDING 10°	NOT EXCEEDING 10°	F	FIG. 4.
INCLINED	EXCEEDING 10° NOT EXCEEDING 45°	NOT EXCEEDING 90°	I	FIG. 5
HORIZONTAL-VERTICAL	NOT EXCEEDING 10°	EXCEEDING 10° NOT EXCEEDING 90°	H	FIG. 6
VERTICAL	EXCEEDING 45°	ANY.	V	FIG. 7
OVERHEAD	NOT EXCEEDING 45°	EXCEEDING 90°	O	FIG. 8

NOTE. THE FIVE POSITIONS DEFINED ABOVE COVER ANY POSSIBLE COMBINATION OF SLOPE AND ROTATION SO THAT EVERY WELD CAN BE CLASSIFIED IN ONE OF THESE POSITIONS.



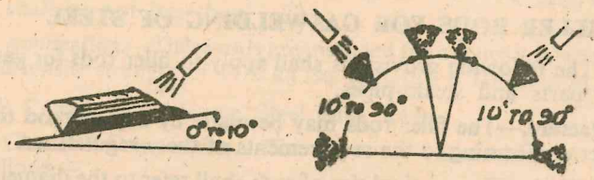
SIDE VIEW - LIMITS OF SLOPE. END VIEW - LIMITS OF ROTATION.

FIG. 4. FLAT (F)



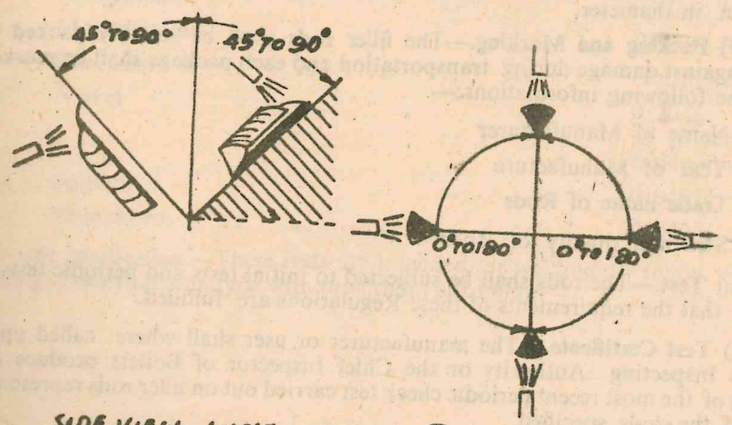
SIDE VIEW - LIMITS OF SLOPE. END VIEW - LIMITS OF ROTATION

FIG. 5. INCLINED (I)



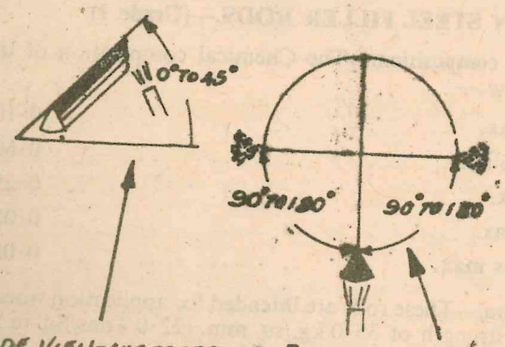
SIDE VIEW - LIMITS OF SLOPE. END VIEW - LIMITS ROTATION

FIG. 6 HORIZONTAL-VERTICAL (H).



SIDE VIEW - LIMITS OF SLOPE. PLAN - LIMITS OF ROTATION

FIG. 7 VERTICAL (V)



SIDE VIEW - LIMITS OF SLOPE. END VIEW - LIMITS OF ROTATION.

FIG. 8. OVERHEAD (O)

FILLER RODS FOR GASWELDING OF STEEL

98-A (*a*) The following provisions shall apply to filler rods for gas welding of boiler parts and steam-pipes.

(*i*) **Manufacture.**—The filler rods may be made by any method that shall yield a product conforming to the requirements of these regulations.

(*ii*) **Size of Rods.**–The nominal size of rods shall refer to the diameter of the rod which shall be expressed in millimeter. The tolerances on the specified diameter of the rod shall be plus or minus 0·05 mm. for rods 1·6 mm. (1/16 in.) and over in diameter, and plus or minus 0·03 mm. for rods less than 1·6 mm. in diameter.

(*iii*) **Packing and Marking.**—The filler rods shall be suitably packed to guard against damage during transportation and each package shall be marked with the following informations:—

Name of Manufacturer

Year of Manufacture

Trade name of Rods

Size and quality of Rods.

(*iv*) **Test.**—The rods shall be subjected to initial tests and periodic tests to ensure that the requirements of these Regulations are fulfilled.

(*v*) **Test Certificate.**—The manufacturer or user shall where called upon by the Inspecting Authority or the Chief Inspector of Boilers produce the results of the most recent periodic check test carried out on filler rods representative of the rods specified.

CHEMICAL COMPOSITION AND APPLICATIONS

(*vi*) **CARBON STEEL FILLER RODS.—(Grade I)**

(*a*) **Chemical composition.**—The Chemical composition of the rods shall be as given below:—

Carbon max.	0·10%
Manganese max.	0·60%
Nickel max.	0·25%
Sulphur max.	0·050%
Phosphorus max.	0·050%

(*b*) **Application.**—These rods are intended for application where a minimum butt-weld tensile strength of 35·0 kg./sq. mm. (22·0 Tons/Sq. in.) is required.

(*vii*) **Carbon Steel Filler Rods—(Grade II)**

(*a*) **Chemical Composition.**—

Carbon	0·10% to 0·20%
Silicon	0·10 to 0·35%
Manganese	1·00 to 1·60%
Sulphur max.	0·040%
Phosphorus max.	0·040%

When the carbon content is in the range of 0·10 to 0·12% the manganese content shall be not less than 1·20%.

(*b*) **Application.**—These rods are intended for application where a minimum butt-weld tensile strength of 44·0 kg./sq. mm. (28·0 Tons/Sq. in.) is required.

(*viii*) **Carbon Molybdenum Steel Filler Rods**

(*a*) **Chemical Composition.**—The Chemical composition of the rods shall be as follows.—

Carbon	0·15% max.
Silicon	0·25 to 0·50%
Manganese	0·60 to 1·50%
Molybdenum	0·45 to 0·65%
Chromium & Nickel	Not more than 0·20% each (if present as a residual)
Sulphur	0·040%
Phosphorus	0·040%

(*b*) **Application.**—These rods are intended for welding of (alloy steels of the) ½% molybdenum type with or without chromium "