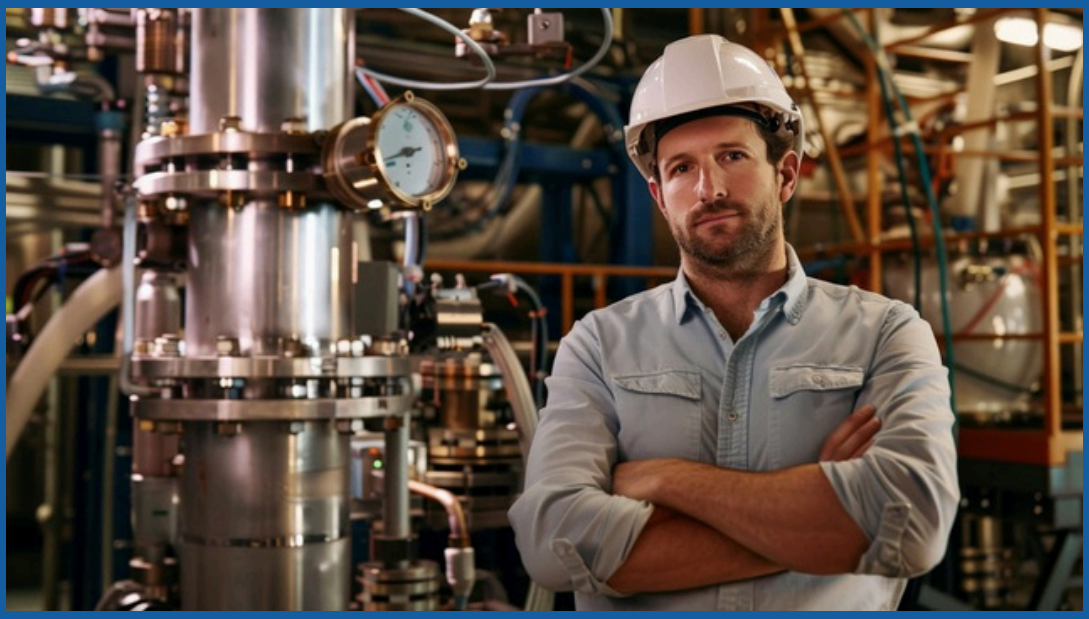
Study Material For Boiler Operation Engineer (BOE) Exams



Theory, Numerical Problems, MCQs and Boiler Drawing Problems from BOE Exams

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REGD No. D-481

The Gazette of India

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EXTRAORDINARY

PART II—Section 3

PUBLISHED BY AUTHORITY

No. 43] NEW DELHI, FRIDAY, SEPTEMBER 15, 1950

GOVERNMENT OF INDIA
MINISTRY OF WORKS, MINES AND POWER
CENTRAL BOILERS BOARD

NOTIFICATION

BOILERS

New Delhi, the 15th September 1950

S.R.O. 600.—In exercise of the powers conferred by section 28 of the Indian Boilers, Act, 1923 (V of 1923), and in supersession of the Government of India Notification No. A. 470, dated Simla, the 27th October 1923, the Central Boilers Board is pleased to make the following Regulations, the same having been previously published as required by sub-section (1) of section 31 of the said Act, namely :—

REGULATIONS

PRELIMINARY

1. Short Title, Extent and Commencement.—(1) These Regulations may be called the Indian Boiler Regulations, 1950.

(2) They extend to the whole of India, except Part B States.

(3) They shall come into force at once.

2. Definitions.—In these Regulations, unless the context otherwise requires,—

(*a*) the "Act" means the Indian Boilers Act, 1923 ;

(*b*) "accident" means an explosion of a boiler or steam-pipe or any damage to a boiler or steam-pipe which is calculated to weaken the strength thereof so as to render it liable to explode ;

(*c*) "boiler" means any closed vessel exceeding five gallons in capacity which is used expressly for generating steam under pressure, and includes any apparatus forming an integral part of a boiler, which is wholly or partly exposed to the action of the flue gases for purpose of recovery of waste heat, and also includes any mountings or other fittings attached to such vessel which is wholly or partly under pressure when steam is shut-off but not withstanding anything contained in section 2(b) of the Act does not include an economiser as defined in clause (cc) of section 2 thereof.

(*d*) "Chief Inspector" and "Inspector" mean, respectively, a person appointed to be a Chief Inspector and an Inspector under the Act ;

(*e*) "economiser" means any part of a feed-pipe that is wholly or partly exposed to the action of flue gases for the purpose of recovery of waste heat ;

(*f*) "feed-pipe" (i) means any pipe or connected fitting wholly or partly under pressure through which feed-water passes directly to a boiler.

(ii) every reference to a steam pipe or steam pipes shall be deemed to include also a feed-pipe or feed-pipes respectively ;

(*g*) " Inspecting Authority " means an authority recognised by the Central Boilers Board as competent to grant a certificate in Form II*.

(*h*) "Inspecting Officer" means—

(i) in respect of material manufactured or boilers constructed in any State an officer appointed by the Inspecting Authority in that State.

(ii) in respect of material manufactured or boilers constructed outside the States an officer acting on behalf of the Inspecting Authority ;

(*i*) "owner" includes any person using a boiler as agent of the owner thereof and any person using a boiler which he has hired or obtained on loan from the owner thereof;

(*j*) "prescribed" means prescribed by regulations or rules made under the Act ;

(*k*) "Steam-pipe" means any main pipe exceeding three inches in internal diameter through which steam passes directly from a boiler to a prime-mover or other first user, and includes any connected fitting of a steam-pipe ;

(*l*) "State" or "States" mean a State or the States to which these regulations extend ; and

(*m*) " Structural alteration, addition or renewal" shall not be deemed to include any renewal or replacement of a petty nature when the part of fitting used for replacement is not inferior in strength, efficiency or otherwise to the replaced part of fitting.

*NOTE.—For List of Inspecting Authorities recognised by the Central Boilers Board, *see* Appendix C.

CHAPTER I

GENERAL REQUIREMENTS, APPLICATION OF STANDARD CONDITIONS AND EXCEPTIONS THERETO

3 (1) A boiler shall not be registered under sub-section (4) of Section 7 of the Act and a certificate shall not be issued under sub-section (5) of that section with reference to a boiler, unless the standard conditions in respect of material, design and construction, which are specified in the subsequent Chapters of these Regulations are satisfied in respect of such a boiler.

(2) Notwithstanding anything contained in sub-regulation (1), the Chief Inspector may, subject to the provisions of Regulation 7, register a boiler and order the issue of a certificate authorising the use thereof, although the standard conditions are not fully satisfied in respect of such boiler ; Provided that the Chief Inspector shall not register such boiler or order the issue of such certificate, if a structural part of such boiler which is subject to pressure is made of Bessemer process steel or of cast or malleable cast iron.

STANDARD REQUIREMENTS

4. (a) **Material.**—All plates, rivets and bars used in the construction of boilers shall be tested and found to conform with the Regulations hereinafter contained.

(b) **Construction.**- All boilers during construction shall be under the supervision of an Inspecting Officer.

(c) **Inspecting Authority's certificate.**—For boilers imported into the States a certificate from an Inspecting Authority in Form II certifying that the material was tested and the boiler built under their supervision shall be furnished to the Chief Inspector before or with the application for registration. Together with such certificate the Inspecting Authority may furnish a Memorandum of Inspection book in Form I prepared in the manner prescribed by Regulation 386 in respect of the inspection of the boiler during construction and the hydraulic test applied on completion. In the case of steel made and tested by well-known makers in India or other countries the certificate of the makers in Form IV as prescribed in Regulation 26 may be accepted in lieu of a certificate from an Inspecting Authority.

The Central Boilers Board shall decide whether for the purpose of this Regulation a maker is "well-known" or not.

(d) **Certificates, etc. under section 14(1) (c) of the Act.**—In advance of or along with an application for registration of a boiler, the following certificates and drawings or specifications should be furnished to the Chief Inspector, namely:—

(i) A certificate in Form III of manufacture and test signed by the maker or by a responsible representative of the maker of the boiler containing a description of the boiler, its principal dimensions. particulars of the kind of material used in its construction, the thickness of all plates, the diameter of and method of forming the rivet holes in the shell plates, particulars of any departure from ordinary practice in making the shell such as solid rolling or welding, the hydraulic test to which the boiler was subjected, the intended working pressure, the area of heating surface, the maximum continuous evaporative capacity, the year and place of make, and the works number of the boiler.

There may be included in such certificate a further declaration that samples of the angle, stay or rivet bars and rivets used in the construction of the boiler have been certified by the makers to have been tested and found to comply with the requirements of Chapter II; in which declaration the kind of material used and the limits of tensile breaking strength with which the tests comply shall be stated with sufficient precision to obviate the risk of confusion in making allowances. Where such further declaration is included in such certificate, the certificates referred to in clause (iii) of this sub-regulation shall not be required.

(ii) A drawing or print to a scale, in the case of large boilers of not less than $\frac{3}{4}$ inch to the foot and, in the case of small boilers, of not less than $1\frac{1}{2}$ inches to the foot, showing the principal dimensions and a longitudinal section and end view of the boiler, and bearing the works number of the boiler and the maker's office stamp. The drawing shall show details of riveting of longitudinal and circumferential seams with pitch of rivets, cross spacing of rivet rows and diameters of rivet holes : the radii of curvature of dished end plates, fillets of flanges and corners of bent plates, and where gusset stays are fitted, the number and diameter of rivet holes in each gusset stay.

In the case of water tube boilers, the foregoing scales shall apply to the main boiler drums only, but in addition a general arrangement drawing of the boiler to a scale of not less than "$\frac{1}{4}$" to the foot shall be provided.

(iii) A certificate from the steel maker and a certificate from the maker of the plates, rivets or bars, of the nature referred to in Regulations 26 and 27 respectively. The certificate from the maker of the plates, rivets or bars, shall show the charge numbers, the plate or bar numbers and the number and dimensions of the various plates, etc., tested, their ultimate tensile breaking strength in tons per square inch of section, the [illegible] elongation and the length on which measured, the number, kind [illegible] or other tests made and the date of tests:

Provided that where an Inspecting Authority furnishes a certificate in Form II together with a Memorandum of Inspection book in Form I in accordance with sub-regulation (c), the certificates prescribed, under clauses (i) and (iii) need not be furnished to the Chief Inspector when application is made for registration of the boiler. But should any question arise in respect of the fitness of the boilers for the working pressure approved by the Inspecting Authority within a period of three years from the date of their certificate, the owner shall, if requested by the Chief Inspector, obtain and furnish the original documents specified in the said clauses.

(c) **Maker's stamp.**—The boiler shall have stamped upon its front plate in a conspicuous position the following particulars :—

Maker's name

Year of make

Work's number

Tested to lbs. on

W.P. lbs.

Inspecting Officer's or Inspecting Authority's official stamp.

5. Modification of formulae.—(i) Under the Regulations for determining the working pressure to be allowed on various parts of boilers, the material to which the formulae apply shall in the absence of express provision to the contrary be steel complying with the requirements of Chapter II.

(ii) Where no test certificates for shell plates and rivets are produced, the material may be treated as iron, if the Chief Inspector is satisfied that the material is of suitable boiler quality. If in such cases the Chief Inspector is clearly satisfied that the material is of good quality, a higher strength than that allowed for iron may be permitted but the strength of the shell plates shall not, save for special reasons, be assumed to be more than 26 tons. In such cases S and S_1 in equations 1, 3 and 4 of Chapter IV may be respectively 26 and 21 for steel and 21 and 18 for iron. For iron across the grain S may be 18.

(iii) Where end plates, furnaces, flat plates, girders, gusset and other stays, etc. are made of steel or iron for which no test certificates are produced, the working pressure as found from the formulae in which S is to be taken at the lowest limit prescribed for the part, reduced by 15 per cent, shall, except where such material is specifically provided for in any formula, be the working pressure permitted. For flat plates of copper, the working pressure as found from the formulae, reduced by 50 per cent. shall be the working pressure permitted.

6. Standard specifications for materials.—The standard specifications for steel wrought iron and copper plates and bars, and for cast steel shall be those prescribed in Chapter II, but certificates of tests of material for wrought iron (except for special wrought iron for screw stays) copper and cast steel shall not be required unless special allowances are required. Such special allowances shall be in the discretion of the Chief Inspector.

7. Boiler Shells not in accordance with standard conditions.—When the standard conditions are not complied with, additions to the appropriate coefficient as defined in Regulation 176 shall be made as follows :—

(a) When there are no proofs of tests of steel, 15 per cent. of the standard coefficient.

(b) When a boiler has not been inspected during construction by an Inspecting Officer and certified by him, 10 per cent. of the standard coefficient.

(c) When the workmanship is in any way doubtful and the Inspector is not satisfied that any of the foregoing additions to the coefficient would be sufficient.

to meet the circumstances, such percentage of the standard co-efficient as the Chief Inspector deems fit.

Provided that nothing in this regulation shall apply to a hollow forged or a fusion welded drum if it is constructed under the supervision of an Inspecting Authority.

8. Welding.—The use of welding in the construction of boilers shall be permitted only where specifically provided for in the standard conditions.

CHAPTER II
MATERIALS OF CONSTRUCTION

STEEL PLATES, RIVETS 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.

11. Freedom from Defects, etc.—The finished material shall be sound and free from cracks, surface flaws and laminations. Hammer dressing, patching or welding is prohibited but this does not prevent the removal of slight scale or shell by the use of chisel, file or buff, 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 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	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	6	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, notwithstanding 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 tensile stress and elongation shall be determined on standard test piece A (see App. B).

(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 $\frac{1}{4}$ square inch.

Where the test piece is over 1 inch diameter, test piece B_1 (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.		
		Test piece A	Test piece B	Test piece C
Plates for shells butt straps, and gusset stays	26—30	23 for 26- 30 20 for 28 -32 20 for 32-- 36		
Plates for flanging or welding	24 —32	23 for 24—30 20 for 28—32		
Plates for furnaces	24—30	23		
Stay angle and tee bars	26—36	23 for 26— 30 20 for 28—32 20 for 32—36	23 for 26—30 20 for 28—32 20 for 32--36	28 for 26- -30 24 for 28- - 32 24 for 32—36
Rivet bars . .	24—30		25 for 24—28 23 for 26—30	30 for 24—28 28 for 26- 30

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 are of the same section or diameter, in which case one tensile test shall suffice. For round bars of $1\frac{1}{4}$ 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.—(a) **Cold Bends.**—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 1½ times the thickness of the test piece and the sides 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 bend cold, and hammered until two parts of the shank 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 and bar shall be clearly and distinctly marked by the maker in two places with an approved quality brand indicating that the material has complied with the required tests; and also with the number or identification marks by which they can be traced to the charge from which the material was made.

24. Defacing of rejected material.—In the event of the material failing in any case to withstand the prescribed tests, the Inspector or Inspecting Officer shall see that the quality brand stamped on the material has been defaced by punch marks extending beyond the brand in the form of a cross, denoting that the material has been rejected.

25. Facilities for inspection.—The maker shall adopt a system of marking 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.

WROUGT 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 Fireboxes 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 AND TUBES

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

(b) **Chemical Composition.**—The plates shall contain not less than 99 per cent. of copper, and between ·3 % and ·5 % of arsenic.

(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, nor 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 1/2 % under the specified diameter

(e) **Tensile Tests.**—The tensile breaking-strength shall not be less than 14 tons per sq. in. with an elongation of not less than 40% on the Standard Test Piece B.

(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 3/8in. 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.

35. 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) **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.

COLD DRAWN SEAMLESS STEEL BOILER AND SUPERHEATER TUBES—FOR DESIGNED STEAM TEMPERATURE NOT EXCEEDING 850°F (454°C)

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 0·045 per cent .of sulphur and 0·04 per cent. phosphorus and the manufacturer shall supply a certificate of the analysis when required to do so.

Note.—Where the material is used for designed steam temperatures above 750°F (399°C) and not exceeding 850°F (454°C) the steel shall be of non-segregated of fully killed type.

(b) **Annealing.**—The tubes shall be carefully annealed throughout their length after the operation of drawing and the ends shall be carefully annealed after the process of swelling or reducing the diameter.

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

(d) **Tolerances.**—(i) **Thickness.**—The tolerance in thickness shall be 5 per cent. below and 10 per cent. above the specified thickness.

(ii) **Swelled or Reduced Ends.**—Where the ends of tubes are swelled or reduced, the thickness at the ends may be reduced, or increased under or over, the actual thickness of the tubes by an amount strictly in proportion to the percentage of such swelling or reducing and in addition to this allowance the tolerances specified in paragraph (i) of this sub-regulation shall also apply.

(iii) **Diameter.**—The external diameter of the tubes, measured at any point shall be not greater than that specified, but may be less by not more than 1 per cent.

(iv) **Length.**—The length of the tubes shall be not less than that specified and not more than 1/8 inch greater.

37. Selection of Tubes for Test.—Two per cent. of the tubes of each thickness and diameter and only one for every 100 or part thereof above 400 tubes of such similar size shall be made available to the Inspecting Officer for testing to the extent of such numbers.

38. Tensile Test.—Test pieces cut from the ends of the selected tubes shall comply with the following requirements :—

—	Ultimate tensile stress. Tons per sq. in.		Minimum elongation per cent.			
			On 8 in.		On 2 in.	
	Not less than	Not more than	¼ in. thick and over	Less than ¼" thick.	¼ in. thick and over	Less than ¼" thick.
Strip cut from tubes and tested in their curved conditions.	20	28	20	18	30	28
Test lengths taken from finished tubes (ends to be plugged for grips).	20	28	25	23	..	.

39. Flattening Test.—A ring not less than 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 $1\frac{1}{2}$ times the diameter of the tube. When the pressure is released, the interior surfaces of the test piece (at the middle) shall remain at the following distances apart and the test piece shall then show no sign of crack or flaw.

Tubes over 10 S.W.G. in thickness	Not more than twice the thickness of the tube.
Tubes up to and including 10 S.W.G. in thickness.	Until the interior surfaces meet at the middle

40. Expanding Tests.—The tubes 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 increases in external diameter without showing crack or flaw.

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

41. Additional test before rejection.—(a) Should a tube selected for testing purposes show definite signs of failure in any one or more of the tests specified in Regulations 38, 39 and 40, 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.

(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 36(b) and then retested in accordance with Regulations 38, 39 and 40 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.

42. Hydraulic Test.—Each tube shall be tested at the makers works by hydraulic pressure in accordance with the following table governing the relation between the test pressure and the design pressure to which the tube will be subjected in service.

Design pressure lb/sq. in.	Hydraulic test pressure lb/sq. in. minimum
Up to and including 500	1000
Above 500 upto and including 1000	Twice the design pressure.
Above 1000	1000 above the design pressure.

In all cases the tensile stress (S) on the material when under these tests shall not exceed 10 tons. per sq. in. as determined by the formula $S = \frac{DP}{2t}$

Where D =outside diameter of the tube in inches
P =test pressure in tons per sq. in.
t =nominal thickness of tube wall in inches.

HOT FINISHED SEAMLESS STEEL BOILER AND SUPERHEATER TUBES FOR DESIGNED TEMPERATURES NOT EXCEEDING 850°F (454°C)

43. (a) **Material.**—To comply with Regulation 36(a).

(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. . .	1/8 in.
Over 30 ft.	1/4 in.

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

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

	Ultimate tensile stress in tons per sq. in.		Minimum elongation per cent.			
			on 8 in.		on 2 in.	
	Not less than	Not more than	1/4 in. thick and over	Less than 1/4 in. thick	1/4 in. thick and over	Less than 1/4 in. thick
Strips cut from tubes and tested in their curved condition.	20	28	20	18	30	28
Test lengths taken from finished tubes (ends of tubes to be plugged from grips).	20	28	25	23	.	. .

(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 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.

(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
Thinner than 5 S.W.G. and up to and including 3 S.W.G.	12
Thicker than 3 S.W.G.	9·5

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 the 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 re-tested 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 by hydraulic pressure in accordance with the following table governing the relation between the test pressure and the design pressure to which the tube will be subjected in service.

Design pressure lb/sq. in.	Hydraulic test pressure lb./sq. in. minimum
Up to and including 500 . . .	1000
Above 500 up to and including 1000 . .	Twice the design pressure
Above 1000	1000 above the design pressure.

In all cases the tensile stress (S) on the material when under these tests shall not exceed 10 tons per sq. in. as determined by the formula :—

$$S = \frac{DP}{2t}$$

Where D = outside diameter of tube in inches.
P = test pressure in tons per sq. in.
t = Nominal thickness of tube wall in inches.

SEAMLESS HALF-PER CENT. MOLYBDENUM STEEL BOILER AND SUPERHEATER TUBES FOR DESIGN STEAM TEMPERATURES NOT EXCEEDING 950°F (510°C)

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 compositions :—

Carbon	0·15% maximum
Manganese	0·40 to 0·70%
Silicon	0·10 to 0·35%
Sulphur	0·05% maximum
Phosphorus	0·05% ,,
Molybdenum	0·45 to 0·65%

The steelmaker shall supply a certificate of the normality of the steel.

(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 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 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.

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

—	Ultimate Tensile Stress in tons per sq. in		Minimum elongation per cent. on 8 inches	
	Not less than	Not more than	1/4" thick and over	Less than 1/4" thick
Strips cut from tubes and tested in their curved condition.	27	33	19	17
Tests Lengths taken from finished tubes (ends of tubes to be plugged for grips).	25	33	23	21

(b) **Flattening Test.**—A ring not less than 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 $1\frac{1}{2}$ times the 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 specified thickness of the tube and the test piece shall then show no sign of crack or flaw.

(c) **Expanding Tests.**—The tubes shall withstand expanding by a drift expander having a total included angle of between 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	$12\frac{1}{2}$
Thinner than 9 S.W.G. up to and including 6 S.W.G. . .	$9\frac{1}{2}$
Thicker than 6 S.W.G.	$6\frac{1}{2}$

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 test, 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 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.

51. Hydraulic Test.—Each tube shall be tested at the maker's works by hydraulic pressure in accordance with the following table governing the relation between the test pressure and the design pressure to which the tube will be subjected in service.

Design pressure lb /sq. in.	Hydraulic test pressure lb/sq. in. minimum
Up to and including 500	1000
Above 500 up to and including 1000	Twice the design pressure.
Above 1000	1000 above the design pressure.

In all cases the tensile stress (S) on the material when under these tests shall not exceed 10 tons per sq. in. as determined by the formula :—

$$S = \frac{DP}{2t}$$

Where D = outside diameter of tube in inches.
P = test pressure in tons per sq. in.
t = nominal thickness of tube wall in inches.

SEAMLESS CHROME-MOLYBDENUM STEEL BOILER AND SUPERHEATER TUBES FOR DESIGN STEAM TEMPERATURES NOT EXCEEDING 1000°F (538°C)

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 :—

Carbon	0·12% maximum.
Manganese	0·35 to 0·65%
Silicon	0·10 to 0·60%
Sulphur	0·05% maximum
Phosphorus	0·05% maximum
Molybdenum	0·50 to 0·70%
Chromium	0·75 to 1·25%

The steelmaker shall supply a certificate of the normality of the steel.

(b) **Heat Treatment.**—The tubes shall be fully annealed, or 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″ — 1/32″
	Over 2½ 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 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 53(*b*).

(*iii*) **Length.**—The tubes shall be not less than the nominal length but may be 1/8 in. greater.

(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 ends of the selected tubes shall comply with the following requirements :—

	Ultimate Tensile Stress in tons per sq. in.		Minimum Elongation per cent. on 8 inches	
	Not less than	Not more than	½″ thick & over	Less than ½″ thick
Strips cut from tubes and tested in their curved condition	27	33	19	17
Test lengths taken from finished tubes (ends of tubes to be plugged for grips).	25	33	23	21

(b) **Flattening Test.**—A ring not less than 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.

(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 flaw :—

Thickness of Tube	Increase in Diameter per cent.
10 S.W.G. and thinner	12½
Thinner than 9 S.W.G. up to and including 6 S.W.G.	9½
Thicker than 6	6½

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 tubes. 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 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 maker's works by hydraulic pressure in accordance with the following table governing the relation between the test pressure and the design pressure to which the tubes will be subjected in service.

Design pressure lb./sq. in.	Hydraulic test pressure lb/sq. in. minimum.
500 or less	1000
Above 500 but not exceeding 1000	Twice the design pressure.
Above 1000	1000 above the design pressure.

In all cases the tensile stress (S) on the material when under these tests shall not exceed 10 tons per sq. in. as determined by the formula :—

$$S = \frac{DP}{2t}$$

Where D = outside diameter of tube in inches.

P = test pressure in tons per sq. in.

t = nominal thickness of tube wall in inches.

ELECTRIC-RESISTANCE-WELDED STEEL BOILER TUBES FOR TEMPERATURES UPTO 750° F, AND PRESSURES UPTO 840 Lbs./SQ. IN. (FOR EXTERNAL PRESSURE).

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 steel shall conform to the requirements as to chemical composition prescribed in Table below :—

TABLE—*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.
Phosphorus, max., per cent. .	0·04	0·04
Sulphur, max., per cent. . .	0·045	0·045

59. (a) **Flattening Test.**—(*i*) A section of the tube not less than 2½ in. in length shall be flattened cold between parallel plates until the opposite walls of the tube

meet. No cracks or breaks in the metal shall occur until the distance between the plates is less than the calculated value of 'H' by the following formula :—

$$H = \frac{(1+e)t}{e+t/D}$$

Where H = distance between flattening plates in inches,
t = nominal wall thickness of tube in inches,
D = actual outside diameter of tube in inches, and
e = deformation per unit length (constant for a given grade of steel, 0·08 for types A, 0·07 for type C).

Evidence of laminations or burnt material, or incomplete penetration of the weld, shall not develop during the entire flattening process

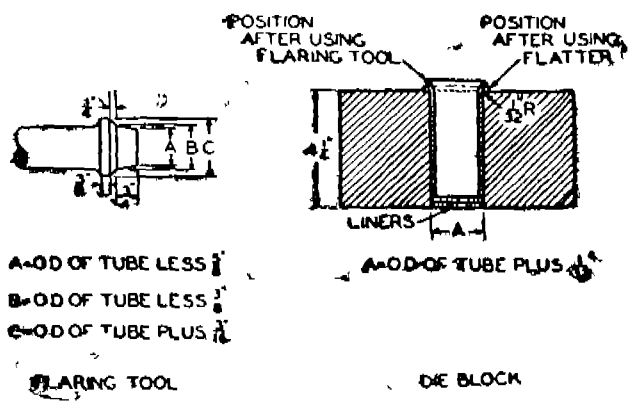
(*ii*) The weld shall be placed 90 deg. from the line of direction of the applied force.

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

(b) **Flange Test.**—(*i*) A section of the tube not less than 4 in. in length shall be capable of having a flange turned 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 1/8 in. nor more than ½ in. Within these limits, the width of the flange shall be not less than the following :—

Outside Diameter of Tube, in.	Width of Flange	
	Type A	Type C
2½ and under	15% of outside diam ter	75 per cent of that required for type A.
Over 2½ to 3-3/4	3/8 in.	
Over 3-3/4 to 5.	10% of outside diameter	

(*ii*) 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 tests 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, in.	Height of Crushed Section, in.	
	Type A Tubes	Type C Tubes
0·135 and under	3/4, or until outside folds are in contact	Crush tests not required.
Over 0·135	1¼	

Slight surface checks shall not be cause for rejection.

(d) **Reverse Bend Test.** A section 4 in. in length shall be taken every 1500 ft. of finished welded tubing to be split longitudinally 180 deg. from the weld and the sample opened and flattened with the weld at the point of max. bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

60. Tensile Properties.—Type C tubes shall conform to the requirements as to tensile properties prescribed in Table below :—

Tensile Requirements

Tensile strength, min., per sq. in	60000	lbs.
Yield point, min., ...	37000	lbs.
Elongation in 2 in., min., per cent.	30	
For longitudinal strip tests a deduction for each 1/32 in. decrease in wall thickness below 5/16 in. from the basic min. elongation of the following percentage.	1·50	

61. Hydraulic Test. –(a) Each tube shall be tested at the maker's works and shall withstand for a minimum of 10 seconds a hydraulic test pressure which shall impose a minimum fibre stress of 16,000 lbs/sq. inch and not exceeding 24,000 lbs/sq. inch. for type A and not exceeding 26,000 lbs/sq. inch. for type C as determined by the following formula:—

$$P = \frac{2tS}{D}$$

Where P = Hydraulic test pressure in lbs/sq. in.
S = fibre stress.
D = Outside diameter of tube in inches, and
T = thickness of tube wall in inches.

(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 tests 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 sections of the tubes up to the capacity of the testing machine. For larger size tubes, the tension test specimen shall consist of a strip cut longitudinally from the tube and not flattened between gauge marks. The sides of the specimen shall be parallel between gauge marks ; the width, irrespective of the thickness, shall be 1 in., the gauge length shall be 2 in.

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

63. Number of Tests.—(a) For type A, one of the tests specified in Regulations 59(a), 59(b) and 59(c) shall be made from each lot of 250 tubes or fraction thereof and from each 2,000 ft. or fraction thereof safe end material. For type C, one of each of the tests specified in Regulations 59(a), 59(b), 59(c) and 60 shall be made from each lot of 250 tubes or fraction thereof. A reverse bend test specified in Regulation 59(d) shall be made on each 1500 ft. of finished tubing.

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

(c) If the percentage of elongation of any tension test specimen is less than that specified in Regulation 60 and any part of the fracture is more than 3/4 in. from the centre of the gauge length, as indicated by scribe scratches marked on the specimen before testing, a re-test shall be allowed.

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

LAPWELDED STEEL BOILER TUBES (FOR EXTERNAL PRESSURE)

64. (a) **Material.**—The tubes 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 margines 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
	Per cent.	Per cent.				
2½ inch and over .	1	1				

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

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

(b) **Flattening test.**—To comply with Reg. 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 purpose in accordance with Regulation 37 fail to satisfy the requirements of any one or more of the tests specified in Regulations 65(a) (b) (c), if so desired by the manufacturer, the tubes 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 Maker's works by hydraulic pressure to not less than 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″.
,, ,, for tubes 2″ 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 lengths 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 Tube SWG	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 1-5/8 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.

STEEEL CASTINGS

73. Scope.—Steel castings shall be of the following grades, according to the purpose for which they are to be used and as may be specified :—

Grade I . . . . . 28 to 35 tons per sq. in.
Grade II. . . . . . 35 to 40 ,, ,, ,,

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

(b) **Chemical Analysis.**—Steel used for grades I and II castings shall not show on analysis more than 0.06 per cent. of sulphur or phosphorus as determined from the test samples, and the manufacturer shall supply an analysis of each cast when requested.

(c) **Heat treatment.**—All castings shall be heat treated to refine the crystalline structure throughout the casting by heating to a uniform temperature not less than the normalising temperature and allowing to cool slowly from the maximum temperature in a practically uniform manner: or alternatively normalised by heating in a similar manner and allowing to cool in still air.

(d) **Freedom from defects.**—All castings shall be free from twists, cracks, flaws and similar defects.

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-heattreated to remove internal stresses. Should a defect impair the strength of the castings, repair by welding or otherwise shall not be permitted.

76. Number of tests.—At least one tensile and one bend test shall be made from the casting from each charge, and when more than one casting is made from one charge, at least one tensile and one bend test shall be made from the castings run from one common pouring head ; but separate tests shall be made from each casting or set of castings run from each separate pouring head.

Test pieces shall not be cut off until they have been stamped by the Inspecting Officer after the annealing has been completed.

77. Tensile tests. -The ultimate tensile stress, yield point and elongation for grades I and II castings shall be not less than shown in table below:—

Tensile Tests on Steel Castings

Grade	Minimum ultimate Tensile strength	Minimum yield point in terms of Tensile strength	Minimum Elongation on test piece 'C' (figure 5 to Appx. B)
	Tons per sq. in.	per cent.	per cent.
I	28	50	20
II	35	50	15

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 test be made of the same casting.

78. Bend tests.—Cold bend tests shall be made upon test pieces having a rectangular section of one inch wide by 3/4 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
I	90°
II	120°

79. Additional tests before rejection.—Should a test piece first selected by the Inspector not fulfil the test requirements, two additional tests of the same kind from the same casting or group of castings shall be made. Should one of the additional test pieces fail to fulfil the specified test requirements, the castings shall be rejected.

80. Waiving of tests.—No tests shall be made from unimportant steel casting or from steel castings which are used for articles usually made of cast iron, if the scantlings are not materially reduced below what would be required if cast iron were used.

CARBON STEEL FORGINGS

(OTHER THAN SEAMLESS DRUMS)

81. (a) **Process of manufacture.**—Carbon 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 from each cast.

83. (a) **Tensile tests.**—The ultimate tensile stress and elongation shall be between the limits of 26 and 32 Tons per sq. in and 28% and 22% respectively determined on British Standard Test Piece C, or subsidiary Standard Round Test Piece (See Appendix B.)

In no case shall the sum of the ultimate tensile stress and corresponding elongation be less than 54.

(b) 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 rectangular section 1 in. wide by 3/4 in. thick. The edges shall be rounded to a radius of 1/16 in. The test pieces shall be bent over the thinner section.

(b) The test pieces shall, when cold, be capable of being bent, without fracture through an angle of 180°, the internal radius of the bend not greater than ¼" inch

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 may be specified by the Inspecting Authority if he so desires.

(c) **Moulding.**—(i) The castings shall be accurately moulded in accordance with the pattern or working drawings supplied by the Inspecting Authority, with the addition of such lettering as may be specified.

(ii) The casting 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

PROVISION OF TEST BARS

87. The Inspecting Authority shall state at the time of enquiry whether he requires tensile or transverse 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 of 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 moulds according as to whether the casting or castings they represent are moulded in green sand, or in loam or dry sand respectively.

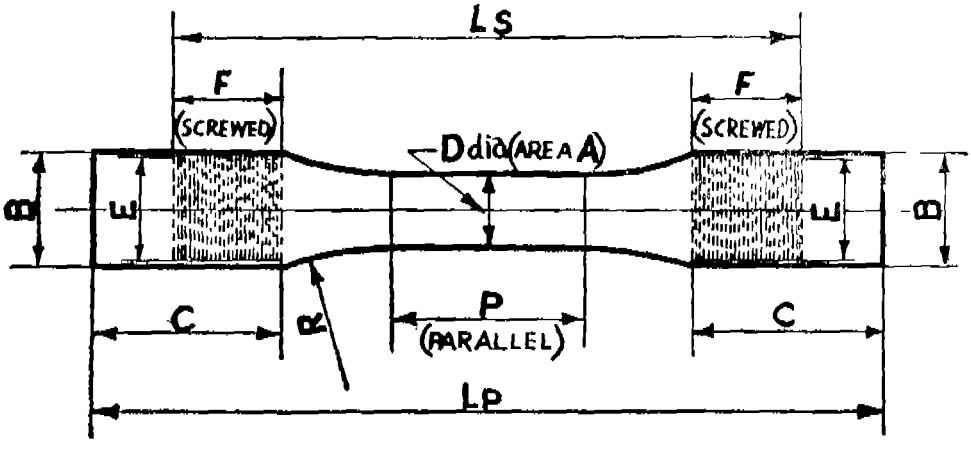
The test bars shall not be subjected to any heat treatment after leaving the moulds.

DIMENSIONS OF TEST BARS

88. (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	Overall length	Main cross-sectional thickness of casting represented
in.	in.	in.	in.
0·6±	0·045	10	Not exceeding 3/8
0·875±	0·065	15	Over 3/8 and not exceeding 3/4
1·2±	0 090	21	Over 3/4 and not exceeding 1,1/8
1·6±	0·10	21	Over, 1,1/8 and not exceeding 1, 5/8
2·1±	0·10	27	Over 1,5/8

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.



DIAGRAM

TABLE

Diameter as cast	Gauge diameter	Area	Min. parallel length	Min. radius	Min. length of plain ends	Screwed ends		Approximate minimum overall length		Main cross-sectional thickness of casting represented
						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	1¼	1¼	¼ B.S.P. 9/16 B.S.F. 9/16 B.S.W.	9/16	4½	3	Not exceeding 3/8
0·875	0·564	0·25	2	3½	1½	3/4 B.S.F. 7/8 B.S.W.	3/4	7-1/16	4-13/16	Over 3/8 and not exceeding 3/4
1·2	0·798	0·50	2	3½	2	1,1/8 B.S.F. 1,1/8 B.S.W.	1-1/8	8½	5-7/8	Over 3/4 and not exceeding 1-1/8
1·6	1·128	1·00	2	3½	2¼	1½ B.S.F. 1½ B.S.W.	1½	9-1/32	7¼	Over 1,1/8 and not exceeding 1-5/8
2·1	1·596	2·00	2	3½	3¼	2 B.S.F.	2	1 1- 1/8	8¼	Over 1-5/8.

The test bars shall be cast as parallel bars of the diameter given in Column B and than machined to the dimensions D and P in the above table.

(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.

(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 pp. 28 to 29

MECHANICAL TEST

89. 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.

TRANSVERSE TEST

90. 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 1/8 inch.

Diameter of test bar	Distance between supports	Minimum breaking load—Grade A	Minimum deflection—Grade A
1	2	3	4
in.	in.	lb.	in.
0·6	9	530	0·07
0·875	12	1,185	0·10
1·2	18	1,350	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.

TENSILE TEST

91. 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.

NUMBER OF TRANSVERSE AND TENSILE TESTS

92. 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 at cast.

Group	Weight of castings	Test requirements
1	Up to 28 lb.	One test for each 30 cwt. of castings or part thereof.
2	Over 28 lb. and upto 1 cwt. . .	One test for each 2 tons of castings or part thereof.
3	Over 1 cwt. and upto 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 rejected.

COVERED ELECTRODES FOR METAL ARC WELDING

(For Hand Operation)

94. Construction.— The metal electrodes shall be provided with a flux covering applied externally by painting, spraying, dipping, wrapping or other method.

95. Application.—The covered electrodes shall be suitable for metal arc welding of mild steel having a tensile strength not exceeding 33 tons per sq inch.

96. Quality.—The electrodes shall be uniform in quality and when used in accordance with the appropriate instructions of the Manufacturer shall be capable of flowing freely and smoothly without producing an undue amount of "under cutting" in the parent metal adjacent to the weld.

97. Covering—(a) **Strength.**—The covering shall be sufficiently robust to withstand without damage the normal conditions of transport, storage, handling and use to which the electrodes are to be subjected.

(b) **Uniformity.**—The covering shall be substantially uniform in outside diameter throughout its length and shall fuse evenly.

(c) **Stability.**—The stability of the covering shall be such that if the electrodes are stored they shall, after a period of three months, be capable of giving results similar to those at the date of despatch from the supplier.

(d) **Storage.**—The requirements of paragraph (c) above shall apply only if the electrodes have been kept in their original packages in an enclosed dry storeroom.

98. Mechanical properties of All-weld Metal test pieces.—The mechanical properties shall be determined on all-weld-metal test specimens as follows :—

(a) **Tensile Test.**—The tensile test shall be made on a specimen having a gauge length of 3·54 times the diameter of the test piece. The ultimate tensile stress, elongation and reduction of area of the deposited metal shall be not less than the figures given in the table.

(b) **Impact Test.**—Impact tests shall be made on a three notch specimen. At least two of the three values obtained shall be not less than that given in the table.

Ultimate Tensile stress (tons per sq. in.) min.	Elongation on 3·54D (per cent.) min.	Reduction of Area (per cent.) min.	Impact Value
28	20	35	30 ft. lb.

CHAPTER III

CONSTRUCTION AND WORKMANSHIP

GENERAL

99. Preparation of Plates.—With the exception of gusset plates, which may be sheared, the edges of all plates and butt straps shall be planned or machine gas cut to an angle of approximately 80° with the surface of the plate.

100. Annealing after working in fire.—All steel plates which are welded, dished, flanged or locally heated shall be afterwards efficiently annealed.

101. Minimum thickness of Plates.—No boiler plate shall be less than $\frac{1}{4}$ inch in thickness.

SHELLS, ANGLE RINGS, BUTT STRAPS, ETC.

102. Cylindrical Shells.—Each ring shall be bent while cold to cylindrical form to the extreme ends of the plate. The bending shall be done entirely by machine and heating or hammering is prohibited.

108. Position of Longitudinal Seams.—Each ring of plate forming the shell, barrel or drum shell, where practicable, be in one piece and have its longitudinal seam well out of line with those of the adjoining rings. In Lancashire, Cornish, and other types of boilers, where parts of the shell are exposed to flame, the longitudinal seams shall, where practicable, be in the steam space, arranged alternately on each side of the crown and clear of the brick work.

104. Circumferential and End Seams.—(a) The strength of the seams joining the end plates of flat end Lancashire and Cornish boilers with the cylindrical shells shall be not less than 38 per cent. of the strength of the calculated thickness of the plate as found by Equation (1). The strength of the intermediate seams of flat ended boilers and all seams of dish ended boilers shall be 50 per cent of that of the longitudinal seams but in no case less than 42 per cent of the strength of the calculated thickness of the plate.

(b) In boilers of other types the strength of the circumferential and transverse seams shall be not less than 38 per cent. of that of calculated thickness of the plate as found by Equation (1) and not less than 50 per cent of that of the longitudinal seams whichever is the greater.

(c) When the shell plate thickness exceeds 11/16 inch the intermediate circumferential seams shall be double riveted.

(d) In the case of the electrode boilers where the diameter of the shell does not exceed 18", the end plates may be attached to the shell by means of Electric Arc fillet welding provided the welds are stress relieved and the cubical capacity and working pressure do not exceed 30 gallons and 120 lbs. respectively.

105. Angle Rings.—Angle rings for the attachment of end plates to shell plates and of flue sections shall be rolled or machined so that they fit closely to the flat and cylindrical surfaces to be connected, and shall be machined or machine gas cut on the caulking edges.

106. Thickness of Shell Angle Rings.—Where shell plates and end plates are connected by means of an external angle ring, the angle rings shall be not less in thickness than as follows:—

(1) For shell plates up to and including 5/8 inch in thickness	10 per cent in excess of the thickness of the shell plate.
(2) For shell plates exceeding 5/8 inch in thickness and upto and including 1 inch in thickness.	90 per cent of the thickness but not less than 11/16 inch.
(3) For shell plates over 1 inch in thickness	Made from angle bar having a section thickness of 1 inch.

107. Welded Shell Plates.—(a) Except as provided for in Chapter V and in Regulation 112, where longitudinal seams are welded the weld shall be entirely covered by a butt strap or butt straps securely riveted to the shell.

(b) For small steam domes when the welding is done by hammer and the plates do not exceed ½ inch in thickness butt straps may be omitted.

(c) The strength of the weld covered by butt straps shall be assumed to be 50 per cent of that of the solid plate. The thickness of a single strap or combined thickness of double straps shall be not less than the thickness of the shell plate.

108. Longitudinal Seams.—The longitudinal seams shall be butt-jointed with double straps when the diameter or Working Pressure exceeds the limits stated below :—

Type of Boiler	When diameter exceeds	When Working Pressure exceeds
	Feet.	Lbs.
Loco Types	2'-6"	200
Vertical Types	6	125
Other Type	6	80

109. Butt Straps.—Butt straps shall be cut from the shell plates or, alternatively, all the butt straps of each required thickness shall be cut from one plate. The lengths of the straps wherever practicable shall be transverse to the direction of rolling of the plate. Straps shall be pressed or bent in rolls to the shell curvature.

110. Thinning of Butt Straps.—Thinning of the ends of butt straps which tuck under shell rings, shall be done cold by machine and not by heating or hammering. The shell plate shall be notched out to receive the thinned end of the butt strap, so that there shall be no undue thinning of the butt strap.

111. Alternative Construction.—(a) As an alternative to the tucking of butt-strap ends under the shell rings, the ends may be terminated at the edge of the shell rings or ends and electrically welded thereto.

112. Local Welding of Butt Seams.—(a) The ends of longitudinal butt seams of shell rings may be welded for a length not exceeding three times the overlap at the circumferential seam, provided the butt straps are run as closely as practicable to the circumferential seam.

(b) Only metal arc welding of the butt seams of shell rings shall be permitted.

113. Flat End Plates.—(a) The end plates of boilers shall preferably be in one piece made from one rolled plate. Alternatively, the end plates shall be built up by butt-welding two pieces. In the latter case the line of welding shall be parallel to the horizontal axis of the boiler and shall run through the centre line of furnace or furnaces of Lancashire boilers and between two rows of stays of marine type boilers. In the case of flat end plates the fusion welding shall comply with stress relieving requirements and in the case of dished end plates the fusion welding shall be subjected to both stress relieving and radiographic examination.

(b) The peripheral flanging of end plates shall be done by machine. Such flanging shall preferably be done in one operation, but where this is impracticable sectional or creep machine flanging may be permitted, provided that the plate is worked at a suitable temperature, and the plate is heated to an adequate distance beyond the portion under immediate treatment.

(c) Care must be taken to see that the flanges are circular and of good surface, free from local irregularities, and that they are parallel and square with the flat part of the plate. For the purpose of relieving internal stresses, all plates which have been flanged or locally heated shall afterwards be efficiently annealed unless during the last stage of manufacture they have been uniformly heated throughout.

(d) Flat portions of end plates, on completion of all flanging and machining operations, shall be flat and free from set or distortion.

114. Strengthening of Flat End Plate at Manhole.—(a) In the End Plates of Lancashire Boiler type the mudhole in the lower part of the front end plate shall be fitted with a flanged riveted strengthening ring, the thickness of the flat portion of which shall be not less than (1·5 T×1/8 in.) where T equals the thickness of the end plate in inches.

(b) In boilers 7 ft. 6 in. diameter and above, the mudhole frame shall be fitted with a peak to reinforce the portion of the end plate between and below the furnaces, and this peak shall be securely riveted thereto with rivets of similar pitch to the remainder of the frame.

(c) In all cases the front end plate gusset stays below the furnaces shall be placed as closely as possible to the mudhole frame.

(d) Where flat end plates are flanged for connection to the shell, the inside radius of flanging shall be not less than 1·75 times the plate thickness, with a minimum of 1½ in.

115. End Plates in steam spaces.—When the end-plates of boilers situated in the steam space are liable to contact with hot gases the end plates shall be efficiently shielded from such contact.

116. Hemispherical Crowns.—(a) All segments shall be pressed in one heat to correct curvature. The adjacent plates shall bed closely at the seams and wherever possible at the junction of two seams the plates shall be machined down to provide a fair surface to the joint. If the thinning is done by heating and hammering the plate shall be subsequently annealed.

(b) The cylindrical portion of the crown shall be tangential to the hemispherical portion and fit truly to the shell.

(c) Where hemispherical shell crowns are pressed from one plate they shall be pressed to form by machine in progressive stages without thinning and on completion shall be annealed.

117. Dished End and Crown Plates.—(a) The inside radius to which a plate is dished shall not be greater than the external diameter of the shell to which it is attached, except in the case of Lancashire and Cornish boilers when the radius shall not exceed 1½ times the diameter of the shell.

(b) The inside radius of curvature of the flanges to the shell or firebox shall not be less than four times the thickness of the crown or end plate and in no case less than 2½ inches.

(c) The inside radius of curvature to uptakes shall be not less than twice the thickness of the crown plate and in no case less than 1 inch.

(d) Bunged mouth-pieces may be welded on to end plates in place of the orthodox flanging for the attachment of furnace tubes. Such welding shall comply with provisions of Regulation 125.

(e) Manhole frames may be similarly welded on the front end plates, and will be subject to provisions of Regulation 125.

118. Tube Plates.—Smokebox tube plates shall be flanged for attachment to the barrel or shall be flat and connected thereto by an external riveted angle ring.

119. Parts of the Smoke Tube Plates within the tube nests.—(a) Where the total area of all the tube nests exceeds 7 sq. ft. stay tubes shall be fitted within the nests. Where stay tubes are not fitted the ends of the tubes shall be beaded or bell mouthed.

(b) The parts of tube plates which lie outside the nests of tubes shall be stayed or supported wherever the size of the area of plate subject to steam pressure necessitates staying or support, either by marginal stay tubes or other means.

120. Flanging of End Plates.—All flanges shall be a good fit to the shell and flues. Flogging and/or hammering in the fitting of these parts is prohibited. The caulking edges of all flanged plates shall be machined or machine gas cut.

FURNACES

121. Furnaces in general.—(a) No furnace or firebox top, whether plain or corrugated, shall exceed 7/8 inch in thickness, and all circular sectioned furnaces when new shall be as near the truly circular form as the type of joint will permit.

(b) The use of Z angle rings for furnace foundation seams shall be prohibited.

122. Furnaces of Horizontal Boilers.—(a) The sections of the internal flues shall each be in one plate and shall be bent while cold to circular form and shall be welded longitudinally.

(b) The maximum permissible variation in diameter at any cross section shall not exceed the thickness of the plate.

(c) The welds shall be placed at the lower part of the flues, and shall break joint in successive sections by at least 12 inches.

(d) Each flange for the circular seams shall be formed at one heat by suitable machinery.

(e) The sections shall be allowed to cool gradually to avoid internal stresses.

(f) The caulking edges of all flue flanges shall be machined or machine gas cut.

(g) The circular seams shall be arranged so that they do not fall in line with those of the adjacent flue or with the circumferential seams of the shell and are at least 6 inches apart.

(h) When flues are flanged for attachment to both end plates the total length of each completed flue shall not exceed the length of the shell measured from the inner surface of the back end plate to the inner surface of the front end plate, both adjacent to the shell.

(i) Where the flues are flanged for attachment to the end plates, the end sections shall be 1/16 inch thicker than the remaining sections, except in cases where the calculated thickness is over 13/16 inch, when the end-sections shall be 7/8 inch in thickness.

(j) The flanged portion of furnace rings shall have a radius of curvative of not less than 1 inch on water side.

(k) Sections of corrugated flues may be fusion butt welded circumferentially and afterwards stress relieved by heat treatment.

123. Furnaces of Vertical Boilers.—(a) The vertical portion shall be in one plate and shall be bent to circular form in a similar manner to the shell plates.

(b) Circular furnaces shall preferably be tappered, a taper of $1\frac{1}{2}$ in. in diameter per 1 foot of height being recommended. The minimum water space at the bottom between the furnaces and the shell shall not be less than 2 in. for boilers up to 2 ft. 6 in. in diameter and shall be not less than $2\frac{1}{2}$ in. for boilers over 2 ft. 6in. in diameter.

(c) Where hemispherical furnace crowns are pressed from one plate they shall be pressed to form by machine in progressive stages without thinning and on completion shall be annealed.

(d) Ogee flanging where integral with the firebox or in a separate ring shall preferably be formed at one heat by suitable machinery and shall be allowed to cool gradually to avoid internal stresses.

(e) Furnaces of vertical type boilers may be attached to the shell at the firehole by a solid rectangular section steel ring riveted together or by a circular ring of substantial section fusion welded to shell and firebox. Where the latter construction is employed the opening in the shell for firehole shall be substantially compensated by a ring welded on the outside of the shell plate.

(f) At the firehole the firebox plate and the shell plate may be flanged and fusion welded together.

124. Longitudinal Seams.—The longitudinal seams of furnaces may be either:

(a) Forge Lap Welded.

(b) Fusion Butt Welded.

(c) Riveted.

Longitudinal seams of furnaces exceeding 3/8" thickness shall not be riveted.

125. Fusion Welded Longitudinal Seams.—Where the longitudinal seam is fusion welded the following precautions shall be observed :—

(a) Plates over 5/8 in. in thickness shall be bevelled from both sides of each abutting edge, but the bevel need not necessarily be the same on each side (see Figs. 1 and 2). Plates less than 5/8 in. in thickness may be bevelled from one side only of each abutting edge (see Figs. 3 and 4).

The included angle of the bevel shall be not less than 60° ,and the bevelling may be any one of the forms shown in Figs. 1—4.

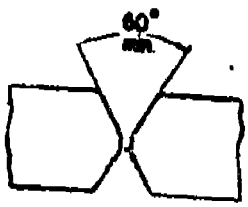


Fig. 1.

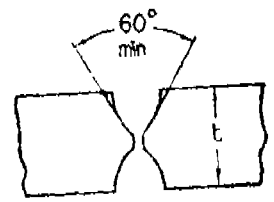


Fig. 2.

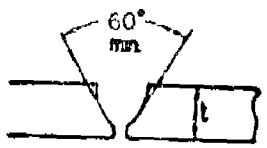


Fig. 3.

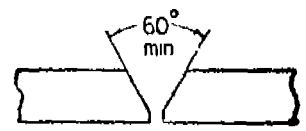


Fig. 4.

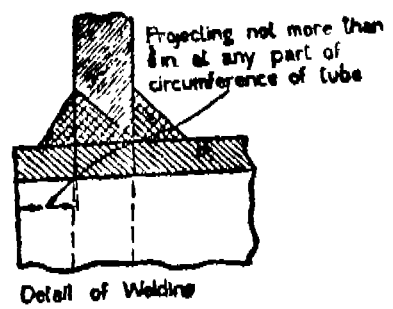


Fig. 5. Fusion Welding of Cross Tubes of Vertical Cross Tube Boilers.

(b) In order to obtain full penetration of the weld metal a gap shall be maintained between the plates when they are being welded. Joints shall be welded from both sides, and the slag shall be removed after making each run. Before

the second side of the joint is welded any slag or defect at the bottom of the first run shall be removed by grinding, chipping or machining. There shall be no appreciable undercutting of the plate.

(c) For the purpose of relieving internal stresses the plates adjacent to a fusion weld shall be efficiently annealed after welding, and when the firebox is forge-welded it should be allowed to cool gradually.

126. Furnace Crown.—(a) The furnace crown seam shall not fall in line with any circumferential seam of the boiler shell.

(b) the furnace crown may be riveted to the vertical portion of the firebox, or alternatively, the joint may be fusion butt welded by the electric arc process, provided the conditions as to fusion welding in Regulation 125 are observed. Where the joint is to be welded the edges of the furnace crown and the firebox body shall be bevelled in accordance with Fig. 3 or Fig. 4. The depth of the flange of the furnace crown plate from the commencement of the curvature of the flanging radius shall be not less than four times the plate thickness with a minimum of $1\frac{1}{2}$ inches. On completion of welding the firebox shall be effectively stress relieved by heat treatment (see also Reg. 128.)

127. Cross Tubes.—(a) Cross tubes shall be made from weldless steel tube or from plate or strip rolled and forge water gas welded. Where welded tubes are used the longitudinal welds shall be so situated that they are not exposed to the direct impact of the flame.

(b) The minimum thickness shall be 5/16 in.

(c) Where cross tubes are flanged and riveted to the furnace, the flanges shall be set to the curvature and taper of the furnace, and shall be a good fit before riveting.

(d) Where welded construction is employed the tubes shall be of sufficient length to enter the furnace plate and be flush with the water side all round or project not more than 5/8 in. into the water space at any part of the circumference. Where the tubes are fusion welded in position, the firebox plates shall be suitably chamfered and the joints shall be welded externally and internally (see Fig. 5).

128. Uptakes.—(a) The uptakes shall be formed from weldless, forge water gas welded or fusion butt welded steel tube and shall be securely riveted to the furnace crown plate and riveted to the shell crown plate.

(b) As an alternative to riveting, the uptake may be fusion butt welded by the electric arc process to the upward flange of the opening in the fire box crown plate provided the conditions as to fusion welding in Regulation 125 are observed. The edges of the upward flange and the adjacent end of the uptake shall be bevelled in accordance with Fig. 3 or Fig. 4. The depth of the crown plate opening from the commencement of the curvature of the flanging radius shall be not less than twice the plate thickness with a minimum of 1 inch. On completion of welding the uptake and crown plate shall be effectively stress relieved by heat treatment.

Where the firebox crown plate is also fusion welded to the body of the firebox, the firebox complete with uptake shall be effectively stress relieved by heat treatment on completion of the welding.

(c) Welded uptakes shall be so arranged that the weld is directly facing the longitudinal centre line of the manhole.

129. Loco Type Fireboxes.—(a) The foundation seam shall be of riveted construction but all other seams may be welded subject to the depth of the flange being such that the welded seams fall between the 1st and 2nd rows of screwed stays or between the flange and the adjacent row of screwed stays.

(b) The firehole mouthpiece may be similarly welded when the firebox and shell are flanged for the purpose.

(c) The welding shall comply with Regulation 125.

STAYS

130. Bar Stays.—Bar stays shall not be welded at any part. They shall preferably have plus threads, the ends of the stays being upset or the middle portion being reduced for this purpose. Stay bars which have been worked in the fire shall be subsequently annealed.

131. Longitudinal Stays.—(a) Longitudinal and similar solid screwed stays shall be efficiently secured with nuts at each end and not merely riveted over. Where they are over 12 feet in length, they shall be supported at intervals of 6 ft. along its length.

(b) Where the stay is screwed through both plates, the stay and holes shall have a continuous thread and fitted with nuts and washers on the outside. Where the stay passes through clearing holes an internal nut and washer shall also be fitted. Where the stay is not normal to the surface of the plate the washers shall be shaped so as to form a true surface for the nuts or a knuckle joint may be fitted.

(c) In vertical boilers the stays shall either be screwed into both crown plates or screwed into the furnace crown plate and passed through clearing holes in the shell crown plate.

132. Nuts and Washers for Stays.— (a) The washers shall be at least $2\frac{1}{2}$ times the diameter of the threaded portion of the stay and not less than 1/4 in. in thickness.

(b) The thickness of the external nuts shall be at least equal to the diameter of the threaded portion of the stay. Where bar stays pass through clearing holes in end plates, internal nuts of a thickness not less than two-thirds of the diameter of the threaded portion of the stay shall be fitted

133. Jointed Stays.—Where jointed longitudinal stays are fitted, they shall, where practicable, be fitted with pins having an effective sectional area 25 per cent. in excess of that of the stay. If the pins are slack in the holes, the total slackness shall not be more than 1/16 inch. The pins shall be as close as possible to the shoulder of the eye forging. The shoulder of the forging shall be at least 1/2 inch wide all round, *i.e.*, the diameter at the shoulder shall be not less than the diameter of the hole plus 1 inch.

134. Diagonal bar or rod stays.—The sectional area of diagonal rod or bar stay shall bear the same proportion to that of a direct stay as the length of the diagonal stay bears to the length of the perpendicular line from the end of the diagonal stay to the surface supported. The ends of diagonal stays, shall not be bent, but shall be attached to the plate with bevelled washers and nuts or with riveted tee, blocks or angles and shackle pins (see Regulation 133 for eyes and pins).

SCREWED STAYS

135. Screwed Stays.—(a) Screwed stays and the holes for these shall be screwed with a continuous thread.

(b) The screwed threads of the stay shall be clean, free from cheeks or imperfections, of full depth, correct Whitworth form and a good fit in the holes. The middle portion shall preferably be turned down to the bottom of the thread.

(c) The stays shall be screwed with fine threads of not less than 11 threads per inch.

(d) The diameter of the stay over the threads shall not be less than 3/4 in. or twice the thickness of the firebox plate whichever is the greater.

(e) The pitch of the stays at the furnace of vertical boilers shall not exceed 14 times the thickness of the furnace plate.

(f) Where the stays are not fitted with nuts, the ends shall be riveted over to form substantial heads.

(g) Crown stays of Loco Type boilers shall either be fitted with nuts or riveted over on the fire side.

136. Axial drilling.– All screwed stays less than 14 in. long should preferably be drilled with a tell-tale hole 3/16 in. diameter to a depth of 1/2 in. beyond the inner face of the plate. Stays which are obscure on one side should preferably be made from hollow staybar.

137. Stay nuts.– (a) Nuts to screw stays in combustion chambers and fireboxes shall not be less than 3/4 inch thick for stays up to 1½ inches diameter over threads, 7/8 inch thick for 1-5/8 inches and 1¾ inches stays, 1 inch thick for 1-7/8 and 2 inches stays, and 1-1/8 inches thick for stays over 2 inches in diameter.

(b) The nuts shall be made of solid mild steel or of iron which shall be without weld if exposed to flame.

138. Spacing of end stays—Allowance for curves, etc.—For the tops of fireboxes and combustion chambers the distance between the rows of stays nearest to the tube plate or firehole plate or back plate as the case may be, and the commencement of curvature of these plates at their flanges shall not be greater than the horizontal pitch of the stays.

GIRDER STAYS

139. Girder Stays for Firebox and combustion Chamber Crowns.—(a) Each girder when of the normal type, fitted with stay bolts and nuts, shall be of the double plate interconnected type of sufficient strength to support its proportion of the load on the crown plate independently of the crown plate.

(b) The clear waterway between the crown plate and the underside of the girder bars shall be as large as practicable but in no case less than 1-1/2 inches as in fig. 7.

(c) The ends of the girders shall not rest on the landing of the flat crown plate but shall be carefully fitted to bed directly on the bends of the corners of the vertical end or side plates.

(d) The toes of the girders shall be solid with the girder plates and not separate pieces attached thereto.

(e) Girders shall be properly attached to the crown plate by bolts or screws.

NOTE.—Alternative methods of staying may be used, or unstayed firebox, crowns of special or patented design of equivalent strength may be fitted. See Regulations 230, 231 and 232.

(f) Where an all welded firebox is fitted, the girder stays may be welded to the firebox prior to stress relieving. The girder stays shall be recessed for waterways as in paragraph (*b*) (Figs. 6 and 7).

Such girders shall be securely welded by an approved method to the firebox crown. The method of welding and the proportions of attachment shall be to the satisfaction of the Inspecting Authority.

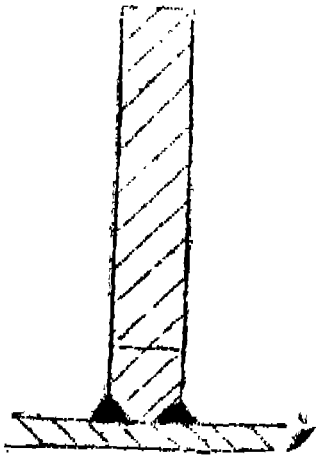


Fig. 6

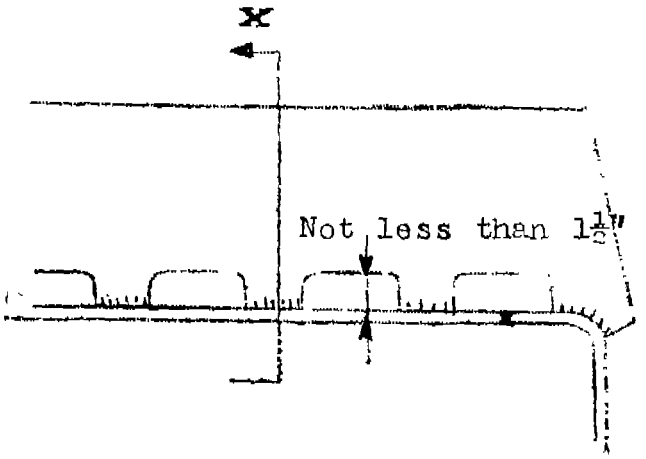


Fig. 7

GUSSET STAYS

140. Gusset Stays.—(a) Gusset plates shall be flat and perpendicular to the end plates. The gusset angles shall be fitted to bed closely to the shell end and gusset plates. Cranking or setting of the plates is prohibited.

(b) Gusset stays, where fitted, shall comprise flat plates secured by double angles to the shell and end plate respectively, and shall be designed in accordance with the following conditions :—

141. Breathing Space.—(a) Gusset stays shall be so arranged as to allow sufficient breathing space around furnace connections and tube nests.

(b) For Lancashire boilers the proportions shown in the table below are recommended for the portion of the end plates above the furnaces and flues :

Thickness of end plates	L= (Fig. 8)	L= (Fig. 9)
in.	in.	in.
1/2	9	10
9/16	10	11
5/8	11	12
11/16, 3/4, 13/16	12	13
Above 13/16	12½	13½

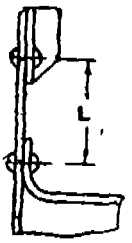


Fig. 8

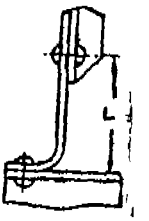


Fig 9

(c) Fig. 8 shows the breathing space recommended for the following conditions : Flat end, furnace or flues flanged for attachment to end plate, furnaces and flues formed with Adamson flanged seams.

(d) Fig. 9 shows similar conditions to Fig. 8 except that the end plate is flanged outwards for the furnace or flue ring connection, the breathing spaces allowed being 1 in. more than those for the same thickness of plate in Fig. 8.

(e) Where a corrugated section not less than 6 feet long is included in each internal flue of a Lancashire boiler, the dimensions given in the table above may be reduced by approximately $1\frac{1}{2}$ in. throughout.

(f) It is recommended that the breathing space below the furnaces and flues shall be approximately one half the dimensions given in the table above. Where it is desired to use any other arrangement which gives a greater or less degree of exibility, the amount of breathing space shall be specially considered and modified as the necessity of the case requires.

(g) For gusset stays above tube nests, as fitted in waste heat boilers without internal furnaces, a breathing space of 8 inches from the centre line of the top tubes to the centre of the toe rivets of the gusset angles is recommended (see Fig. 9).

142. Gussets Angles.—The gusset angles connecting the stays to the shell and end plates shall be at least 7/8ths of the thickness of the shell plate, but shall be not less than 1/2 in. in thickness

143. Load on Gusset Stay.—Each gusset stay supporting the end plate of a boiler shall be designed to carry the whole load due to pressure on the area supported by it.

144. Gusset Riveting.— (a) Rivets securing gusset stays shall be not less in diameter than the thickness of the cylindrical shell plate and the riveting shall be arranged so that the strength of the shell plate where drilled for the gusset rivets shall not be less than the strength of the longitudinal seams.

(b) Not less than three rivets shall be used to connect any gusset plate to any angle or any angle to the end plate or to the shell plate.

BOILER TUBES SUBJECT TO EXTERNAL PRESSURE

145. Steel and Wrought Iron Tubes.— (a) Both plain and stay smoke tubes may be made either of wrought iron or steel and may be either lapwelded or weldless.

(b) Tubes may also be fabricated by electric resistance welding from strip plate. This may be accepted for temperatures up to 750°F and pressures up to 840 lbs./sq. in.

146. Fitting Plain Tubes.—Where stay tubes are not fitted, the ends of the tubes shall be beaded over at the fire box end and beaded or bell-mouthed at the other end. If bell-mouthed the tubes shall protrude not less than $\frac{1}{4}$ inch beyond the tube plate.

147. Screw Threads of stay tubes.— Stay tubes shall be screwed at both ends with continuous threads, and the holes in the tube plates shall be tapped with continuous threads. The pitch of the threads shall not be finer than 11 threads per inch. The stay tubes shall be expanded by roller expanders and not made tight by caulking only.

148. Minimum thickness of stay tubes.—The minimum thickness of stay tubes in the body or at the ends under threads shall not be less than 5/32nds of an inch.

149. Thickened ends of stay tubes.—If stay tubes are required to have their thickness increased at the screwed ends so that the thickness at the bottom of the threads is approximately the same as in the body of the tube the thickening shall be attained by upsetting and not any welding process, and the tubes shall be annealed after the upsetting.

150. Load on stay tubes. (a) Stay tubes shall be designed to carry the whole load due to pressure on the area to be supported In each case the areas to be calculated as follows :—

(b) For a stay tube within the tube nest the net area to be supported shall be the product of the horizontal and vertical pitches of the stay tube less the area of the tube holes embraced. Where the pitch of the stay tube is irregular the area shall be taken as the square of the mean pitch of the stay tubes (*i.e.*, one-quarter the sum of four sides of any quadrilateral bounded by four adjacent stay tubes) less the area of the tube holes embraced.

(c) For a stay tube in the boundary row, the net area to be supported shall be the area enclosed by lines passing midway between it and the adjacent points of support less the area of any tubes embraced. The adjacent points of support may be other stay tubes, or the commencement of curvature of flanging of centre line of the circle of rivets securing the end plate to the shell angle.

BOILER AND SUPERHEATER TUBES SUBJECT TO INTERNAL PRESSURE

151. Steel Tubes.— (a) All tubes which are subject to internal pressure of water or steam shall be cold drawn or hot finished seamless in accordance with Regulations 30 to 56. Except as provided for in sub-reg. (*b*) below they shall be without joint.

(b) Tubes having an external diameter not exceeding 5 inches may be jointed and such joints may be flash welded, machine forge welded, arc or gas welded.

(c) Flash welding shall be undertaken on a welding machine of a type approved by the Inspecting Officer and the external fin caused by welding shall be completely removed. The internal fin caused by welding shall also be removed subject to a maximum height of 20 per cent. of the wall thickness of the tube.

(d) Arc welded butt joints shall be made by the metallic shielded arc process.

(e) When gas welding is employed the technique followed shall be approved by an Inspecting Officer and all welds shall be suitably heat treated.

(f) For design steam temperatures over 850°F the material to be used shall be in accordance with Regs. 48 & 53.

152. Attachment of steel tubes.—(a) Tubes shall be connected to the tube plates by one of the following methods :—

(1) Expanding.

(2) Strength welding.

(3) Mechanical bolted ball joint.

(b) Drift or roller expanded tubes shall project through the neck or bearing part in the holes by at least a quarter of an inch and shall be secured from drawing out by being bell mouthed to the extent of 1/32″ for each inch in diameter plus 2/32″.

(c) Tubes may be seal welded into fittings or headers for both boilers and superheaters after they have been expanded and flared provided the material in the fittings or headers does not contain carbon in excess of 0·35 per cent.

(d) In the case of drifted or roller expanded tubes, the tube holes in the tubes plates of drums, pockets, or headers shall be formed in such a way that the tubes can be effectively tightened in them. Where the tube ends are not normal to the tube plate, there shall be a neck or belt of parallel seating of at least 1/2″ in depth measured in a plane normal to the axis of the tube at the holes.

(e) Where the tubes are strength welded direct to the tube plates, the technique followed shall be approved by the Inspecting Authority and all welds shall be suitably heat treated.

(f) Tube spacers, supporting clips and lugs may be welded to the tubes. Flash welding of studs for supporting refractories, etc., is also permissible.

(g) The tubes shall be so arranged that they are accessible for cleaning internally and externally.

153. Copper tubes.—Copper tubes up to one inch in external diameter may be used for small boilers ; such tubes shall be not less than 12 s.w.g. thick.

HEADERS, MUD BOXES, ETC., OF WATER TUBES BOILERS

154. (a) Headers, mud boxes, etc., of water tube boilers may be of solid drawn or welded steel, or of cast steel complying with the requirements of Regulations 73 to 80.

(b) Each piece prior to being fitted in place shall be subjected to hydraulic test to double the working pressure of the boiler into which it is to be fitted.

For pressures over 1000 lbs. per sq. inch, the hydraulic test pressure shall be the permissible working pressure plus 1000 lbs. per sq. inch.

(c) (*i*) the sighting hole doors shall be substantial and capable of being removed and replaced from time to time without loss of efficiency or safety.

(*ii*) The bolts by which they are held in place shall be fitted to them in such a way as to satisfy the above conditions.

(*iii*) The doors shall be so designed that they will not blow out in the event of breakage of the bolt.

(*iv*) Circular holes also may be provided in addition to elliptical holes, if provision is made to prevent the door bolts from turning, while securing the joint.

(d) All flanges shall have a fillet with a radius of curvature at least equal to the thickness of the necks to which they are attached.

STAND PIPES, PADS, ETC.

155. Stand Pipes and Pads.—Stand pipes and seatings for carrying mountings shall be made of wrought, cast or fabricated steel. Where pipes are fabricated by welding they shall be stress relieved. These shall take the form of short stand pipes, pressed steel plate saddles, forged pads or pads cut from round rolled bar as may be most convenient and secured to the boiler by riveting or welding. Where short stand pipes are used they shall be of solid forged, fabricated or cast steel. They shall be carefully bedded to the shell before attachment and where riveted the rivets shall be so pitched as to ensure a tight joint. The jointing faces to which mountings are to be bolted shall be machined. Pads shall have sufficient thickness

to allow the drilling of stud holes for mountings without the inner surface being pierced and the length of the screwed portion of the stud in the pad shall be not less than the diameter of the stud.

156. Design of Stand Pipes.—Where short stand pipes are used, the bolting flanges shall be forged solid with the bodies or attached by combined screwing and welding or by welding alone. The thickness of the stand pipes shall comply with table below:—

	Maximum permissible working pressures lbs. per sq. in.							
	Upto 150		Above 150 & upto 250		Above 250 & upto 350		Above 350 & upto 600	
	Flange adjoining drum	Thickness of Body	Flange adjoining drum	Thickness of Body	Flange adjoining drum	Thickness of Body	Flange adjoining	Thickness of Body
Stand pipes in bore	in	in	in	in	in	in	in	in.
3/4		..	..	..	...	..	3/4	3/8
1	7/16	3/8	1/2	3/8	3/4	3/8	3/4	3/8
1¼	7/16	3/8	1/2	3/8	3/4	3/8	3/4	3/8
1½	7/16	3/8	1/2	7/16	3/4	1/2	3/4	1/2
2	7/16	3/8	9/16	7/16	3/4	1/2	7/8	1/2
2½	7/16	3/8	9/16	7/16	7/8	5/8	7/8	5/8
3	9/16	7/16	5/8	1/2	7/8	5/8	7/8	5/8
3½	9/16	7/16	5/8	1/2	7/8	5/8	7/8	5/8
4	9/16	7/16	5/8	1/2	7/8	5/8	7/8	5/8
4½	9/16	7/16	5/8	1/2	7/8	5/8	7/8	5/8
5	5/8	9/16	3/4	5/8	7/8	5/8	7/8	5/8
6	5/8	9/16	3/4	5/8	7/8	5/8	7/8	5/8
7	5/8	9/16	3/4	5/8	7/8	5/8	7/8	5/8
8	5/8	9/16	3/4	5/8	7/8	5/8	7/8	5/8
9	5/8	5/8	3/4	5/8	7/8	5/8	..	..
10	5/8	5/8	3/4	5/8	7/8		..	..
Pressed saddles	5/8	..	3/4		7/8	..	.	..

157. Pressed Plate Saddles.—Where pressed plate saddles are employed they shall be formed to bed closely to the boiler, and be machined on the face jointing the mounting and on the edges. The studs for the attachment of mountings, if screwed through the saddle, shall each be fitted with a nut on the inside having a

thickness equal to the diameter of the stud. Where the stud holes do not penetrate through the saddle, the length of the screwed portion of the stud in the plate shall not be less than the diameter of the stud.

158. Seatings for Mountings.—For pressures not exceeding 125 lbs. per sq. in. mountings with screwed ends not exceeding 1 in. B.S.P.T. may be used; the screwed portion of any such mounting being an integral part thereof and the thickness at the bottom of the thread being not less than 3/16″.

The mountings may be screwed :—

(*a*) Directly into the boiler shell plate, nuts being fitted on the waterside, or

(*b*) Into steel distance pieces the length of thread engaged being in no case less than the bore of the mounting plus 1/4 in.

159. Attachment of Mountings.—(*a*) Mountings may be attached directly to any shell or end plate where the plate is of sufficient thickness to allow a suitable surface to be obtained for the attachment of the boiler mountings.

(*b*) The minimum thickness at the hole in the shell or end plate shall be not less than the thickness required for the maximum permissible working pressure considering the plate as being unpierced.

(*c*) Where the boiler mountings are secured by studs, the studs shall have a full thread holding in the plate for at least one diameter. If the stud holes penetrate the whole thickness of the plate, the stud shall be screwed right through the plate and be fitted with a nut inside having a thickness equal to the diameter of the stud. Where bolts are used for securing mountings they shall be screwed right through the plate with their heads inside the shell or end plate.

160. Insufficient thickness of End Plates.—(a) In cases where the thickness of the end plate is insufficient for this purpose the mountings shall be jointed to suitable steel seatings as provided in Regulation 155.

(b) The following constructions as to stand pipes attached to end plates shall be permissible:—

(*i*) Where the internal diameter of the stand pipe does not exceed 1 inch, the standpipe may be screwed into the plate and fitted with a nut on the waterside.

(*ii*) Where the internal diameter of the standpipe exceeds 1 inch but does not exceed 2 inches, it may be screwed in and seal-welded.

(*iii*) Where the diameter of the standpipe exceeds 2 inches, it may be welded to the end plate.

The foregoing provisions as to the standpipe shall be regulated by the following conditions.

(*iv*) When standpipes are screwed, the screwing shall be British or American Standard Pipe Thread.

(*v*) Where standpipes, saddles or other forms of seatings are fabricated by fusion welding they shall be stress relieved by heat treatment before attachment to the boiler.

(*vi*) Where the bore of the standpipe or seating and the hole in the plate does not exceed 5 inches plus twice the thickness of the plate, the seating may be welded to the plate without subsequent heat treatment of the weld so made. Where the hole in the plate exceeds 5 inches plus twice the thickness of the plate, the plate to which the seating is attached shall be stress relieved by heat treatment.

161. Attachment of Water and Pressure Gauges.—Water gauges and pressure gauge syphons may be attached direct to the front end plates without the intervention of a pad or standpipe, provided they are flanged and secured by studs

If the studs are screwed through the plate, nuts shall be fitted on the inside of the plate.

162. Mountings on Flat Plates.—Where the flanged mountings are attached direct to a flat plate, such mountings shall be provided with a substantial spigot, the full thickness of the boiler plate.

163. Bolts and Nuts.—Bolts and nuts shall be machined where they come in contact with the flanges, and all holes in saddles and pads shall be drilled.

NOTE:—In all cases where the boiler is lagged, the joint of the mountings shall be clear of the lagging surface or the lagging kept clear of the flange so that the joint can be inspected and, when necessary, remade.

MANHOLES, MUDHOLES, ETC.

164. Access.—(a) Sufficient sight and cleaning holes shall be provided to permit of efficient inspection and cleaning. Such holes shall normally be elliptical in form and not less than $3\frac{1}{2}$ in. $\times 2\frac{1}{2}$ in.*

(b) At least one manhole or sight hole shall be provided in the upper part of the cylindrical shell or in the shell crown, or end plate and this shall not be less than:—

	in.
Boilers not exceeding 2 ft. 6 in.	9 × 7
Boilers over 2 ft. 6 in. diameter and not exceeding 3 ft.	12 × 9
Boilers over 3 ft. diameter and not exceeding 3ft. 6 in.	14 × 10
Boilers over 3 ft. 6 in. diameter and not exceeding 4 ft.	15 × 11
Boilers over 4 ft.	16 × 12

(c) Where the size or construction of the boiler does not permit of entry for cleaning and inspection sufficient cleaning holes shall be provided in the shell for these purposes.

(d) Where cross tubes are fitted in Vertical boilers one cleaning hole shall be provided opposite at least one end of each tube. At the bottom of the narrow water spaces at least three cleaning holes shall be provided. The cleaning holes shall be so arranged that the circumferential distance between them does not exceed 3 ft. unless the foundation ring is sufficiently accessible to permit of cleaning and inspection from the inside of the boiler.

(e) Cleaning holes or mudholes in Loco Type boilers shall be provided at each bottom corner of the outer firebox casing, above the fire hole ring and on each side of saddle plate in line with bottom of barrel.

(f) In the case of small boilers or where the foregoing provisions are impracticable the cleaning holes or mudholes shall be as nearly as possible in the corner of the outer firebox casing and the holes as large as circumstances permit.

165. Compensating Rings and Frames for Openings in Shells.—(a) Compensating rings and frames for openings in shells shall be of wrought or cast steel. The compensation provided shall preferably be flanged frames which shall be fitted in all cases where the shell plate exceeds 9/16in. thick. Flanged frames shall be weldless and shall be flanged or pressed to provide a flat jointing surface for the cover.

NOTE.—Wherever practicable the frames should be secured to the inside of the shells so that the shorter axis is parallel to the longitudinal centre line of the boiler.

*NOTE.—Standard sizes of mudholes and sightholes are 7″ × 5″, 5″ × $3\frac{1}{2}$″ and $3\frac{1}{2}$″ × $2\frac{1}{2}$ ″.

(b) All compensating rings and frames shall be formed to bed closely to the surfaces to be connected. Where attached to cylindrical shells and are 12 in. × 9 in. or larger they shall be at least double riveted. All caulking edges shall be machined or machine gas cut.

(c) The flat jointing surfaces of all flanged or pressed frames and all doors or covers shall be machined.

166. Doors and Cross Bars.—(a) All internally fitted doors of manholes, mudholes and sightholes shall be of wrought steel built up or pressed to shape and annealed or made from one thickness of plate with a machined recess for the jointing material or may be a steel casting. Their spigot part or the recess shall not have a greater clearance than 1/16th inch all round, *i.e.*, the axis shall not be less than 1/8th inch smaller than the holes in which they are fitted.

(b) The studs or bolts of large doors shall be screwed through the plates and riveted over.

(c) Internal doors for openings not larger than 9 in. × 7 in. in size need only be fitted with one stud, which shall be provided with an integral collar and screwed through the plate with a nut on the inside of the door. Internal doors for openings not larger than 5 in. × 3½ in. may have the stud forged solid with the door or if screwed be efficiently riveted to the doors.

(d) Cross bars shall be of substantial proportions and either solid steel forging or of cast steel.

167. Raised Manhole frames and Cover plates.- (a) Raised circular manhole frames not exceeding 16 inches in diameter shall be at least 3/4 inches thick in all parts. The circular cover plates and joint flanges for such frames shall be not less than :

1 inch thick for pressures not exceeding 120 lb. sq. inch.

1-1/8 inch thick for pressures over 120 lb. but not exceeding 200 lb. sq. inch.

1-1/4 inch thick for pressures over 200 lb. but not exceeding 250 lb. sq. inch.

For pressures 250 lb. sq. inch and over raised circular manhole frames shall not be fitted.

The cover plates shall be secured by at least sixteen steel bolts not less than 1 inch diameter.

(b) External raised circular mouthpieces shall be :—

(1) formed in one piece without welds,

(2) formed from a suitable rolled section and forge welded, or

(3) fabricated by fusion welding provided they are stress relieved by heat treatment after welding and before attaching to the boiler.

Welds should be positioned so that they are located on the transverse centre line of the boiler. The jointing flanges of mouthpieces and covers shall be machined on the face and edge and on the bearing surface for the bolts.

Bolts and nuts shall be machined where in contact with the flanges and the joints should be formed inside and outside the bolts to preclude the possibility of flange distortion. Cover plates shall be dished outwards to a depth of approximately one-eight of the internal diameter of the frame.

All frames and mouthpieces shall bed closely to the surfaces to which they are to be connected, and where riveted to cylindrical shells shall be at least double riveted. All Caulking edges shall be machined or machine gas cut.

168. Position of Manhole in Shell.—Manholes in cylindrical shells shall be placed as far as possible from any riveted seams, preferably towards the back end of the boiler top.

169. Compensation Rings to Manholes. (a) Compensation shall be provided in every case for the part cut out of a cylindrical shell for a manhole. The strength of the net section of compensating ring and of the rivets securing it to shell compared with that of the part of shell cut out shall not be less than the strength of the longitudinal seams.

(b) The spacing of the rivets shall be such as not to reduce the strength of the shell plate below that of the longitudinal seams.

170. Compensation for cutting large holes in shell Type Boilers.—Where holes are cut in the cylindrical shell for the purpose of attaching a seating, frame or door, compensation shall be provided such that the added sectional area, including parts of the frame within 4 inches of the shell and excluding rivet holes, shall be not less than the sectional area of the plate removed which shall be the product of the diameter of the opening and the calculated thickness of the plate as found by Equation 1. Where holes are cut in the cylindrical shell for the purpose of fixing seating for mountings and the diameter of the holes is greater than 2·1/2 times the thickness of the shell plate plus 2·3/4 inches, compensation shall be provided. Where a large opening is cut in a cylindrical shell to receive another part of the structure, the sides where cut away shall be efficiently cross stayed or strengthened in some other effective manner.

171. Rivets securing compensating Rings and Stand Pipes.

For manholes or frames.—The total effective shear strength of the rivets on each side of the longitudinal centre line shall be not less than the tensile strength of that portion of the shell plate, as found by Regulation 170, which is removed and the rivets securing any compensating ring or frame shall be so arranged that the joint efficiency calculated on any line parallel to the axis of the boiler through any part of such ring or frame shall not be less than the efficiency of the longitudinal seam of the boiler.

For stand pipes.—Where the hole in the shell to accommodate a standpipe does not exceed 8 inches diameter, the total effective shear strength of the rivets on each side of the longitudinal centre line shall not be less than 75 per cent. of the tensile strength of the portion of the plate, as found by Regulation 170, which has been removed

The strength of rivets in double shear shall be taken as 1·875 times the strength of rivets in single shear.

RIVETING

172. Rivet Holes.—(a) Rivet holes shall not be punched, but shall be drilled full size from the solid plate, and wherever possible rivet holes shall be drilled in place with plates, straps and ends bolted in position. After drilling, the plates shall be separated, the burrs and the sharp edges of the holes shall be removed and the contact surfaces of the plates shall be cleaned. All tacking holes shall be drilled to a size which will allow the holes to be enlarged to the required rivet size by drilling or reamering. All rivet holes shall be slightly countersunk under each rivet head.

(b) The diameter of the rivet hole shall be not more than 1/16 in. larger than the standard diameter of the cold rivet as manufactured.

(c) Where sizes of rivets are mentioned the sizes refer to the diameters of the rivet holes not to the diameters of the rivets used before closing.

173. Riveting.—(a) Rivets shall be closed by hydraulic machinery wherever the design of the boiler permits ; the rivets may be closed by hand or pneumatic hammer in position where hydraulic riveting is impracticable.

(b) Rivets shall be of sufficient length to fill rivet holes and form sound and substantial heads. The heads shall be finished concentrically with the rivet shanks. Rivets shall be heated uniformly throughout their full length.

(c) Drift pins shall not be used with such force as to distort the rivet holes. If the rivet holes are found not to be fair when the plates are bolted up for riveting the holes shall be reamered fair before the riveting is commenced.

(d) For hydraulic riveting the pressure shall be the least necessary to ensure a tight joint, and only sufficient pressure shall be used to close the rivets properly and securely without indenting, buckling or otherwise damaging the plate. The rivets shall be allowed to shrink while under pressure from the riveting machine.

174. Fullering and Caulking.—All seams shall be fullered or caulked inside and outside and this shall be done in such a manner that the plates are not sprung or damaged.

CHAPTER IV

REGULATIONS FOR DETERMINING THE WORKING PRESSURE TO BE ALLOWED ON VARIOUS PARTS OF BOILERS OTHER THAN FUSION WELDED AND SEAMLESS FORGED DRUMS.

175. The maximum pressure at which a boiler may be used shall be determined in accordance with the provisions of this Chapter. The Regulations in this Chapter refer to material subjected to steam temperature not exceeding 500°F.

SHELLS

176. Formula for working pressure of shell.– (a) For cylindrical shells, barrels, steam and water drums, and domes of boilers the maximum working pressure per square inch to be allowed shall be calculated from the following formula :—

[NOTE. Where parts of drums of water tube boilers are perforated for tubes, the working pressure shall be calculated by equation (53) under 'Tube Plates'.]

$$W.P. = \frac{(t-2) \times S \times J}{C \times D} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (1)}$$

W.P. is the working pressure in lbs. per square inch,

t is the thickness of shell plates in 32nds of an inch,

S is the minimum tensile breaking strength of the shell plates in tons per square inch or whatever strength is allowed under Regulation 5,

J is the percentage of strength of the longitudinal seams of shell or of a line of holes in the shell for stays, or rivets, or of an opening in the shell not fully compensated, whichever is least calculated by the methods hereafter described,

C is a co-efficient as follows :—

2·75 when the longitudinal seams are made with double butt straps and when small shells are formed from solid rolled sections ;

2·83 when the longitudinal seams are made with lap joints and are treble riveted ;

2·9 when the longitudinal seams are made with lap joints and are double riveted ;

3·0 when the longitudinal seams are welded and are fitted with a single butt strap ;

3·3 when the longitudinal seams are made with lap joints and are single riveted.

D is the inside diameter of the outer strake of plating of the cylindrical shell measured in inches.

(b) **The Factor of Safety** shall in no case be less than 4.

The actual Factor of Safety in each case may be found from the equation :—

$$F = 1 \cdot 4 \times C \times \frac{t}{t-2}.$$

With the best form of joint and least co-efficient (C) the Factor of Safety for shell plates, $\frac{1}{2}$ inch to $1\frac{3}{4}$ inches in thickness, varies from 5·13 to 3·99.

(c) An addition of 10 per cent. shall be made to the appropriate co-efficient for shells of boilers in which the longitudinal seams are lap jointed and are not accessible to close visual inspection and for shell plates of externally fired boilers exposed to the direct impact of furnace flame ; provided that this addition shall not apply to the steam and water drums of water tube boilers where the drums are not close to the fire-grate and there are tubes between the fire-grate and the drum.

(d) The above co-efficient are standards and shall be used only for boilers open to inspection by an Inspecting Officer during the whole period of construction and which are certified by him as having been constructed in accordance with the standard conditions laid down in these Regulations.

177. Methods of calculating the strength of riveted joints.—(a) The percentage of strength of a riveted joint (J) shall be found from the following formulæ (i) (ii), (iii) : (i) and (ii) are applicable to any ordinary type of joint ; (iii) is applicable only to that type of joint in which the number of rivets in the inner rows is double that of the outer row. The lowest value given by the application of these formulæ is to be taken as the percentage of strength of the joint compared with the solid plate.

(i) $\frac{100(P-D)}{P}$ = Plate percentage . . . . . Eqn. (2)

(ii) $\frac{100 \times A \times N \times C \times S_1}{P \times T \times S}$ = Rivet percentage . . . . . Eqn. (3)

(iii) $\frac{100(P-2D)}{P} + \frac{100 \times A \times C \times S_1}{P \times T \times S}$ = Combined plate and rivet percentage. Eqn. (4)

P is the pitch of rivets at outer row in inches,

D is the diameter of rivet holes in inches,

A is the sectional area of one rivet hole in square inches

N is the number of rivets per pitch, (P),

T is the thickness of plate in inches,

C = 1 for rivets in single shear as in lap joints, and 1·875 for rivets in double shear as in double butt strapped joints,

S_1 is the shearing strength of rivets, which shall be taken to be 23 tons per square inch for steel and 18 tons per square inch for iron,

S is the minimum tensile breaking strength of shell plates in tons per square inch, or whatever strength is allowed under Regulation 5 of Chapter I.

In the first formula (i) D is the diameter of the rivet holes in the outer rows and in the third formula D is the diameter of the rivet holes in the next rows. In the last formula A is the area of one rivet hole in the outer row.

(b) When the sectional area of the rivet holes is not the same in all rows, and when some of the rivets are in double shear and others in single shear the rivet sections per pitch of each size or shear shall be computed separately and added together to form the total rivet section.

178. When Pitch exceeds maximum allowed.—Should the pitch of the rivets exceed the maximum pitch allowed, the permissible pitch shall be used in place of the actual pitch in determining the percentage of plate section. No greater percentage than 85 shall be allowed for any type of riveted joint.

179. Butt Straps and spacing of rivets below requirements.—Should the spacing of the rows of rivets or the distance between edge of plate and rivet hole or the thickness of butt straps be less than is specified in Regulations 182 and 184 the percentage representing the strength of joint shall be modified as prescribed in those regulations.

180. Percentage of Welded and Strapped Seams.—In determining the percentage of strength of a welded seam covered by a strap or straps the formulæ and allowances in Regulations 177, 178 and 179 shall be applied, but 50 per cent. shall be added to the rivet percentage for the weld.

181. Percentage to be allowed for Solid Rolled Shells.—When small shells are rolled from the solid, J. in equation (1) shall be taken as 100 per cent.

182. Thickness of Butt Straps.—The minimum thickness of butt straps for the longitudinal seams of cylindrical shells shall be determined by the following formulæ but all straps should be of sufficient thickness to permit of efficient caulking, and in any case shall not be less than 3/8 inch in thickness.

Single butt straps having ordinary riveting :—

$$1 \cdot 125T = T_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (5)}$$

Single butt straps having every alternate rivet in the outer rows omitted :—

$$1 \cdot 125T \times \frac{(P-D)}{(P-2D)} = T_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (6)}$$

Double butt straps of equal width having ordinary riveting :—

$$\cdot 625T = T \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (7)}$$

Double butt straps of equal width having every alternate rivet in the outer rows omitted :—

$$\cdot 625T \times \frac{(P-D)}{(P-2D)} = T_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (8)}$$

Double butt straps of unequal width either having ordinary riveting, or having every alternate rivet in the outer rows omitted.

$$\cdot 75T = T_1 \text{ (wide strap)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (9)}$$

$$\cdot 625T = T_1 \text{ (narrow strap)} . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (10)}$$

T_1 is the thickness of the butt straps in inches. The other symbols have the same significance as in Regulation 177.

Single and wide butt straps shall, wherever practicable, be on the inside of the shell.

Should the thickness of butt straps be less than that above described, the least percentage of joint as determined under Regulation 177 shall be reduced in the proportion of the actual thickness to the prescribed thickness.

183. Maximum Pitch of Rivets in longitudinal joints.—The maximum pitch of the rivets in the longitudinal joints of boiler shells shall be :—

$$\mathbf{C \times T + 1 \cdot 625 = \text{maximum pitch in inches} \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (11)}}$$

T is the thickness of the shell plate in inches,

C is a co-efficient as given in the following table :—

Number of Rivets per pitch	Co-efficients for Lap joints	Co-efficients for single Butt-strapped joints	Co-efficients for double Butt-strapped joints
1	1·31	1·53	1·75
2	2·62	3·06	3·50
3	3·47	4·05	4·63
4	4·17		5·52
5	..		6·00

184. Spacing of rows of rivets. (*a*) In joints, whether lapped or fitted with butt straps, in which there are more than one row of rivets and in which there is an equal number of rivets in each row, the distance between the rows of rivets shall be not less than—

Zig-zag riveting.

$$\cdot 33P + \cdot 67D = \text{distance between centre lines of rows (R)} \quad \text{Eqn. (12)}$$

Chain riveting,

$$2D = \text{distance between centre lines of rows (R)} \quad \text{Eqn. (13)}$$

(*b*) In joints in which the number of rivets in the outer rows is one half of the number in each of the inner rows, and in which the inner rows are chain riveted the distance between the outer rows and the next rows shall be not less than as required by equations (12) and (13) whichever is the greater, and the distance between the rows in which there are the full number of rivets shall be not less than $2D(R_1)$.

(*c*) In joints in which the number of rivets in the outer rows is one half of the number in each of the inner rows and in which the inner rows are zig-zag, the distance between the outer rows and the next rows shall be not less than—

$$\cdot 2P + 1 \cdot 15D = \text{distance between centre lines of outer and next rows (R)} \quad \text{Eqn. (14)}$$

The distance between the rows in which there are the full number of rivets shall be not less than—

$$\cdot 165P + \cdot 67D = \text{distance between centre lines of inner rows } (R_1) \quad \text{Eqn. (15)}$$

P is the pitch of the rivets in the outer rows,

D is the diameter of the rivet holes in inches or the mean of the diameters of rivet holes when the distance to be determined is between two rows of rivets of different diameters.

(*d*) Should the distance between rows of rivets be less than as prescribed above the plate percentage determined by equation (2) shall be modified thus—

$$\frac{100\left[P-\left(2-\frac{\text{actual distance}}{\text{prescribed distance}}D\right)\right]}{P} = \text{modified plate percentage.} \quad \text{Eqn. (16)}$$

(*e*) In all cases the clear space between a rivet hole and the edge of a plate shall not be less than the diameter of the rivet holes, *i.e.*, the centre of the rivet hole shall be at least $1\frac{1}{2}$ diameters distant from the edge of the plate (E)—

Provided that, if this condition be not observed, the strength value of the rivets affected shall be reduced in the proportion of the actual distance between the outer edge of the rivets and the edge of the plate to the prescribed distance.

185. Circumferential and End Seams of Water Tube Boilers.—The suitability of circumferential seams including the seams joining ends to shells shall be verified by the following formula :—

$$\frac{K \times J \times (t-2)}{D \times C} \text{ is equal to or greater than WP} \quad \text{Eqn. (17)}$$

K = 150 for 26/30 tons tensile plates.

K = 157 for 28/32 tons tensile plates.

Due to higher stresses, see Reg. 271 and 340.

WP = The working pressure in lbs. per sq. in.

D = The diameter of shell in inches, measured inside the outer ring of plates.

J Circumferential Joint efficiency calculated by Eqns. 2 or 3.

C = 8·24 where the seams are made with lap joints and are treble riveted

= 8·44 where the seams are made with lap joints and are double riveted

= 9·60 where the seams are made with lap joints and are single riveted.

t = thickness of plate in 32nds of an inch.

186. Compensation for Manholes and other openings.—The percentage of compensating section shall be determined by the following formulæ :—

$$\frac{200\ (W-D) \times Tr}{(L-2D) \times Ts} = \text{percentage strength of compensating section} \quad \text{Eqn. (18)}$$

$$\frac{80 \times A \times N}{(L+2D) \times Ts} = \text{percentage strength of rivet section} \quad \text{Eqn. (19)}$$

W is the width of compensation ring in inches measured in the direction of the longitudinal axis of the boiler,

L is the length of opening in shell in inches measured in the direction of the longitudinal axis of the boiler,

D is the diameter of rivet holes in inches,

Tr is the thickness of compensation ring in inches,

Ts is the thickness of shell plate in inches,

A is the area of one rivet hole in inches,

N is the number of rivets on one side of the longitudinal line. When the rivets are in double shear 1·875 times the single rivet section shall be allowed.

Parts of raised manhole mouthpieces within four inches of the shell shall, in addition to the ring, be included in the compensating section.

187. Uncompensated Holes in Water Tube Boilers.—The maximum diameter of any uncompensated opening in a shell shall be determined, subject to the condition that the minimum thickness at the hole in the shell or end plate shall be not less than the thickness required for the maximum permissible working pressure, considering the plate as being unpierced, as follows :—

$$d = \tfrac{1}{2} \times \sqrt{(D+T)}\ T + N \quad \text{Eqn. (20)}$$

Where d=Maximum mean effective diameter of uncompensated hole in inches.

T = Thickness of drum shell in inches.

D = Internal diameter of drum in inches, but not exceeding 60.

N = 3 where E does not exceed 0·50.

$$=3\times\frac{\sqrt{1-E}}{0\cdot50} \text{ in other cases} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (21)}$$

$$\text{Where } E = \frac{\text{The required thickness of a seamless unpierced shell}}{T} \quad \text{Eqn. (22)}$$

DISHED END PLATES

188. Complete hemisphere without stays or other support made of one or more plates and subject to internal pressure.—The maximum working pressure shall be determined by the following formula :—

$$\text{W.P.} = \frac{(t-2)\times S\times J}{C\times R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (23)}$$

W.P. is the working pressure in lbs. per square inch,

t is the thickness of the end plates in 32nds of inch,

S is the minimum tensile breaking strength of the end plates in tons per square inch, or whatever strength is allowed for them,

J is the least percentage of strength of the riveted joints of the plates forming the hemisphere or securing it to the cylindrical shell,

R is the inner radius of curvature in inches,

C for single riveting is 3·3,

C for double riveting is 2·9,

C for treble riveting is 2·83.

189. Dished ends subject to internal pressure.—(*a*) For unstayed ends of steam and water drums, tops of vertical boilers, etc., when dished to partial spherical form the maximum working pressure shall be determined by the following formula :—

$$\text{W.P.} = \frac{15\times S\times(t-1)}{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (24)}$$

W.P. is the working pressure in lbs. per square inch,

t is the thickness of end plates in 32nds of an inch,

R is the inner radius of curvature of the end in inches, which shall not exceed the diameter of the shell to which it is attached,

S is the minimum tensile breaking strength of plate in tons per square inch, or whatever is allowed for it.

(*b*) The inside radius of curvature at the flange shall be not less than 4 times the thickness of the end plate, and in no case less than 2½ inches.

(*c*) When the end has a manhole in it (t−5), shall be substituted for (t−1) in the formula.

(*d*) In the case of the electrode boilers where the attachment of ends is permitted by fillet welding as per Regulation 104(d), for co-efficient 15, the co-efficient 10 shall be substituted.

(*e*) The total depth of flange of manhole from the outer surface in inches measured on the minor axis shall be at least equal to—

$$\sqrt{T\times W} = \text{depth of flange in inches} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (25)}$$

where T is the thickness of the plate in inches and W is the minor axis of the hole in inches.

NOTE.—The foregoing provisions shall not preclude the use of dished ends in compliance with Regs. 275 to 278 where not fitted with an up-take.

190. Dished ends subject to external pressure.—In the case of unstayed dished ends, for the co-efficient 15 in equation (24) the co-efficient 12 shall be substituted, and R shall be the outer radius of curvature of plate. For plates exposed to furnace flame the co-efficient shall be 10·5. In no case shall $\frac{R}{t}$ exceed 2·75".

191. Dished ends of Lancashire and Cornish type Boilers.—(*a*) For dished ends of Lancashire and Cornish boilers with external or internal flanges for furnaces formed in one piece, without stays and subject to internal pressure the maximum working pressure shall be determined by the following formula :—

$$W.P. = \frac{(t-8)\times 30\times S}{R} \quad \text{Eqn. (26)}$$

W.P. is the working pressure in lbs. per square inch,

t is the thickness of the end plate in 32nds of an inch,

R is the inner radius of curvature of the end in inches which shall not exceed one and a half times the internal diameter of the shell to which it is attached,

S is the minimum tensile breaking strength of the plate in tons per square inch or whatever is allowed for it.

(*b*) The inside radius of curvature at the flange shall be not less than 4 times the thickness of the plate and in no case less than $3\frac{1}{2}$ inches.

192. Dished shell and firebox crowns.—(*a*) In determining the working pressure in accordance with Regulations 189 and 190 no account shall be taken of the influence of the uptake tube in vertical boilers. If dished crown plates having uptakes are fit for higher pressures, when considered as flat plates, under Reg. 197 such higher pressure shall be allowed.

(*b*) The radius R of the dished part may be found as follows :—

$$R = \frac{C^2+H^2}{2H} \quad \text{Eqn. (27)}$$

C and H are the lengths in inches of half the base line or chord on which H is measured and the height of the dish or camber at the middle of the chord respectively.

FLAT PLATES

193. Flat plates supported by solid screwed stays, marginal seams or flanges.—(*a*) For plain flat plates supported by solid screwed stays or riveted marginal seams or flanges the maximum working pressure shall be as follows :—

$$W.P. = \frac{C(t-1)^2}{A^2+B^2} \quad \text{Eqn. (28)}$$

In this formula and in those following in the succeeding regulations relating to "Flat Plates" unless otherwise specified.

W. P. is the working pressure in lbs. per square inch,

t is the thickness of the flat plate in 32nds of an inch,

t_1 is the thickness of the washers, strips, or doublings employed, in 32nds of an inch,

A is the horizontal pitch of stays in inches,

B is the vertical pitch of the stays in inches,

C is a co-efficient which varies in value with the method of fixing the stays and nature of the support.

Where the plates are exposed to the direct impact of the flame the following values of C shall be reduced $12\frac{1}{2}$ per cent.—

C = 60 for stays screwed into the plate with their ends riveted over.

C = 90 for stays screwed into the plate and fitted with nuts on the outside,

C = 100 for stays passed through the plate and fitted with nuts inside and outside,

C = 110 for a riveted seam or flange, in the flat plate securing it to the shell side plate, end plate, furnace or uptake.

Where portions of plate are supported by stays or riveted seams or flanges having various values of support, the value of C, shall be taken as the mean of the points of support concerned.

The support of a riveted seam shall be assumed to be at the line through the centres of rivets in the nearest row and of a flange at the commencement of curvature. In the latter case, if the inner radius of curvature of the flange exceeds $2\frac{1}{2}$ times the thickness of the plate, the support shall be assumed to be at a distance of $2\frac{1}{2}$ times the thickness of the plate from the inner side of the flange.

(*b*) For portions of plate where the stays are irregularly pitched D^2 shall be used instead of A^2+B^2, D being the diameter in inches of the largest circle which can be drawn passing through not less than three points of support, viz., the centres of stays, or rivets or the commencement of the curvature of flanging, whichever is applicable.

(*c*) For the tops and sides of combustion chambers and fireboxes the distance between the rows of stays nearest to the back tube late, or the back or firehole plate respectively, and the commencement of curvature of these plates at their flanges, shall not be greater than the maximum pitch of the stays.

(*d*) For the tops of combustion chambers and fireboxes where they are joined to the sides by curved portions, if the outer radius of the curved portion is less than half the allowable distance between the girders, the distance between the first girder and the inner surface of the side plates shall not exceed the allowable distance between the girders. If the radius of curvature is greater than half the allowable distance between the girders, the width of the flat portion measured from the centre of the girder shall not be more than half the allowable distance between the girders.

(*e*) Where stay tubes are not fitted in nest of tubes, as in tube plates of loco-type boilers, and parts of plate outside the space occupied by tubes are supported, in accordance with Regulation 212 (b), by screwed stays each stay in the row nearest the tubes shall be sufficient strength to support the plate up to the edges of the tube holes in addition to its share of the plate on the opposite side of the line of stays.

The working pressure for the plate between tubes and stays shall be determined by Eqn. (28), A being the horizontal pitch of the stays in the nearest row, B twice the distance between the centre line of stays and a line touching the tubes opposite them and C the co-efficient appropriate to the kind of stay.

194. Flat plates supported by stays and nuts and large washers or strips or doublings.—(*a*) Where the plates are supported by stays passing through them and are fitted with nuts inside and washers and nuts outside, the diameter of the washers being at least $3\frac{1}{2}$ times that of the stay, and their thickness at least two-thirds that of the plate, but not greater than that of the plate, the maximum working pressure shall be :—

$$\text{W. P.} = \frac{100}{A^2+B^2}[(t-1)^2+\cdot 15t_1^2] \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (29)}$$

(*b*) where the washers have a diameter of at least two-thirds of the pitch of the stays and a thickness of at least two-thirds of the thickness of the plate, but not

greater than that of the plate, and are riveted to the plate in an fficient manner, the maximum working pressure shall be :—

$$W.P. = \frac{100}{A^2+B^2}[(t-1)^2+\cdot 35t_1^2] \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (30)}$$

(c) Where the plate is stiffened by strips at least two-thirds of the pitch of the stays in breadth which have a thickness of at least two-thirds of that of the plate but not greater than that of the plate, and are riveted to the plate in an efficient manner, the maximum working pressure shall be :—

$$W.P. = \frac{100}{A^2+B^2}[(t-1)^2+\cdot 55t_1^2] \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (31)}$$

(d) Where the plates are fitted with doubling plates having a thickness of at least two-thirds of that of the plate but not greater than that of the plate, and are riveted to them in an efficient manner, the maximum working pressure shall be :—

$$W.P. = \frac{100}{A^2+B^2}[(t-1)^2+\cdot 85t_1^2] \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (32)}$$

195. Flat tube plates.—(a) For the portions of tube plates in the nests of tubes where stay tubes are required and where the minimum thickness and cross section of tube plate are not less than as prescribed in Regulation 211 the maximum working pressure shall be :—

$$W.P. = \frac{C(t-1)^2}{P^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (33)}$$

P is the mean pitch of the stay tubes supporting any portion of the plate (being the sum of the four sides of the quadrilateral divided by four).

C = 70 for stay tubes screwed and expanded into the plate and no nuts fitted.

C = 85 for stay tubes screwed and expanded into the plate and fitted with nuts.

(b) No nuts shall be fitted to stay tubes at the combustion chamber or firebox end.

(c) Where the plates are exposed to the direct impact of flame, the co-efficient C shall be reduced by 12½ per cent., and where the thickness or cross section of tube plate between tubes is less than as prescribed in Regulation 211 the appropriate co-efficient shall be reduced in proportion to the deficit.

(d) For the wide water spaces of tube plates between the nests of tubes and between the wing rows of tubes and the shell, the maximum working pressure shall be :—

$$W.P. = \frac{C}{A^2+B^2}[(t-1)^2+\cdot 55t_1^2] \quad . \quad . \quad . \quad . \quad \text{Eqn. (34)}$$

A is the horizontal pitch of stay tubes in inches measured across the wide water space from centre to centre,

B is the vertical pitch of stay tubes in the bounding rows in inches measured from centre to centre,

C = 60 for stay tubes screwed and expanded into the tube plates and no nuts are fitted,

C = 80 for stay tubes screwed and expanded into the tube plates and fitted with nuts,

C = 70 for stay tubes screwed and expanded into the tube plates and nuts are fitted only to alternate stay tube,

t is the thickness of the flat plate in 32nds of an inch,

t_1 is the thickness of the washers, strips or doublings employed in 32nds of an inch.

(*e*) Where the plates are exposed to the direct impact of flame, the co-efficient C shall be reduced 12½ per cent.

196. Plates supported by gusset stays.—(*a*) For the end plates of Lancashire, Cornish, Vertical and Locotype boilers, and other flat surfaces supported by irregularly pitched gusset stays, the maximum working pressure shall be :—

$$\text{W. P.} = \frac{C\,(t-1)^2}{D^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (35)}$$

D is the diameter in inches of the largest circle which can be drawn passing through not less than three points of support, *viz.*, the centre lines of rivets or the commencement of the curvature of flanging, whichever is applicable.

C = 100 for plates not exposed to flame.

C = 88 for plates exposed to flame.

(*b*) Where such plates are stiffened by suitable tee or angle bars securely riveted to the plates within the circle D, the appropriate co-efficient may be increased thirty per cent. Such stiffening bars shall be placed so as to transmit their load in a direct manner to the gusset stays or shell plate.

(*c*) For the part of the end plate containing the manhole in Lancashire boilers the maximum working pressure shall be :—

$$\text{W P} = \frac{C}{D^2}\left[(t-1)^2 + (t_1-1)^2\right] \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (36)}$$

D is the diameter in inches of the largest circle which can be drawn enclosing the manhole and passing through the centres of the rivets in end plates connecting the shell and gusset angles and furnaces or to the commencement of curvature of flanging, whichever is applicable where the circle passes through only three of the possible five points of support mentioned the remaining two shall be embraced within the circle.

t is the thickness of the end plates in 32nds of an inch,

t_1 is the thickness of the base of the mouthpiece or flat ring in 32nds of an inch,

C = 90 where the manhole mouthpiece is either of mild or cast steel, and has a turned-in flange of a depth, measured from inside of end plate, of not less than 4 times the thickness of the end plate, and thickness not less than the thickness of the end plate,

C = 70 where only a flat steel compensating ring is fitted,

C is to be taken as the mean of the points of support through which circle passes in accordance with Regulation 193 where there is no mouthpiece or flat ring and the end plate is flanged around the manhole to the depth required in Regulation 201.

197. Flat Crown plates of vertical boilers.—(*a*) For the flat crown plates of vertical boilers either with or without bolt stays, Equation (35) shall be used in determining the working pressure with C=80, when the plates are not exposed to flame, and 70 when they are exposed to flame. In this case D is the diameter of the largest circle in inches that can be drawn passing through the centres of the rivets or bolt stays when fitted, or the commencement of the curvature of the flanging, whichever is applicable. Where bolt stays are fitted with washers of the same thickness as the

plate securely riveted thereto, the circle shall pass through the centres of the washer rivets but where the washers are not riveted or where none are fitted the circle shall pass through the centre of the stays. In the case of electrode boilers where the attachment of ends is permitted by fillet welding as per Regulation 104(d), the working pressure shall be determined by Equation (35) with C=40.

(*b*) Where the crown plate is flanged the inside radius of curvature at the flange shall not be less than 4 times the thickness of the end plate, but in no case less than $2\frac{1}{2}$".

198. Circular flat ends of drums, etc., supported only at edges.—(*a*) For these ends C in Equation (35) shall be taken as 140 when the plates are not exposed to flame, and 122·5 when they are exposed to flame. In this case the circle D shall pass through the centres of rivets or bolts securing the end to the shell or, where the end is flanged, through the commencement of curvature.

(*b*) Where flanged the inside radius of curvature at the flange shall not be less than 4 times the thickness of the end plate but in no case less than $2\frac{1}{2}$".

199. Bar or bulb stiffened end plates and smokebox tube plates of locotype boilers.—Where such plates instead of being supported by stays are stiffened in the steam space by substantial tee or angle bars securely riveted to the plate and extending across the plate to within the margin allowed by Equation (37) or where such plates are formed with a deep bulb extending across the plate to well within the margin allowed, for the support thus given,

C shall be taken as equal to 80 and 70 for plates not exposed, and exposed, to flame respectively. The margin or pitch for such stiffening shall be measured from the centre line of rivets or commencement of curvature of bulb provided it is not more than 2 inches from the centre line of bulb.

For the flat plate above the stiffener or bulb, C shall be taken as the mean of the values appropriate for the points of support.

200. Flat plate margins.—The amount of support in relief of stays which may be credited to the sides of shells, furnaces, uptakes, fireholes and foundation rings to which flat plates are attached shall not exceed that found by the following formula :—

$$\text{Width of margin in inches} = \frac{C(t-1)}{\sqrt{W.P.}} \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (37)}$$

t = Thickness in 32nds of an inch

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

C = 3·47 for plates exposed to flame

C = 3·70 for plates not exposed to flame.

Where the plates are flanged the margin shall be measured from the commencement of curvature or from a line $2\frac{1}{2}$ times the thickness of the plate distant from the side of the flange next to the inner radius of the corner whichever is the less. In other cases, the margin shall be measured from the centre line of rivets in the nearest row of the seam by which the flat plate is attached.

Doubling plates shall cover the area supported between the stays and extend beyond the stays so that the centre of the rivets securing the doubling plate to the end plate shall be at least half the distance from the outermost stays to the nearest substantial point of support.

Where flat end plates are flanged for connection to the shell, the inside radius of flanging shall be not less than 1·75 times the plate thickness with a minimum of $1\frac{1}{2}$ inches.

201. Manholes and Mudholes in Flat Plates.—Where a flat plate is flanged to stiffen it at a manhole or sighthole, to permit same working pressure as would be allowed upon an unpierced plate, the depth of the flange measured from the outer surface shall be at least equal to—

$\sqrt{T \times W}$ = depth of flange in inches . . . . . Eqn (38)

Where T is the thickness of the plate in inches, and

W is the minor axis of the hole in inches.

STAYS

202. Solid screwed stays.—For screw stays to combustion chambers and fire boxes and for longitudinal and cross stays, the maximum working pressure for the stays is to be calculated from the appropriate one of the following two formulæ :—

$$W.P. = \frac{C}{A}\left(D - \frac{1 \cdot 28}{N}\right)^2 \quad \text{Eqn. (39)}$$

$$W.P. = \frac{C \times D_1^2}{A} \quad \text{Eqn (40)}$$

W P. is the working pressure in lbs. per square inch,

D is the diameter of stays over threads in inches,

D_1 is the diameter of body of stay at its smallest part in inches,

N is the number of threads of stay per inch,

A is the area in square inches supported by one stay [for area to be supported by stays near tubes in firebox tube plates of locotype boilers, see Regulation 193(c)],

C=7100 for steel or special wrought iron screw stays to combustion chamber or fireboxes

C=8640 for steel longitudinal or cross stays fitted with nuts,

C=4700 for copper screw stays to fireboxes.

Where stays are made with enlarged ends and the body of the stay is smaller in diameter than at the bottom of the thread the working pressure shall be calculated from the second formula.

203. Stresses in steel jointed stays.—(a) The section of least strength whether of stay, rivets, shackle or pin shall be used in calculating the working pressure for the stay. For parts in tension a stress of 9,000 lbs. per square inch of net section shall be allowed, and for parts in shear a stress of 8,000 lbs. per square inch of net section.

(b) Parts in double shear shall be allowed a section of 1·875 times the single section

204. Stay tubes.—For stay tubes, whether of wrought iron or steel, seamless or lap-welded the maximum working pressure shall be calculated from the following formula :—

$$W.P. = \frac{5900}{A}\left[\left(D - \frac{1 \cdot 28}{N}\right)^2 - D_1^2\right] \quad \text{Eqn. (41)}$$

D is the diameter of the tube over threads in inches,

D_1 is the internal diameter of the tube under the threads in inches,

N is the number of threads of stay per inch.

A is the area in square inches supported by one stay tube, measured from centre to centre of stay tubes. When the area contains tubes or parts of tubes their aggregate area, calculated from their smallest external diameter of body when in tension

and smallest internal diameter when in compression, shall be deducted from the area of the containing figure and the remainder used as A in the formula.

205. Stays in tension and compression.- (a) The same stress shall be allowed in compression as in tension. The strength of short stays in compression and not liable to bending shall be calculated on the net section of the stay at bottom of thread or in body, whichever is less.

(b) The stress to be allowed on any stay or part of a stay not provided for in foregoing shall be the same as that allowed for stays or parts of stays of approximately like kind in similar condition.

206. Measurements of stayed areas in the end plates of locotype and vertical boilers.—When the areas supported by stays are semi-circular as in the upper parts of the end plates and smokebox tube plates of locotype boilers, or annular as in the crown plates of vertical type boilers, the area to be supported by stays, A in Eqns. 39 and 40 shall, in the first case, be the area of the plate contained within the margins credited to casing or barrel sides, screw stays, fire door ring or tube stays as the case may be, and in the second case be the area of the annulus between the margins credited to uptake and shell. When bolt staying is necessary, the stays shall be properly distributed ; the aggregate stay section shall then be used in the formula for calculating the working pressure.

207. Gusset stays.—The maximum working pressure for gusset stays shall be calculated by the following formula :—

$$W.P. = \frac{9000 \times C}{A} \quad \text{Eqn. (42)}$$

C, the co-efficient, is the number representing the least of the following :-

(1) $N_1 \times A_1$.

(2) $N_2 \times A_2 \times 1 \cdot 875$.

(3) $N_3 \times A_3 \times 1 \cdot 875$.

(4) $N_4 \times A_4$.

(5) $(G - N_2 D_2) \times (t - 2) \cdot 037$.

(6) $(G_1 - D_3) \times (t - 2) \times \cdot 037$.

N_1, N_2, N_3, N_4, D_1 D_2, D_3, D_4, and A_1, A_2, A_3, A_4, are respectively the numbers, diameters and sectional areas of the rivets in the joints of each gusset stay, only rivets in the supported area, to be considered effective the order of the joints being (1), angles to end plate, (2) end plate angles to gusset, (3) shell angles to gusset, and (4) angles to shell,

G is the depth in inches of gusset plate measured through the line of rivets attaching it to the end plate angles.

G_1 is the depth in inches of gusset plate measured normal to the slant edge of plate through the rivet nearest to the end plate in the joint attaching gusset plate to shell angles,

t is the thickness of the gusset plate in 32nds of an inch,

A is the area in square inches of flat plate supported by the gusset stay which, in the case of Lancashire and Cornish boilers, shall be determined as follows :

(a) The margins allowed under flat plate regulations for shell and furnace shall be marked on end plates and the lengths of the centre lines of gussets between them measured, also the distance between each pair of gusset lines from the middle of the smaller in a direction normal to the greater. If L and L_1 be the lengths of two adjacent

gusset lines and if the distance between them be W, the area contained by the gusset lines and the shell and furnace margin lines may be apportioned between the stays thus :—

$$\frac{W(3L+L_1)}{8} = \text{Portion of area in square inches,}$$

apportioned to L line gusset . . . . . Eqn. (43)

$$\frac{W(3L_1+L)}{8} = \text{Portion of area in square inches}$$

apportioned to L_1 line gusset . . . . . Eqn. (44)

(b) The portion of the area on the other side of each gusset line shall, except when of triangular form, be found in like manner and its amount added to that already found to form the total.

(c) For the triangular portions in the wing spaces the area shall be taken as half the product of the length of gusset line into the perpendicular distance between it and the intersecting point where the marginal curves meet.

BOLTS AND STUDS

208. (a) Bolts and studs connecting parts of boilers such as shell, end plates, tube plates, furnaces, uptakes, externally fitted manhole covers, mountings, etc., may be made either of steel or good quality wrought iron.

(b) The maximum working pressure for the bolts or studs shall be calculated by the following formula :—

$$\text{W.P.} = \frac{N \times C}{A}\left(D - \frac{1{\cdot}28}{n}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (45)}$$

D is the diameter of bolt or stud over threads in inches,

N is the number of bolts or studs securing the part,

n is the number of threads of screw per inch,

C=4,700 for steel bolts or studs of 28 tons/sq. in. minimum ultimate tensile stress where the diameter over thread is less than 3/4 inch.

C=5,100 for steel bolts or studs of 30 tons/sq. in. minimum ultimate tensile stress where the diameter over thread is less the 3/4 inch.

C=5,600 for steel bolts or studs of 35 tons/sq. in. minimum ultimate tensile stress where the diameter over thread is less than 3/4 inch.

C=5,600 for steel bolts or studs of 28 tons/sq. in. minimum ultimate tensile stress where the diameter over thread is not less than 3/4 inch and not greater than 7/8 inch.

C=7,000 for steel bolts for studs of 28 tons/sq. in. minimum ultimate tensile stress where the diameter over thread is greater than 7/8 inch.

When the material is iron, a reduction of 15 per cent shall be made in the working pressure as calculated by the formula.

A the area in square inches of the surface supported by the bolts or studs. For jointed flanges the area shall be taken to extend to midway between the pitch line of the bolts and the inner edge of the flange by which the part is secured.

TUBE PLATES

209. Compression of tube plates.- (a) For fire-box or combustion chamber tube plates which are subject to compression due to the pressure on the roof plate, the maximum working pressure shall be :—

$$W.P. = \frac{C \times (P-D) \times t}{L \times P} \quad \ldots \quad \text{Eqn. (46)}$$

t is the thickness of the tube plate in 32nds of an inch,

P is the pitch of the tubes in inches, measured horizontally where the tubes are chain pitched, and diagonally where the tubes are zigzag pitched and the diagonal pitch is less than the horizontal,

D is the internal diameter of the plain tubes in inches,

L is the internal length of the fire-box or combustion chamber in inches measured at top between tube plate and firehole plate or back plate, or between tube plates in double ended boilers with combustion chambers common to two opposite furnaces,

C = 875 for steel and 437·5 for copper.

Provided that the above formula shall not apply in the case of fire-boxes where the girders do not rest on the tube plate, or where the roof plate is stayed direct to the outer shell or to girders supported by the shell.

(b) where girders rest on the side plates or the roof plate is so formed that the load is carried both by side and end plates, in no case shall the compressive stress on the plates exceed 14,000 lbs. per square inch for steel of 7,000 lbs. per square inch for copper.

210. Parts to be stayed.—(a) The stiffness of tube plates and pitch of stays within the nests of tubes where stay tubes are required and where marginal stay tubes are required in support of blank spaces adjacent to or between the nests shall be determined by flat plate rules under Regulation 195.

(b) Tube plates within the nests of tubes whether fitted with stay tubes or not shall comply with the requirements of Regulation 211 in regard to thickness and cross section between tubes.

211. Minimum thickness and cross section.—To provide a secure attachment for plain tubes in the tube plates the thickness and cross section of the plate between the tube holes shall not be less than :—

Steel tube plate,

·125D + ·2 = minimum thickness in inches . . . . Eqn. (47)

·17D + ·025 = minimum cross section in square inches . . Eqn. (48)

Copper tube plate,

·2D + ·4 — minimum thickness in inches . . . . . Eqn. (49)

·527D — ·263 = minimum cross section in square inches . . Eqn. (50)

D is the diameter in inches of the tube at the part of attachment to tube plate.

Where the thickness and cross section of the tube plates are less than the minimum the appropriate co-efficient in Eqn. (51) shall be reduced in proportion to the deficit.

212. Holding power of plain tubes.—(a) Where tube plates are not specially stayed in nests of tubes, the working pressure, based on the holding power of the tubes shall not exceed that found by the following formula :—

$$W.P. = \frac{C \times D}{A} \quad \ldots \quad \text{Eqn. (51)}$$

D is the diameter of tube at the part of attachment to tube plate in inches,

A is the area in square inches of the tube plate supported by each tube, which generally may be taken as the product of the horizontal and vertical pitches of the tube less the area of the tube itself,

C = 470 for tubes expanded into parallel holes in steel or irontube plates,

C = 530 for tubes expanded into taper holes in steel or irontube plates.

For copper tube plates or copper or brass tubes the appropriate co-efficient should be reduced 20 per cent.

(b) In the unstayed tube plates of locotype boilers and in other tube plates in which stay tubes are not required the support afforded by the plain tubes shall not be taken to extend beyond the lines enclosing the outer edges of the tubes. Parts of flat plate outside this line shall either lie in the plate margin or be separately supported. No account need be taken of the stiffness of tube plate in the nests of tubes when the above conditions are fulfilled.

Ordinarily the requirements of this clause are applicable only to expanded smoke and water tubes in flat continuous tube plates containing more than one row of tubes.

(See Reg. 152 for attachment of tubes in Water tube boiler.)

213. Tube plates, other than ends, of vertical boilers forming parts of outer shell.—(*a*) When vertical boilers have a nest or nests of horizontal tubes so that there is direct tension on the tube plates due to the vertical load on the boiler ends, or to their acting as horizontal ties across the shell, the thickness of the tube plates and the spacing of the tubes shall be such that the section of metal taking the load is sufficient to keep the stress within that allowed on the shell plates.

(*b*) Each alternate tube in the outer vertical rows of tubes shall be a stay tube. The tube plates between the stay tubes shll be in accordance with the rules for tube plates and in addition, considered as part of shell, the maximum working pressure,—

$$\text{W. P.} = \frac{17 \cdot 24\,(t-2) \times (P-D) \times S}{R \times P} \quad \ldots \quad \text{Eqn. (52)}$$

t is the thickness of the tube plate in 32nds of an inch,

P is the vertical pitch of the tubes in inches,

D is the diameter of the tube holes in inches,

S is the minimum tensile breaking strength of the tube plates in tons per square inch, or whatever is allowed for them,

R is the radial distance of the centre of the outer row of tube hole from the axis of the shell in inches.

214. Curved Tube plates of water-tube boilers.—For tube plates forming part of cylindrical drums the maximum working pressure shall be

$$\text{W.P.} = \frac{33 \cdot 3(t-4) \times E \times S}{D} \quad \ldots \quad \text{Eqn. (53)}$$

t = thickness of tube plate in 32nds of an inch,

E = Efficiency of the longitudinal joint or the ligament between the tube holes, whichever is less,

S = Minimum Tensile Stress of the tube plate in tons per sq. in. or whatever is allowed for it,

D = Inside diameter of the drum in inches.

215. Efficiency of ligament.—(a) When a shell or drum is drilled for tubes in a line parallel to the axis of the shell or drum, the efficiency of the ligament between the tube holes shall be determined as follows :—

(*a*) When a pitch of the tube holes on every row is equal (as in fig. 10), the formula is :—

$$\frac{p-d}{p} = \text{efficiency of ligament.} \quad \ldots \quad \text{Eqn. (54)}$$

Where p = pitch of tube holes, inches,

d = diameter of tube holes, inches.

The pitch of tube holes shall be measured either on the flat plate before rolling or on the median line after rolling.

Example.—Pitch of tube holes in the drum as shown in Fig. 10 = $5\frac{1}{4}$ in. Diameter of tube = $3\frac{1}{4}$". Diameter of tube holes = 3-9/32".

$$\frac{p-d}{p} = \frac{5{\cdot}25-3{\cdot}281}{5{\cdot}25} = 0{\cdot}375, \text{ efficiency of ligament.}$$

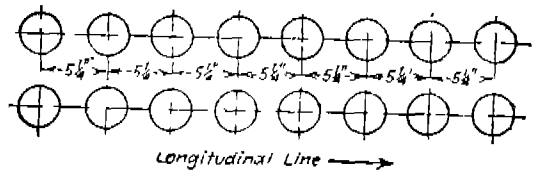


Fig. 10. Example of Tube Spacing with Pitch of Holes equal in every Row.

(*b*) When the pitch of tube holes on any one row is unequal (as in Figs. 11 & 12) the formula is :—

$$\frac{p-nd}{p} = \text{efficiency of ligament.} \quad \ldots \quad \text{Eqn. (55)}$$

Where p = unit length of ligament, inches,

n = number of tube holes in length p,

d = diameter of tube holes, inches.

Example.—Spacing shown in Fig. 11. Diameter of tube holes = 3-9/32".

$$\frac{p-nd}{p} = \frac{12-2\times 3{\cdot}281}{12} = 0{\cdot}453, \text{ efficiency of ligament.}$$

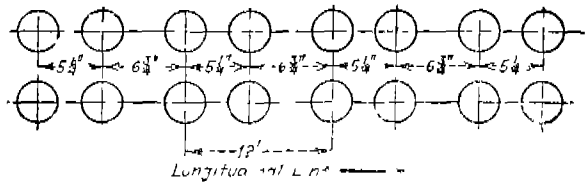


Fig. 11. Example of Tube Spacing with Pitch of Holes Unequal in every Second Row.

Example.—Spacing shown in Fig. 12. Diameter of tube holes = 3-9/32".

$$\frac{p-nd}{p} = \frac{29{\cdot}25-5\times 3{\cdot}281}{29{\cdot}25} = 0{\cdot}479, \text{ efficiency of ligament.}$$

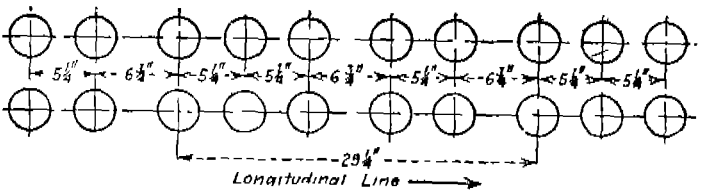


Fig. 12 Example of Tube Spacing with Pitch of Holes varying in every Second and Third Row

(*c*) The strength of those ligaments between the tube holes which are subjected to a longitudinal stress shall be at least one half the required strength of those ligaments which come between the tube holes which are subjected to a circumferential stress.

(*d*) When a shell or drum is drilled for tube hole so as to form diagonal ligaments as shown in Fig. 13, the efficiency of these ligaments shall be that given by the diagram in Fig. 14.

In this diagram the abscisses are $\frac{p}{d}$ and the ordinates $\frac{p'}{p}$

Where p = longitudinal pitch of tube holes, or distance between centres of tubes in a longitudinal row, inches,

p' = diagonal pitch of tube holes, inches,

d = diameter of tube holes, inches.

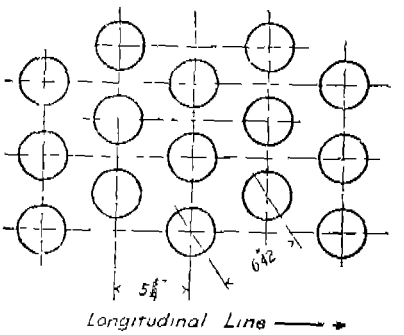


Fig. 13. Example of Tube Spacing with Tube Holes on Diagonal Lines

To use the diagram in Fig. 14. the values of $\frac{p}{d}$ and $\frac{p'}{p}$

are computed and the efficiency for the corresponding points is read off from the diagram. Should the point fall above the curve of equal efficiency for the diagonal and longitudinal ligaments, the longitudinal ligaments will be the weaker, in which case the efficiency is computed from the following formula :—

$$\frac{p-d}{p}$$

Example.– (1) Diagonal pitch of tube holes in drum as shown in Fig. 13 = 6·42 in.

Diameter of holes = $4\frac{1}{16}$ in

Longitudinal pitch of tube holes = $11\frac{1}{2}$ in.

$$\frac{p}{d} = \frac{11\cdot5}{4\cdot031} = 2\cdot853 \qquad \frac{p'}{p} = \frac{6\cdot42}{11\cdot5} = 0\cdot558.$$

The point corresponding to these values is shown at A on the diagram in Fig. 14 and the corresponding efficiency is 35·3 per cent. As the point falls below the curve of equal efficiency for the diagonal and longitudinal ligaments, the diagonal ligament is the weaker.

(2) Diagonal pitch of tube holes in drum = 6-35/64 in.
Diameter of tube holes . . = 4-1/64 in.
Longitudinal pitch of tube holes = 7 in.

$$\frac{p}{d} = \frac{7}{4\cdot0156} = 1\cdot743 \qquad \frac{p'}{p} = \frac{6\cdot547}{7} = 0\cdot935.$$

The point corresponding to these values is shown at B on the diagram in Fig. 14 and it will be seen that it falls above the line of equal efficiency for the diagonal and longitudinal ligaments, in which case the efficiency is computed from formula (1).

Applying formula (1), we have :

$$\frac{7-4\cdot0156}{7} = 0\cdot426, \text{ efficiency of ligament, or } 42\cdot6 \text{ per cent.}$$

For holes placed longitudinally along a drum but which do not come in a straight line, the above rules for calculating efficiency shall hold, except that the equivalent longitudinal width of a diagonal ligament shall be used. To obtain the equivalent width the longitudinal pitch of the two holes having a diagonal ligament shall be multiplied by the efficiency of the diagonal ligament. The efficiency to be used for the diagonal ligaments is given in Fig. 15.

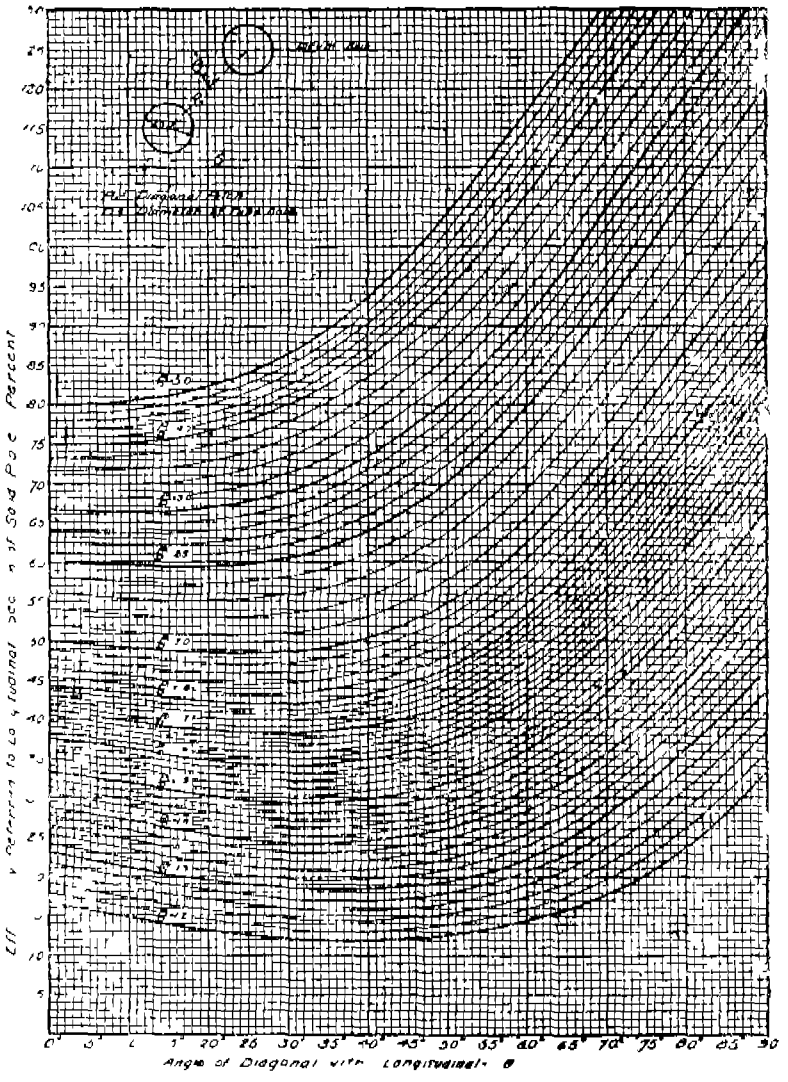


FIG 15 DIAGRAM FOR DETERMINING EFFICIENCY OF DIAGONAL LIGAMENTS IN ORDER TO OBTAIN EQUIVALENT LONGITUDINAL EFFICIENCY

BOILER AND SUPERHEATER TUBES SUBJECT TO INTERNAL PRESSURE

216. The maximum working pressure for the tube shall be determined by Equation No. 87. (See Regulation 338).

The minimum thickness of the tubes shall comply with the table given in Regulation 338(b).

HEADERS AND SECTION BOXES OF WATER TUBE BOILERS

217. See Eqn. 88 . . . . . Reg. (340)

BOILER TUBES (SMOKE) SUBJECT TO EXTERNAL PRESSURE

218. Steel and Wrought Iron Tubes.—(*a*) The maximum working pressure for the tubes shall be .—

$$\text{W.P.} = \frac{100\ (t - 6)}{D} \quad \text{Eqn. (56)}$$

t is the thickness of the tubes in 100ths of an inch,

D is the external diameter of the tubes in inches,

(*b*) No tube shall be less than 12 S. W. G. (·104″) thick.

219. Brass and Copper Tubes.—The thickness of tapered brass and copper smoke tubes for locomotive boilers shall, in the case of tubes of an external diameter of $1\frac{1}{2}$ to $1\frac{7}{8}$ inches inclusive, be not less than 12 S. W. G. (·104 inch) at the smoke-box end and 10 S.W.G. (·128 inch) at the other and in the case of tubes of an external diameter of 2 to $2\frac{3}{8}$ inches inclusive, the thickness at the smoke-box end shall not be less than 11 S. W. G. (·116 inch) and at the other end not less than 9 S. W. G. (·144 inch).

FURNACES

220. Plain Furnaces of Horizontal Boilers.—For plain furnaces or furnaces strengthened by Adamson or other joints or stiffeners of sufficient strength and for the semi-cylindrical tops of fire-boxes and bottoms of combustion chambers where the sides are securely stayed, the working pressure shall not exceed the smaller of the values obtained from the following formulæ—

$$\text{W.P.} = \frac{C}{D} \times \frac{(t-1)^2}{(L + 24)} \quad \text{Eqn. (57)}$$

$$\text{W.P.} = \frac{C_1}{D} \times [10\ (t-1) - L] \quad \text{Eqn. (58)}$$

D is the external diameter of the furnace or chamber top or bottom in inches,

t is the thickness of the furnace plate in 32nds of an inch,

L is the length of the furnace or other part in inches measured between points of substantial support, *i.e.*, centres of rows of rivets in end seams or commencement of curvature of flange, whichever is applicable,

C = 1450 where the longitudinal seams of steel furnaces are welded and 1300 where they are riveted,

C = 725 where the longitudinal seams of circular copper fire-boxes or furnace are fitted with double butt straps and 650 where they are lapped,

$C_1 = 50$ where the longitudinal seams of steel furnaces are welded and where they are riveted.

$C_1 = 25$ where the longitudinal seams of circular copper fire-boxes or furnaces are fitted with double butt straps and 22·5 where they are lapped.

221. Corrugated Furnaces of Horizontal Boilers.—The maximum working pressure to be allowed on corrugated furnaces shall be determined by the following formula—

$$W.P. = \frac{C}{D}(t-1). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (59)}$$

D is the least external diameter in inches measured at the bottom of the corrugations on the water side,

t is the thickness of the furnace plate in 32nds of an inch measured at the bottom of the corrugation or chamber,

C = 480 for the Fox, Morrison, Deighton, Purves, and other similar furnaces and 510 for the Leeds Forge Bulb Suspension Furnace.

222. Plain Furnaces of Vertical Boilers.—The same formulæ as for the plain furnaces of horizontal boilers shall be used, but where the furnaces are tapered, the diameter to be taken for calculation purposes shall be the mean of that at the top and of that at the bottom where it meets the substantial support from flange or ring. The length for the same purpose shall be the distance from the centre of the row of rivets connecting the crown and the body of the furnace to the substantial support at the bottom of the furnace, or to a row of screwed stays connecting the furnace to the shell, provided that the pitch of stays at the furnace does not exceed 14 times the thickness of the furnace plate when the stays are riveted at their ends, or 16 times when the stays are fitted with nuts. Such screwed stays shall be in diameter over the threads not less than twice the thickness of the furnace plate and in no case less than $\frac{3}{4}$"—diameter (see Reg. 135(d).)

223. Hemispherical Furnaces of Vertical Boilers.— When furnaces are hemispherical in form and subject to pressure on the convex side and are without support from stays of any kind, the maximum working pressure shall be :—

$$W.P. = \frac{275(t-1)}{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn.(60)}$$

t is the thickness of the top plate in 32nds of an inch,

R is the outer radius of curvature of the furnace in inches.

224. Corrugated Fireboxes of Vertical Boilers.—For the semi-spirally corrugated fireboxes of "Sentinel" standard motor wagon boilers the working pressure shall be determined by the following formula :—

$$W.P. = \frac{C\,(t-1)}{D} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn.(61)}$$

t is the thickness of the firebox plate in 32nds of an inch,

D is the mean of the external diameters of firebox measured over the plain part at each end at commencement of curvature of flange.

C = 390.

225. Foundations of Vertical Boiler Furnaces.—Where circular furnaces or fireboxes of vertical boilers are not connected to the shell crown by uptake tube, smoke tubes or bolt stays and the whole load on the firebox vertically is borne by the bottom part of the firebox where it is connected to the shell the working

pressure for the part, if firebox is joggled out to meet the shell or if an ogee ring is fitted, shall not exceed that found by the following formula :—

$$W.\ P. = \frac{140(t-1)^2}{D(D-D_1)} \quad \text{Eqn. (62)}$$

t is the thickness of the joggled firebox plate or ogee ring in 32nds of an inch,

D is the inside diameter of the boiler shell in inches.

D_1 is the outside diameter of the joggled firebox at the commencement of curvature above joggled part or the outside diameter of the firebox where it joins the ogee ring.

226. Foundations of Loco-type Boiler Fireboxes.—Where the fire-box roof in loco-type boilers is not stayed direct to the external casing crown or to girders carried by the casing or is not connected to the casing by slings in accordance with Regulation 229 (c) and the whole load on the firebox vertically is borne by the bottom parts of the firebox where connected to the external casing the working pressure for the parts, if plates are joggled out to meet the casing or if an ogee ring is fitted, shall not exceed that found by the following formula :—

$$W.\ P. = \frac{70\ (t-1)^2 \times (L+W)}{L \times W(W-W_1)} \quad \text{Eqn. (63)}$$

t is the thickness of the joggled firebox side plates or fire hole plate (whichever is less), ogee ring in 32nds of an inch,

L is the length of firebox casing in inches measured between the water sides of front end plate and saddle plate at the foundation seam,

W is the width of firebox casing in inches measured between the water sides casing side plates at the foundation seam,

W_1 is the width of firebox in inches measured between the water sides of fire box side plates at the commencement of curvature above joggled part or where it joins the ogee ring.

Where only a comparatively narrow strip of the firebox roof is stayed directly to the casing crown the area so stayed shall be deducted from the area represented by L × W in the bottom line of the formula thus, $(L \times W - A)(W - W_1)$ and so used in Equation (63) in determining the working pressure for the parts, "A" being the area in square inches of the part of roof supported by the casing crown.

227. Cross Tubes.—The working pressure of the tubes shall be determined by the following formula :—

$$W.\ P. = \frac{200(t-7)}{D} \quad \text{Eqn. (64)}$$

W. P.= Working pressure in lbs. per sq. inch,

t= minimum thickness in 32nds of an inch,

D= the internal diameter in inches of the cross tube.

228. Uptakes of Vertical Boilers.—The working pressure for uptake tubes of vertical boilers shall be determined by Eqns. 57 and 58 but only half the least pressure so found is to be allowed for uptake tubes.

SUPPORTS FOR COMBUSTION CHAMBER AND FIREBOX CROWN

229. Girder stays for firebox crowns.—(a) For girders supporting crown plates of rectangular fireboxes, where the ends of the girders are supported by the vertical end or sideplates, their proportions shall be calculated from the following formula:—

$$W.P. = \frac{C\ S\ T\ d^2}{L^2\ Y} \quad \ldots\ldots\ldots \text{Eqn. (65)}$$

Where WP = Working pressure in lb. per sq. inch,

S = Minimum tensile stress of the material in tons per sq. inch,

T = Total thickness of the stay in thirty seconds of an inch,

d = Depth of the girder stay in inches,

L = Length of girder stay in inches measured between the inside of the tube plate and the firehole plate, or between the inside of the side plates, according to the method of support.

Y = Pitch of girder stays in inches,

C = 22 for steel plates or steel forgings 19 for steel castings.

(b) Where girders are supported in any other way than by the end or side plates of the firebox or combustion chamber the calculations for determining the working pressure shall be made in accordance with the actual conditions of support.

In such cases the length of the strip of firebox or combustion chamber top plate to be supported by the girder shall, subject to the limit imposed on the distance of the nearest stay, be taken as equal to the product of the number of bolts carried by the girder into the pitch of the bolts. A maximum nominal stress of 14,000 lbs. per square inch on girder section shall be allowed for steel.

(c) Slings, links, pins, rivets, and connections to shell of slung girders shall be sufficient to carry the whole load that would otherwise be carried by the girder, and each girder must be equally slung or supported. For stresses allowed on the sections, see Regulation 203.

(d) In the case of girders supported at the ends only by angle bars riveted to the casing crown, the length L may, when the girder extends over the full breadth of the angle face, be taken as the distance between the centres of the angle faces. When this distance does not exceed that of L in the formula, the pressure shall be determined in the ordinary way. The supporting angles and rivets shall be of sufficient section for the intended purpose. For stresses allowed on the sections, see Regulation 203.

PATENT FIREBOX ROOFS OF LOCOTYPE BOILERS

230. Marshall Type.—For Messrs. Marshall Sons and Company's patent stayless roof for fireboxes of locotype boilers made of steel in which the centre lines of the corrugations meet the centre lines of the end riveted seams at points not farther distance from the side plates than one half the inner radius of curvature of the corner formed by the roof and side plate, in order to ensure that the thickness and height of the pressed diagonal corrugations of the camber are satisfactory, the working pressure shall not exceed the smaller of the values obtained from the following formulæ :—

$$W\ P. = \frac{25000\ (t-1) \times H^2}{W \times L \times \sqrt{W^2+L^2}} \quad \ldots\ldots \text{Eqn. (66)}$$

$$W.P. = \frac{55\ (t-1)^2 \times (W \times \sqrt{W^2+L^2})^2}{W^2 \times L^2} \quad \ldots\ldots \text{Eqn. (67)}$$

t is the thickness of the roof plate in 32nds of an inch,

H is the height of the corrugation at its highest part measured perpendicularly on one side of the plate in inches,

W is the width of the roof plate between the flat of side plates at top less the inner radius of curvature of corner of roof and side plate in inches, *i.e.*, W+radius = internal width of firebox at top,

L is the length of the roof plate between centre lines of rivets in inches.

231. Garrett Type.—For Messrs. Richard Garrett and Son's corrugated stayless roof for fireboxes of locotype boilers made of steel in which the side corrugations are parts of true circles and the radius of the middle corrugation is not more than about $\frac{1}{4}$th of the radius of the outer corrugations and the corrugations are cambered longitudinally, the working pressure shall not exceed the smaller of the values obtained from the following formulæ :—

$$\text{W.P.} = \frac{C}{R} \times \frac{(t-1)^2}{(L+24)} \quad \text{Eqn. (68)}$$

$$\text{W.P.} = \frac{C_1}{R} \times [10\,(t-1)-L] \quad \text{Eqn. (69)}$$

t is the thickness of the corrugated plate in 32nds of an inch,

L is the length of the roof plate between centre lines of rivets in inches,

R is the external radius of the side corrugations at the middle of the length in inches,

C = 363 where the roof and side plates are in one piece and 325 when they are riveted,

C_1 = 12·5 where the roof and side plates are in one piece and 11·25 where they are riveted.

232. Fowler Type.—(a) For Messrs. John Fowler and Company's (Leeds) corrugated roof for fireboxes of locotype boilers made of steel in which the crown of the roof is transversely curved and corrugated in the style of Fox's corrugated furnace and the roof plate, if not solid with the side plates of the firebox, is securely riveted thereto and to the flanges of the tube plate and firehole plate and there is a row of suitably sized and spaced screw stays below the commencement of corrugations on each side attaching the roof plate to the external casing, when the conditions hereunder are complied with, the working pressure shall not exceed the smaller of the values obtained from the following formulæ :—

$$\text{W.P.} = \frac{C\,(t-3)}{R} \quad \text{Eqn. (70)}$$

$$\text{W.P.} = \frac{C_1\,(t_1-1)}{W} \quad \text{Eqn. (71)}$$

t is the thickness of roof plate before corrugations are formed, in 32nds of an inch,

t_1 is the thickness of side plates of firebox to which roof plate is attached in 32nds of an inch,

R is the radius of transverse curvature or camber of middle part of corrugation measured from the bottom of corrugation on water side, in inches,

W is the width of firebox in inches measured over water sides of side plates at the seams attaching them to roof plate,

$C = 240$,

$C_1 = 875$,

(b) The corrugations measured from top to bottom on one side, shall not be less than three times the thickness of the finished plate in depth and not more than 12 times the thickness of the finished plate apart.

(c) The inner radius of corner at sides where corrugations merge into the flat sides shall be not less than 4 times the thickness of the finished plate.

(d) The length of the plain parts at ends of roof between the centre lines of riveted seams and commencement of curvature of corrugations shall not exceed that allowed for flat plate margins under Regulation 200.

CHAPTER V

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

GENERAL REQUIREMENTS

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

MATERIALS OF CONSTRUCTION

234. Material For Fusion Welded Boiler Drums.—(a) The requirements of Regulations 9 to 20 so far as they relate to plates, shall apply to steel plates for fusion welded boiler drums excepting that the ultimate tensile stress and elongation of the materials shall be between the limits shown in table below and shall be specified for each component part of the boilers.

Description	Ultimate tensile stress Tons per sq. in.	Minimum elongation per cent. Test piece A or B
Plates for drum shells (*i.e.*, wrapper plates and tube plates).	28-32	20
Drum ends, stand or branch pipes and seatings for mountings.	26–30 or 28–32	23 for 26–30 tons per sq. in 20 for 28–32 tons per sq. in

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

SEAMLESS FORGED DRUMS

235. Process of Manufacture.—Carbon steel for seamless steel drums shall be made by the open hearth or an electric process, acid or basic.

236. Chemical Analysis.—The steel shall contain not more than 0 06 per cent. of sulphur or of phosphorus.

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

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

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

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

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

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

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

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

(b) **Tensile Tests.**—The ultimate tensile stress and elongation shall be between the limits shown below. A range of not more than 4 tons per sq. in. for any one forging shall apply, such range to be specified for each drum.

(i) Ultimate tensile stress 28 to 38 tons per sq. in.

(ii) Elongation 29 per cent. to 19 per cent. determined on British Standard Test Piece C, or a subsidiary standard round test piece (see Appendix B).

In no case shall the sum of the ultimate tensile stress and corresponding elongation be less than 57.

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

(c) **Bend Test Pieces.**—Bend test pieces shall be of rectangular section 1 in wide by $\frac{3}{4}$ in. thick. The edges shall be rounded to a radius of 1/16-in. The test pieces shall be bent over the thinner section.

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

Ultimate tensile stress, Tons per sq. in.	Internal radius of bend Inches
Upto 32	1/4
Above 32 and upto 36	3/8
Above 36 and upto 38	5/8

Bend test may be made by pressure or by blows.

241. 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 test rings. If the results obtained from these re-tests are satisfactory, the drum shall be accepted, provided that in other respects it fulfils the conditions of this Chapter. If these re-tests do not give satisfactory results the drum represented

may be re-heat-treated together with the remainder of the test rings, and presented for further testings.

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

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

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

244. Tubes.—(a) Tubes shall be of cold drawn weldless or hot finished weldless steel and shall comply with Regulations 36 to 56.

Headers.—(b) Headers and similar pressure parts shall be of forged steel, seamless steel tube or of cast steel, to comply with the appropriate Regulations in Chapter II.

245. Pipes.—Pipes forming an integral part of the boiler unit shall comply with the Regulations of Chapter VIII.

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

FUSION WELDED DRUMS

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

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

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

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

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

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

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

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

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

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

Before welding of the joint is commenced (apart from tack welding) the surfaces of the plates of the longitudinal and circumferential seams shall at no part be out of alignment with one another by more than 10 per cent. of the plate thickness, but in no case exceeding 1/8 in. for longitudinal joints or 3/16 in. for circumferential joints.

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

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

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

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

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

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

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

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

255. Position of tube holes.—Tube holes shall not be located in a welded joint. The distance between the edge of a hole and the edge of a longitudinal or circumferential seam shall be not less than 1 in. where the plate has a thickness less than 1 in. In plates 1 in. to 2 in. thickness the minimum distance shall be not less than the thickness of the plate. For plates of thickness greater than 2 in. the minimum distance shall be 2 in.

NOTE.—The edge of the weld shall be considered as the edge of the weld groove as machined in the plate prior to welding.

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

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

Nominal internal diameter of drum	Percentage of nominal internal diameter
Inches	
Up to and including 36	0 375
Over 36 up to and including 45	0 35
Over 45	0·3

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

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

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

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

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

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

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

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

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

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

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

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

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

(j) For heat treatment see Regulation 267.

(k) If any defects in the weld metal of a test plate are revealed by radiographical examination, the position of these shall be clearly marked on the plate and test pieces shall be selected from such parts of the test plates as may be decided by the Inspecting Authority.

258. Selection of Test Pieces.*—(a) From the test plate or plates on each longitudinal seam, test pieces shall be selected for the following tests, the specimens being cut out as shown in Figs. 16 and 17 and stamped by the Inspecting Officer for identification :—

(i) One tensile test specimen for the welded joint.
(ii) One all-weld metal tensile test specimen.
(iii) Two bend test specimens.
(iv) Two Izod impact test specimens.
(v) One specimen for micro and macro examination.

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

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

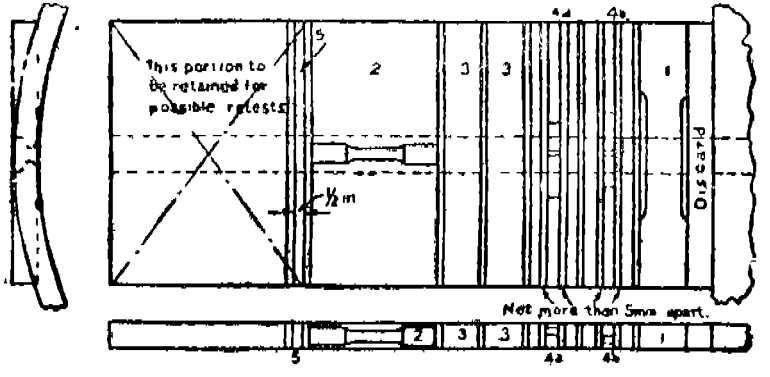


Fig. 16.—Details of test plates.

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

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

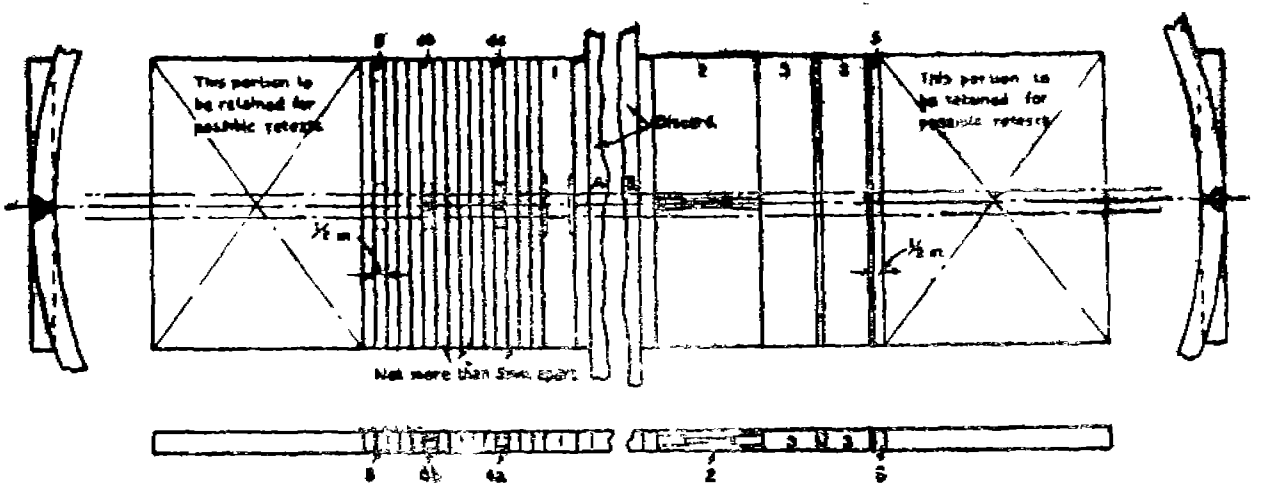
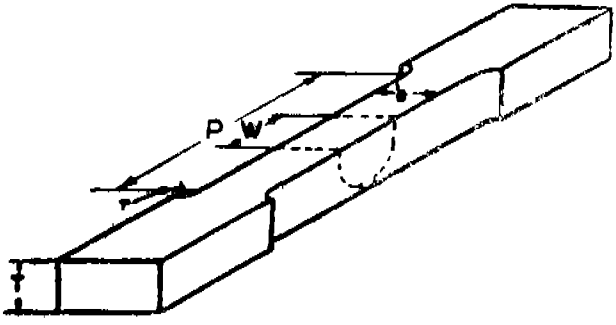


Fig. 17.—Details of test plates.

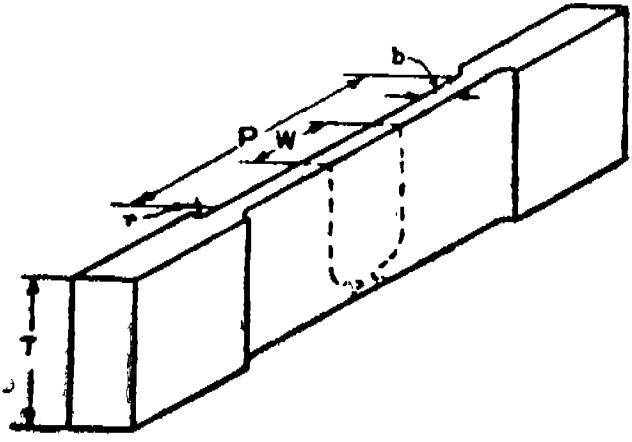
1. Tensile test for joint.
2. Tensile test for all-weld metal.
3. Bend tests, outer and inner surfaces of plates (at weld).
4. a Izod impact test, outer surface of plate
   b. Izod impact test, inner surface of plate.
5. Micro and macro specimen.

259. Tensile Test Pieces—(a) **Welded Joint.**—The dimensions of the specimens shall be in accordance with the sketch in Fig. 18. Specimen 1, and the specimen shall be cut transversely to the welded seam. When the capacity of the available testing machine does not allow the full specimen to be tested, two narrower tensile specimens shall be substituted. These specimens shall be the full thickness of the plate at the welded joint and their breadths shall be as great as the testing machine will reasonably allow, provided the effective cross sectional area of the test piece is not less than 1½ sq. in. (see Fig. 18 Specimen 1a).

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



Specimen 1: Tensile test for joints.



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

Fig. 18.—Tensile test pieces.

T = Thickness of plate.

b = Breadth of test piece :

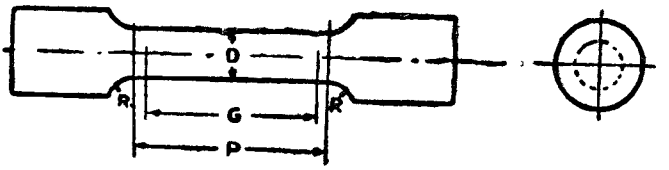
Specimen 1. Not less than T and in no case less than 1½ in.

Specimen 1a. T × b not less than 1½ sq . in.

W = Width of weld groove.

P = Parallel length, minimum = 3 × W.

r = Radius at shoulder, minimum = ½ in.



Specimen 2

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

Diameter D	Cross-sectional area A	Gauge length G	Parallel length P minimum	Radius at shoulder R minimum
in.	in.	sq. in.	in.	in.
0·798	0·5000	2·82	3·18	0·70
0·564	0·2500	2·00	2·25	0·50
0·505	0·20	1·79	2·01	0·45
0·479	0·18	1·70	1·91	0·42
0·452	0·16	1·60	1·80	0·40
0·437	0·15	1·55	1·74	0·39
0·424	0·1412	1·50	1·69	0·37
0·399	0·1250	1·41	1·58	0·35
0·357	0·1000	1·26	1·42	0·31

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

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

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

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

(b) Where plate thicknesses do not exceed, 1, 1/4-in. the thickness of the specimen shall be equal to the full thickness of the test plate Where the plate thickness exceeds 1, 1/4-in. the specimen shall in all cases have a thickness of at least 1, 1/4-in. The specimen to be tested with the outer surface of the weld in tension shall be prepared by cutting to waste the metal local to the inner surface of the weld so that the desired specimen thickness is obtained (see Fig. 20, Specimen A). The specimen to be tested with the inner surface in tension shall be prepared by cutting to waste the metal local to the outer surface of the weld so that the desired specimen thickness is obtained (see Fig. 20, Specimen B). Where the thickness of the plate permits, both specimens may be cut from the same piece of plate, the specimen being located in the plate one above the other (see Fig. 20, Specimen C).

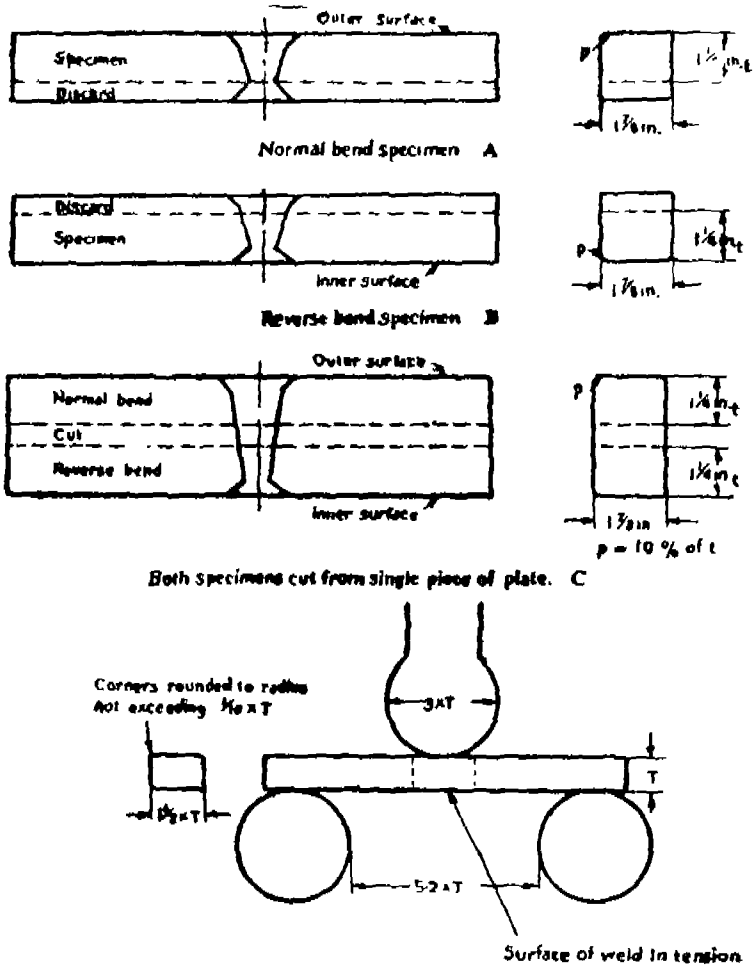


Fig. 20.—Specimen 3 Bend Test.

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

On completion of the test no crack or defect on the outer surface of the specimen shall be greater than 1/16 in. measured across the specimen or 1/8 in. measured along the length of specimen. Premature failures at the corners of the specimen shall not be considered cause for rejection.

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

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

The tests shall show a minimum Izod impact test-value of 30 ft. lb.

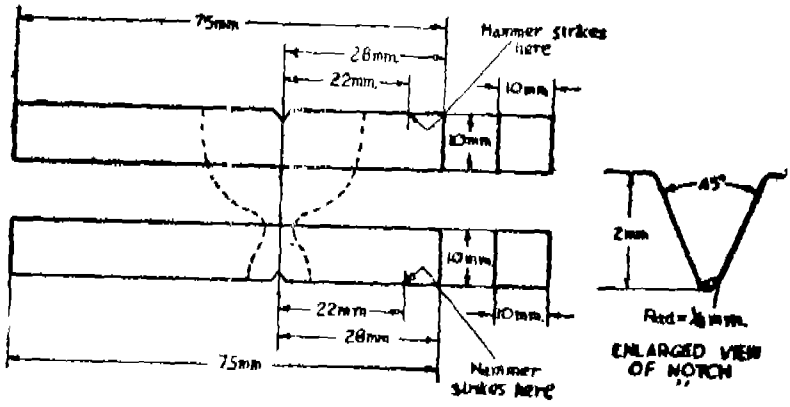


Fig. 21. Specimens 4a and 4b Izod impact test pieces.

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

(i) Reduction in area 30 per cent.

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

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

(c) If an Izod impact test fails to meet the specified requirements, two re-tests shall be taken from the test plate, one each side of the original specimen and separated from it by not more than 5 mm. Both re-tests shall show a minimum Izod impact test value of 30 ft. lb.

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

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

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

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

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

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

REPAIRS TO WELDED SEAMS AFTER RADIOGRAPHICAL EXAMINATION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

HEAT TREATMENT

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

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

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

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

(e) For this heat treatment the drum shall be placed in a furnace sufficiently large to accommodate to the whole drum. The furnace shall be slowly raised to a temperature between 600°C. and 650°C. and the drum shall remain until it has, uniformly reached this temperature. Such temperature shall be sustained for 75 to 90 minutes per 1 inch thickness of metal. The drum may be allowed to cool in the furnace, but, if withdrawn, shall be screened from draughts whilst cooling.

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

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

Rate of heating.

Maximum temperature.

Time held at maximum temperature.

Conditions of cooling.

HYDRAULIC AND HAMMER TESTS

268. Each drum on completion of all welding and after heat treatment shall be subjected to a hydraulic test pressure of one-and-a-half times the boiler drum maximum permissible working pressure, and while the pressure is applied the welds shall be given a thorough hammer test throughout their length, care being taken to avoid damage to the surface of the plates.

After this the pressure shall be raised to twice boiler drum maximum permissible working pressure and be maintained for a length of time sufficient to enable an inspection to be made of all seams and connections, but for not less than half an hour.

INSPECTION AND TESTING

269. Inspection during construction.—Inspection shall be made at least at the following stages of construction :—

(i) When the test plates are ready for stamping for identification and before they are cut from the parent plate or plates.

(ii) When the drum shell plates are bent to the circular form, the drum ends are flanged, the welding grooves are machined, and the parts are assembled ready for welding.

(iii) When welding is in progress.

(iv) When welding at the outside surface has been completed.

(v) When the inside surface has been prepared for welding and before the outside surface is dressed.

(vi) When the seams are dressed.

(vii) When the seams are being radiographed.

(viii) When the openings are prepared for stand pipes and seatings, and these are being welded in place.

(ix) When the drum has been heat treated, prior to the hydraulic test.

(x) When the test plates are ready for marking off the test specimens.

(xi) When the test specimens have been machined and are ready for testing.

(xii) When the drum is ready for hydraulic test.

(xiii) When the tube holes are bored and the drum is completed.

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

SHELLS

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

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

T = Thickness in inches.

D = Maximum internal diameter in inches.

WP = Working pressure in lb. per sq. inch.

f = Permissible working stress in lb. per sq. inch at working metal temperature (See Reg. 271).

E = Efficiency of Ligaments between tube holes or other openings in shell or of longitudinal joints (expressed as a fraction) whichever applies.

In the particular case of an unpierced wrapper plate of a fusion welded drum E=1 and f=permissible stress on butt weld from the table in Reg. 271, column B.

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

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

(*ii*) All tubes shall be carefully expanded into the holes in the tube plates. The tubes shall be belled of bead'd to resist withdrawal and if belled they shall project through the parallel tube seat at least $\frac{1}{4}$ inch.

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

TABLE

Outside diameter of tube	Amount of diameter of belling over diameter of the tube hole
	in.
Upto and including $1\frac{1}{2}$ in.	3/32
Over $1\frac{1}{2}$ in. upto and including 2 in. . . .	4/32
Over 2 in. upto and including $3\frac{1}{4}$ in.	5/32
Over $3\frac{1}{4}$ in. upto and including 4. in. . . .	6/32

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

(*e*) Where the tubes are practically normal to the tube plate or the header this parallel seating shall, wherever practicable, be no less than $\frac{3}{8}$ in. in depth

271. Permissible working stresses for shells of Boiler and Integral Superheater drums and headers.— The maximum permissible stresses for drum shells and headers shall be as given in the Table below :—

Working metal temperature	Permissible stress for steel having an ultimate tensile stress in tons per sq. in. of :				
	28-32			32-36	34-38
	Wrapper plates of riveted and seamless forged drums	Butt welds of fusion welded drums	Tube plates of riveted fusion welded seamless forged drums and headers	Seamless forged drums and headers	Seamless forged drum and headers
	lb. sq. in.	lb./sq. in.	lb./sq. in.	lb./sq. in.	lb./sq. in.
	A	B	C	D	E
Upto—					
650°F . .	15 700	14 000	14 300	16 400	17 300
700°F . .	15 200	13 500	13 800	15 600	16 500
750°F . . .	13 400	11 900	12 300	13 600	14 200
800°F	11 300	9 900	10 500	11 200	11 600
850°F .	8 900	7 000	8 500	8 900	9 100
900°F	6 300	5 700	6 300	6 300	6 300

Intermediate values may be interpolated.

The working metal temperature shall be taken as :—

(*a*) For saturated steam, water and muddrums, the saturation temperature corresponding to the pressure WP plus 50°F

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

Where the drums are adequately protected from the gases of combustion or swept by such gases in the third or subsequent pass of a boiler, the working metal temperature shall be taken as the saturation or designed maximum steam temperature as defined above, whichever applies A covering of refractory or insulating material which may be liable to become dislodged shall not be deemed adequate protection.

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

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

273. Longitudinal Stress.—The maker of the boiler and the Inspecting Authority concerned shall be responsible for ascertaining that the longitudinal stress resulting from the combination of stress arising from internal steam pressure, the self weight of the drum and its contents, and all externally applied loads, shall not exceed the permissible working stress corresponding to the working metal temperatures included in Regulation 271.

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

END PLATES

275. Shape of Dished End Plate.—Where an end plate is dished to semi ellipsodial or partial spherical form, the maximum radius of dishing shall not be greater than the inside diameter of the shell to which the end is attached and the corner radius measured to the mean thickness shall be not less than four times the thickness of the end plate or $2\frac{1}{2}''$ whichever is the greater.

276. General.—The thickness T to be used in the formulae is the thickness of the plate after pressing and is applicable over the whole area of the end plate up to the point where the dishing radius joins the corner radius. From this point a gradual thinning is permissible upto a maximum of 10% of the thickness T at the point where the corner radius joins the straight portion of the flanged end plate. This permissible reduction in thickness applies also to the flange for the manhole opening. In no case, however, shall the thickness of the edge of the flange for connection to the shell be less than the thickness of an unpierced seamless shell of the same diameter and material.

277. End Plate with Manhole. (*a*) When an end plate has a flange in manhole or access opening the thickness shall be increased by not less than 15% of the thickness computed by the formula for an end plate without an opening but in no case shall this increase be less than $\frac{1}{8}''$.

(*b*) The depth of the flange forming the access opening measured from the outer surface of the plate at the minor axis of the opening shall be not less than $\sqrt{T \times W}$ (Eqn. 73).

Where T = Thickness of the end plate in inches ;

W = Length of minor axis in inches when full compensation is provided for an access opening cut in a dished end plate, no additional thickness is necessary.

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

$$WP = \frac{2f\,(T-0{\cdot}06)}{DFK} \qquad \text{(Eqn. 74)}$$

WP = Working Pressure in lb./sq. in.

f = Permissible stress in lb./sq. in. at working metal temperature (See table below).

T=Thickness of end plate in inches.

D=Mean Diameter of end plate in inches.

F=1 for end plate without holes, or having only reinforced holes, or having widely spaced unreinforced holes with diameter no greater than $2\frac{1}{2}$".

=1·15 for end plates having a flanged-in-manhole (complying with Eqn. 73).

K=Factor dependant upon the ratio h_e/D_1 where h_e is effective external height and obtained from the curve shown in fig. 22.

h=Mean height of dishing in inches as in Fig. 23.

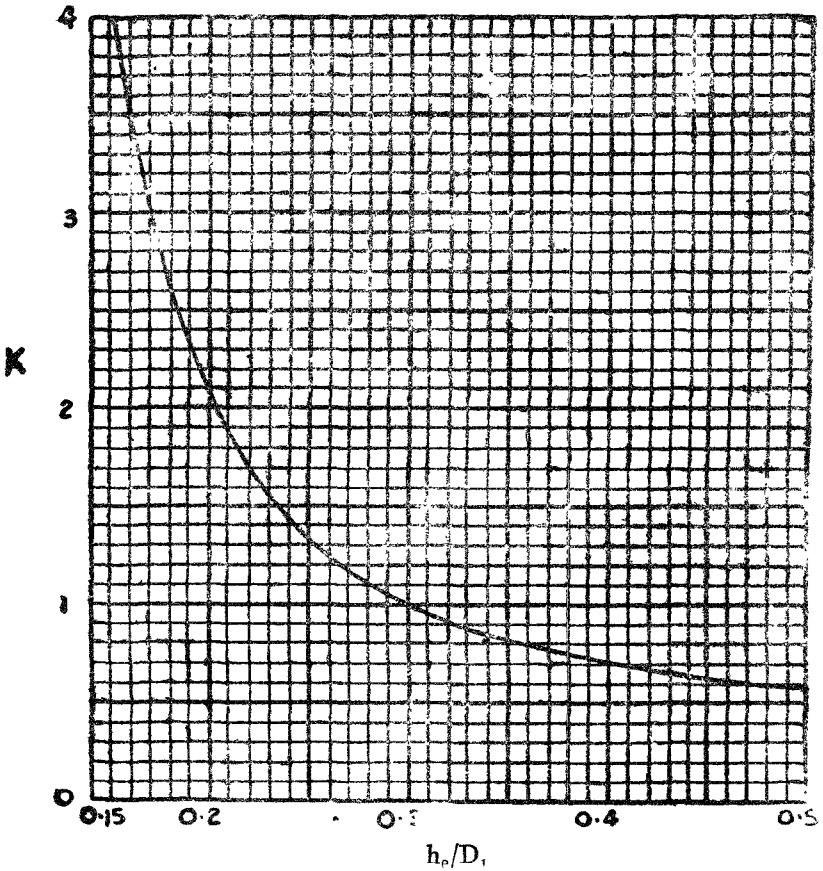
or

$$=R-\sqrt{\left(R-\frac{D}{2}\right)\left(R+\frac{D}{2}-2r\right)} \quad . \quad . \quad . \quad . \quad \text{(Eqn. 75)}$$

R=Mean radius of dishing in inches.

r=Mean corner radius of flange.

D_1=Outside diameter of Drum end in inches.



(*b*) *Maximum permissible stress of steel*

Working metal temperature	Tensile Strength of Plate in lbs. per sq. inch.				
	24—28 tons per sq. in.	26—30 tons per sq. in.	28—32 tons per sq. in.	32—36 tons per sq. in.	34—38 tons per sq. in.
Upto—					
650° F . . .	13440	14560	15700	17900	19000
700° F . . .	13000	14100	15200	17400	18500
750° F . . .	11600	12600	13400	15200	16100
800° F . . .	10000	10700	11300	12700	13300
850° F . . .	8200	8650	8900	9600	9900
900° F . . .	6300	6300	6300	6300	6300

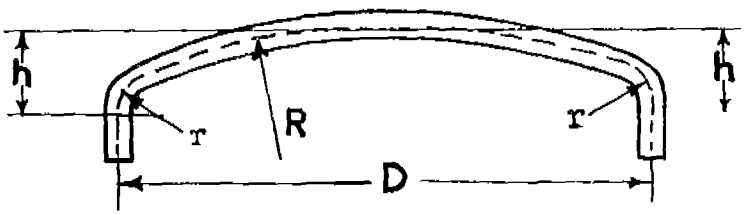


Fig. 23

STAND PIPES OR BLOCKS

279. Compensations.—(*a*) Except for those cases where no compensation is necessary as defined in Regulation 187 adequate compensation for the hole cut for stand pipe shall be provided. Compensation shall be considered adequate when the equivalent cross sectional area provided is not less than 1·25 times the cross sectional area obtained by multiplying the diameter of the hole cut in the shell by the thickness required for an equivalent unpierced drum shell.

(*b*) The equivalent cross sectional area provided shall be calculated as follows :—

(1) The cross sectional area of the wall of the stand pipe upto a point 4 in from the outside surface of the drum shell, but proportionately reduced in the ratio of the ultimate tensile stresses of the metals composing the stand pipe and the drum shell.

(2) The cross sectional area of the welding fillets external to the drum shell.

(3) The area obtained by multiplying the difference between the actual drum shell thickness and the thickness of an equivalent seamless unpierced drum shell by a length 2 $(3+T_s)$. (See Fig. 25).

(*c*) In cases where the total compensation obtained by the sum of the areas iven above is less than the total compensation required, a compensating plate

shall be fitted to the drum shell at the stand pipe and secured by fillet welds as shown in Fig. 26.

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

(*d*) The minimum thickness of the flanges and of the body of stand pipes shall be in accordance with the table under Reg. 156.

280. Attachment of Stand Blocks.— (*a*) The method of attachment shall be in accordance with that shown in Figs. 24, 25, 26 or 27 and after the welding the parts shall be heat treated. The hole drilled in the shell plate for the reception of the stand pipe shall be $\frac{1}{8}$ in. greater in diameter than the outside diameter of the stand pipe where this is secured by fillet welds only as in Figs. 24 and 25.

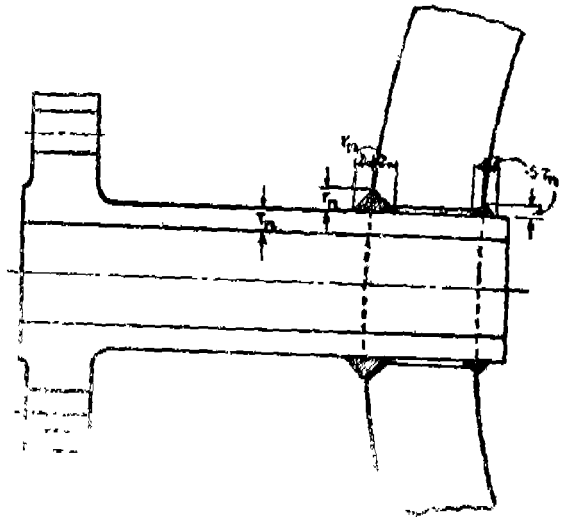


Fig. 24.—Minimum weld attachment for stand pipes 2 in. bore and under.

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

(*c*) Where one side of a double Vee weld has been completed, the under surface of the original first run of metal shall be chipped out before welding on the other side is commenced.

(*d*) The final finish of the weld shall be such that change of section from shell to nozzle is gradual and free from sharp notches.

(*e*) So far as the attachment of flanges to standpipes is concerned construction shown in Figs 28 & 29 shall be permissible.

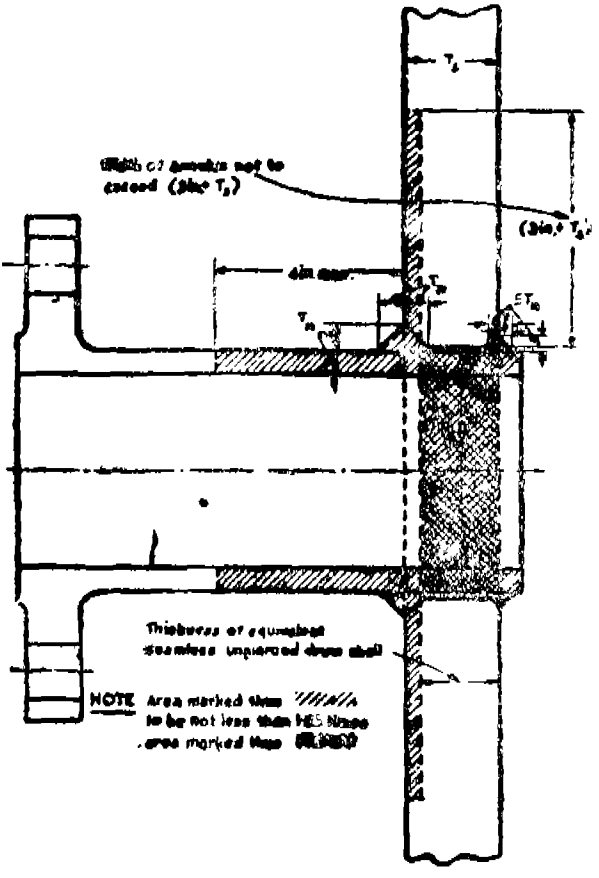


Fig. 25.—Minimum weld attachment for stand pipes over 2 in. bore upto and including 4 in. bore.

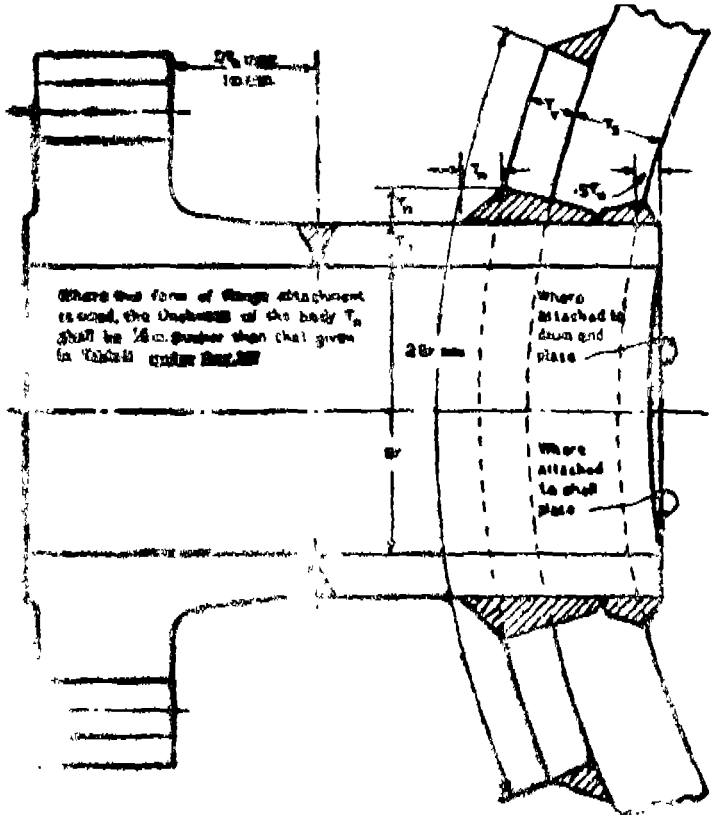


Fig. 26.—Minimum weld attachment for stand pipe over 4 in. bore where compensating ring is required and for attachment of flange to stand pipes 6-in. bore and over. (Alternative to flange attachment shown in Fig. 27).

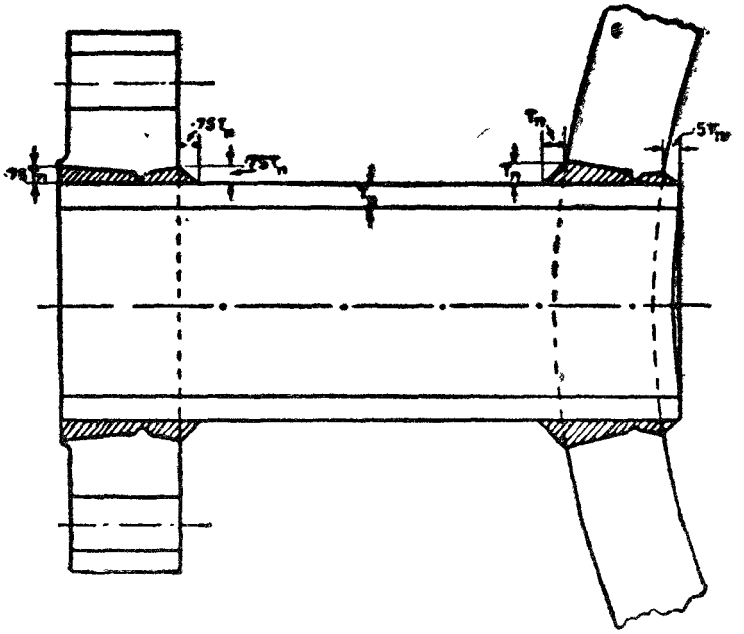


Fig. 27.—Minimum weld attachment for stand pipes over 4 in. bore where a compensating ring is not required and minimum weld attachment of flange to stand pipes over 4 in. bore.

CHAPTER VI

VALVES, GAUGES AND SIMILAR FITTINGS

281. *Requisite Mountings and Fittings.—Every boiler shall be fitted at least with the following:—

Two safety valves (Minimum diameter 3/4")
Two independent means of indicating the water level;
A steam pressure gauge,
A steam stop valve;
A feed check valve;
Two means of feeding the boiler when the heating surface exceeds 200 sq. feet;
A blow down cock or valve;
A fusible plug when boiler has internal furnaces.
An attachment for Inspector's test gauge.
A manhole, where the size and construction permit, and such mudholes or sightholes as are necessary for effectively cleaning the boiler

GENERAL REQUIREMENTS

Materials, Temperature and Pressure Limits

282. (a) **Materials.**—The materials used in the manufacture of the bodies of the fittings shall comply with the following requirements:—

*NOTE.—It is recommended that in Lancashire and Cornish Boilers one of the safety valves should be of High steam and low water type In water tube and horizontal multitubular boilers a low water alarm should be fitted Ramsbottom type safety valves consisting of two valves with spring and lever in common may be considered as two safety valves for the purpose of this Regulation

In the case of marine type boilers low water alarm may be fitted in place of a fusible plug.

(i) *Steel castings shall comply with 28 tons grade II. See Regulations 73 to 80.

(ii) Steel forgings shall comply with Regulations 81 to 85.

(iii) Iron castings shall comply with Regulations 86 to 93.

(iv) Bronze castings shall have a tensile breaking strength of not less than 16 tons per sq. in. with an elongation of not less than 8·0 per cent. measured on standard test piece C.

(v) The seats and discs of valves shall be made of non-corrodible metal.†

(b) **Limits of Cast Iron.**- Cast iron shall not be used for :—

(i) Temperatures above 400°F.

(ii) Steam pressures exceeding 160 lbs. per sq. in. (gauge).

(iii) Feed valves and scum valves directly attached to boilers for pressures above 160 lbs. per sq. in. (gauge).

(iv) Blow-down fittings.

(c) **Limits of Bronze Fittings.**—Bronze shall not be used for steam temperature above 425°F.

METHOD OF CONSTRUCTION

283. Castings.—(a) All castings shall be smooth, sound and free from flaws, cracks or other injurious defects. Variations in thickness at any part shall be gradual, and substantial fillets shall be provided.

(b) The body of a boiler mounting shall be connected to the boiler flange by a strong and stiff neck. In no case shall the thickness of the neck of bronze mountings be less than 3/16 inch for sizes up to and including 3/4 inch bore or 1/4 inch for sizes over 3/4 inch bore.

284. Packing of Cocks.—The bodies of all cocks except those for pressure gauges shall be packed with asbestos or other heat resisting material and shall be of substantial design, those over one inch bore shall have special provision, other than the gland for securing the plug.

Water gauge column cocks may be either asbestos packed or solid plug type.

285. Covers and Spindles.—(a) Valves of 1½ inch bore and over directly connected to boilers, and other valves of 2½ inch bore and over where fitted with a cover shall have such cover secured by bolts or studs and the screwed portion of the spindle shall be outside the stuffing box. All valves for superheated steam shall be fitted with an external screwed spindle.

(b) Where the covers of valves are secured by studs, the studs shall be screwed into the body with full thread for a length of at least one diameter. The stud holes shall not penetrate into the pressure space of any casting.

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* NOTE.- Steel castings which will be subject to the action of feed water shall be made of steel of which the manganese content does not exceed ·8 per cent.

†By non corrodible metal is meant metal specially resistant to corrosion and/or erosion.

(c) Valves with screwed covers shall be fitted with a suitable locking device to prevent rotation of the cover.

286. Direction of Operation.—Valves shall be clearly marked to indicate the direction of flow. Valves directly connected to boilers shall be fitted with indicators to show clearly whether the valve is closed or open and all valves shall open by ante-clockwise rotation.

287. Moving Parts.—The valves and spindles shall be efficiently guided and means shall be provided in every case to prevent them leaving their guides. The working parts shall have sufficient clearance to ensure freedom of movement under all conditions of service.

288. Flanges.—(a) Flanges shall be in accordance with the tables for the appropriate pressure. (App. E).

(b) In the case of safety valves, the drilling, thickness and bolting of inlet flanges shall be in accordance with tables for the appropriate pressure and material and for the diameter of flange adopted. In the case of outlet flanges the pressure taken shall be the pressure on the outlet side of the valve.

(c) For the purpose of determining particulars of flanges for blow down and scum pipe fittings, the design pressure of the fittings shall be assumed to be the working pressure of the boiler.

(d) All flanges shall be machined on the face, spot faced, or machined at the back, and the bolt holes shall be drilled.

289. Valve Seatings.—Where separate seats are fitted they shall be efficiently secured. Means shall be provided in every case to prevent the valves leaving their guides.

290. Chests etc., in General.—(a) All chests and fittings shall be smooth, sound and free from flaws, cracks or other injurious defects. After completion they shall withstand satisfactorily a hydraulic test to at least twice the working pressure of the boiler for which they are intended.

(b) Valves may be fabricated from seamless steel pipes for pressures not exceeding 250 lbs. per sq. in. and temperatures not exceeding 800° F The welding should conform to Regulation 125 and the valve chests should [illegible] ess relieved after fabrication. The working pressure of the valves shall [illegible] mined from equation 91 where 2 Se shall be substituted by 1·8 S. The wal[illegible] ness shall not be less than 3/8″. They shall withstand satisfactorily a hydr[illegible] to at least twice the working pressure of the boiler for which they are in[illegible]

(c) The working pressure and thickness of the chests shall [illegible] ined by the following formulae (Subject to the minimum thickness in R[illegible] 283(b).

$$W.P. = \frac{C\,(t-X)}{D} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad F[illegible]$$

$$= \frac{W.P. \times D}{C} + X \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [illegible]$$

D is the internal diameter of the chest in inch[illegible]
t is the thickness of the chest in 32nds of an in[illegible]
C is a co efficient from the following table,

X is a provision for tolerance, etc., from the following table :—

Table of Values of C and X

Material of Casting	C	X
Cast iron, at least 10 tons tensile strength	160	6
Bronze, at least 16 tons tensile strength	175	4
Cast steel, 28/35 tons tensile strength—		
For temperature up to 550°F.	350	8
For temperature up to 600°F.	315	8
For temperature up to 650°F.	280	8
For temperature up to 700 F.	265	8
For temperature up to 750°F.	252	8
For temperature up to 800°F.	236	8
For temperature up to 850°F.	220	8
For temperature up to 900°F.	154	8

Intermediate values may be interpolated.

SPECIAL REQUIREMENTS

Safety Valves

291. General.—Safety valves, ordinary, high lift and full lift, shall be so constructed that breakage of any part will not obstruct the free and full discharge of steam from the boiler.

292. Definitions.—(a) An *ordinary* safety valve is a valve which lifts automatically at least D/24, where D=diameter of valve seating.

(b) A high lift safety valve is a valve which lifts automatically at least D/12, where D=diameter of valve seating.

(c) A full lift safety valve is a valve which lifts automatically a distance giving a discharge area round the edge of the valve seating equal to the area through the valve orifice, when the valve is fully lifted, after deducting the area of guides or other obstructions.

293. Minimum Aggregate Area.—(a) **Saturated Steam.**—The minimum aggregate area of the orifices through the seatings of the safety valves on each boiler* (including high steam and low water safety valves) shall be found by the following formula :—

$$A = \frac{E}{CP} \quad \text{Eqn. (78)}$$

Where A=for ordinary and high lift safety valves the aggregate area in square inches of the orifices through the seatings of the valves.

=for full lift safety valves the nett area in square inches through the seats after deducting the area of guides or other obstructions when the valves are fully lifted.

E=total peak load evaporation in lbs. per hour (including evaporation from water walls, steaming economiser, and other heating surface in direct communication, with the boiler), for which the boiler is specified. In no case, however, shall the evaporation as calculated for this purpose,be based on less than 6 lbs. per hour per sq. ft. of heating surface (exclusive of superheater and non-steaming economiser).

*Subject to the application of Eqn. 79 the term "boiler" shall include any superheater fitted to the boiler without an intervening stop valve.

P=absolute pressure in lbs. per sq. in. to which the safety valve is set.

C=a constant as follows :—

Type of Valve	Spring loaded Valves, Direct and Lever C.	Weight loaded Valves, Direct or Lever C.
Ordinary Valves	4	4·8
High Lift Valves	8	9·6
Full Lift Valves	16	16

For water tube boilers of evaporative capacity greater than 10,000 lbs. of water per hour C may be increased as follows:—

Type of Valve	Spring loaded Valves, Direct and Lever C.	Weight loaded Valves, Direct or Lever C.
Ordinary Valves	4·8	4·8
High Lift Valves	9·6	9·6
Full Lift Valves	20	20

Where two valves are loaded by a single spring the above areas shall be increased by 50 per cent.

(b) **Superheated Steam.**—If the valves have to pass superheated steam the area shall be determined in accordance with the following formula :—

$$As = A\left(1 + \frac{1 \cdot 5T}{1000}\right) \quad \text{Eqn. (79)}$$

Where As=area in sq. inch for superheated steam.

A=Area in sq. inch for saturated steam.

T=degree of superheat in deg. Fahr.

294 Over Pressure.—The valves shall be so designed that the maximum peak load evaporation for which the boiler is specified will be completely discharged with a rise in pressure of not more than 10 per cent. of the safety valve blow-off pressure.

295. Pressure Drop.—The valves shall shut down at a pressure (a) not more than 5 per cent. and (b) not less than $2\frac{1}{2}$ per cent. below the safety valve blow-off pressure. For valves less than $1\frac{1}{4}$ inch diameter the limits shall be increased to (a) 10 and (b) 5 per cent. respectively. Valves for superheated steam and for water tube boilers of an evaporative capacity greater than 10,000 lbs. of water per hour shall be exempt from the minimum requirements (b).

296. Attachment to Boiler.—(a) All the safety valves of a boiler may be fitted in one chest but, with the following exception, such chest shall be separate from any other valve chest.

In the case of boilers with overhead engines where the cylinder casting is mounted directly on the shell, the safety valves may be attached to the engine cylinder casting, provided that the passage way to the valve complies with the above rules.

(b) The chest shall be connected to the seating by a strong and stiff neck, the passage through which shall have a cross sectional area at least equal to the sum of the areas of the valves.

(c) Safety valves shall be mounted so that the axis of the valve is vertical.

(d) Shut-offs or obstructions or any description shall not be placed between the boiler and the safety valve.

(e) The inlet and outlet flanges shall be drilled in accordance with the appropriate table in App. E for the diameters of flanges adopted.

297. Openings in Shell.—No accessories other than those integral with the Safety Valve shall obstruct the openings in the boiler shell. Discharging steam shall have direct access to the safety valve without flowing through internal pipes.

298. Discharge Passage.- Steam Safety Valves.—The area of the waste steam passage both in the valve itself and in the escape pipe, shall be not less than $\frac{E}{4P}$ sq. in. for ordinary valves, $\frac{E}{6P}$ sq. in. for high lift valves, and $\frac{E}{9 \cdot 6P}$ sq. in. for full lift valves.

Where E and P are as defined in Reg. 293.

299. Drainage.—For each enclosed safety valve chest a means of draining shall be provided. The drain pipe shall be laid with a continuous downwards gradient clear of the boiler to a place where the discharge is visible and cannot do injury to any person.

300. Moving Parts.—The valves and spindles shall be efficiently guided and means shall be provided in every case to prevent their lifting out of their guides. The working parts shall have sufficient clearance to ensure freedom of movement under all conditions of service. The spindle shall not be fitted with a stuffing box.

301. Bearings for Levers.—The bearings of the levers of lever valves shall be so designed as to allow of free working of the valve under all conditions of service. Where the lever is mounted on pin bearings, the holes in the lever shall be bushed with non-corrodible metal, or the pins shall be of non-corrodible metal.

302. Attachments of Weights and Springs.—(a) In a lever and weight safety valve the weight shall be in one piece and attached to the lever in such a way that the safety valve cannot be overloaded.

(b) In the case of spring loaded safety valves, washers or ferrules shall be fitted under the adjusting screws so that the valves cannot be overloaded when under steam. Where springs are in tension, links or other suitable stops shall be fitted to prevent the spring being extended a greater amount than that corresponding to a valve lift of D/4,

where D=diameter of valve seating.

303. Easing Gear.—Safety valves shall be so arranged that they can be eased off their seats when under pressure and the easing lever shall positively lift the valve.

304. Lift.—Safety valves shall be capable of being lifted a distance such that the area of the discharge edge shall be not less than the minimum aggregate area, A in Reg. 293.

305. High and Low Water Alarms.—High and low water alarms shall be adjusted so that the alarm is sounded with the water level visible in the gauges.

306. Final Setting.—Each safety valve shall, before leaving the maker's works be adjusted to blow-off at the specified pressure.

SPRINGS

307. Materials.—(a) The springs shall be manufactured from steel made by the Acid or Open Hearth process and shall show an analysis the following composition :—

Carbon	not less than 0·9 per cent and not more than 1·2 per cent.
Manganese	not less than 0·45 per cent. and not more than 0·75 per cent.
Silicon	not more than 0·30 per cent.
Sulphur	not more than 0·05 per cent.
Phosphorus	not more than ·05 per cent.

The manufacturer shall supply an analysis of each cast when required to do so. Should independent analysis be required, these shall be made at the rate of one per cast.

(b) All springs shall be formed hot and shall be hardened in oil and suitably tempered.

308. Dimensions.—The compression or extension of safety valve springs required to load the valves to the set pressure shall not be less than one quarter of the diameter of the valve, due consideration being paid in the case of spring loaded lever safety valves to the ratio of leverage.

The proportion of unloaded length to external diameter of the spring shall not exceed 4 to 1.

309. Determination of Working Pressure.—The maximum working pressure to be allowed for steel springs of round, square or rectangular section shall be determined from the following formulae :—

(a) Round section

$$W.P.=\frac{10{,}000\ d^3}{DACK} \quad \text{Eqn. (80)}$$

(b) Square section.

$$W.P.=\frac{33{,}333\ d^3}{DACK} \quad \text{Eqn. (81)}$$

(c) Rectangular section.

$$W.P.=\frac{160{,}000B^2\ H^2}{DACK\ (3B+1\cdot8H)} \quad \text{Eqn. (82)}$$

Where (all dimensions in inches) :—

$$K=\frac{4\frac{D}{d}-1}{4\frac{D}{d}-4}+\frac{\cdot615}{\frac{D}{d}}$$ (In case of rectangular section substitute B for d) Eqn. (83)

W.P.=Working pressure in lb. per square inch (set pressure).

A=Loading area of valve.

d=diameter of round of side of square steel.

B=Breadth of wire (radial to spring axis).

H=Depth of wire (parallel to spring axis).

D=Mean diameter of coil.

$$C = \text{Constant} = \frac{L_1 + L_2}{L_1} \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (84)}$$

L_1=Initial compression or extension of the spring to give the required loading. (W.P.×A.)

L_2=The further compression or extension of the spring to give the lift as defined in Regs. 293, and 304.

Examples:—

C=2 where compression or extension of spring to give the required loading is $\frac{1}{2}$ diameter of valve.

C=1·5 where compression or extension of spring to give the required loading is $\frac{1}{3}$ diameter of valve.

C=1·25 where compression or extension of spring to give the required loading is full diameter of valve.

NOTE.—The above formulae are based on a maximum allowable safe stress on the section of the springs of 80,000 lbs. per square inch.

310. Tests.—Compression springs shall not show any permanent set after being compressed coil to coil six times in a quick acting scrag. Extension spring shall not show a permanent set after being tested to 25 per cent. in excess the load necessary under working conditions to lift the valve.

311. Extension Springs.—Extension springs shall be made from round section wire.

312. Number of Effective Coils.—The number of effective or free coils in a compression or extension spring shall be determined from the following formulae :—

(i) **For Round or Square Wire**

$$N = \frac{K \times C \times d^4}{S \times D^3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (85)}$$

(ii) **For Rectangular Wire**

$$N = \frac{66B^3H^3K}{(B^2+H^2)\ SD^3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (86)}$$

Where N=Number of effective coils.

K=Compression or extension in inches at set pressure.

C=22 for round, 30 for square steel.

d=diameter or side of square steel in 16ths of an inch.

S=Load on spring in lb. at blow off pressure.

D=Mean diameter of coil in inches.

B=Breadth of wire in 16th of an inch.

H=Depth of wire in 16th of an inch.

313. Spacing of Coils.—The space between the coils, when the valve is lifted one-fourth of its diameter shall be not less than 1/16 in.

The springs shall be coiled in such a manner as ensures the coils being uniformly spaced and the sides to be parallel to the axis of the spring.

314. Finishing of Ends.—Compression springs shall have their ends ground flat and smooth and at right angles to the axis of the spring over the full circumference so that when placed on end the springs will stand perpendicular.

STOP VALVES

315. Lever Valves.—Where the valve is operated by means of a lever, whether hand or mechanically controlled, the lever shall be of ample strength and the bearings shall be so designed as to allow of free working of the valve under all conditions of service.

316. Steam Stop Valve.—(a) A steam stop valve shall be fitted between the boiler and the steam pipe and, except in the case in which a superheater forms an integral part of the boiler itself (e.g. in the Babcock and Wilcox water tube boiler) between the boiler and the superheater. Where two or more boilers are connected with a steam receiver or any other vessel, a steam stop valve shall be fitted between the boiler and such receiver or vessel.

(b) Steam stop valves shall be attached direct to the boiler shell or to suitable pads or stand blocks riveted to the shell, and the neck of the valve chest shall be reasonably short and of strong construction : Provided that in the case of a larger boiler in which it is proposed for the purpose of drainage or owing to obstruction, to connect the steam pipes to the steam stop valve at a higher level than would be obtained under this Regulation, a vertical stand pipe not exceeding 5 diameters in height will be permitted between the stop valve and the boiler. Such stand pipes shall be of strong construction, and of wrought iron, mild steel, or cast steel. The flanges of wrought iron or mild steel pipes shall be riveted or welded to the pipes, and there shall be no branch on the stand pipe for any other connection.

Provided also that in the case of a large boiler in which it is desired to fit a tee piece for the purpose of providing a branch connection between the stop valve and the boiler, such a tee piece may be so fitted. The tee piece shall be of strong construction, of wrought iron, mild steel, or cast steel and shall not exceed 2½ diameters in height. A stop valve shall be fitted direct to each tee piece branch.

(c) No stop valve of the wedge type shall be employed for steam service.

BLOW-DOWN COCK OR VALVE AND PIPES

317. General.—The blow-down cock or valve shall be of substantial construction. The waste pipe attached to the cock or valve shall not be connected to a pipe common to another boiler. The pipe shall not be bound fast in earth or brickwork.

318. Blow-down Mountings.—(a) Each boiler shall be fitted with a suitable blowdown valve or cock placed at, or as near as practicable, to the lowest point of the boiler.

(b) For locomotive, vertical and marine type boilers, the valve or cock shall be attached direct to the boiler or to a suitable pad or stand pipe. For water tube boilers the valve or cock shall be outside the brickwork with a substantial steel pipe between it and the mudbox.

(c) For Cornish and Lancashire boilers the cock or valve may be attached to a cast steel elbow pipe of substantial section bolted to a suitable stand pipe or pad riveted to the boiler. But cast iron elbow pipes shall not be permitted.

319. Blow-down Valve or Cock.—(a) Each valve or cock shall be fitted with a device which shall indicate clearly its open and closed positions, and any key or similar device for operating the valve or cock shall be such that it cannot be removed unless the valve or cock is fully closed.

(b) The locking feather shall be secured by welding.

(c) Cocks fitted with taper plugs shall be of the bolted cover type with separate packing glands.

WATER GAUGES

320. (a) Every boiler shall have two independent means of indicating the water level in it and have marked on it, when applicable, in a contiguous position easily seen, the level of the highest part of the furnaces, firebox or combustion chamber as the case may be.

(b) All boilers 3 ft. dia. and over shall be fitted with two glass water gauges. For small boilers where there is difficulty in fitting two glass water gauges two test cocks may be fitted in place of the second glass water gauge.

(c) The lowest visible part of the glass of the water gauge and lower, test cock shall be fixed at safe working level. For locomotive type and vertical boilers this shall not be less than 2 inches above the highest part of the firebox roof plate.

(d) Glass water gauges shall be so placed as to be easily seen and reached by the boiler attendant. The fittings of glass water gauges and test cocks shall be of substantial make with large passage ways through them to facilitate cleaning. The gauge cocks when open shall have their handles in a vertical direction and each handle at its junction with the plug shall be plainly marked with a deep line to indicate the direction of the passage way through the plug. When detachable handles are provided arrangement shall be made to prevent incorrect fitting of the handles.

321. Drains.- A drain cock or valve with a suitable discharge pipe shall be fitted to each water gauge.

322. Protectors. -Where tubular glass water gauges are fitted, substantial protectors shall be provided. The glass shall be suitably treated to prevent splintering.

323. Glass Size.—Tubular water gauge glasses shall be not less than $\frac{1}{2}$ inch and not more than $\frac{3}{4}$ inch outside diameter.

324. Safety Devices.—Water gauge glass mountings shall be fitted with self-closing devices in the bottom arm and it is recommended that a similar device should be fitted in the top arm.

325. Gauge Columns.—Where the gauges are mounted on a column there shall be no connecting passage between the top and bottom arms of the column unless valves or cocks are fitted between the column and the boiler.

326. Isolating Cocks.—Where isolating cocks or valves connecting water gauge pipes top the boiler are fitted, they shall be not less than 1 inch bore and of the bolted cover type with separate packing gland.

PRESSURE GAUGES

327. Dials.—(a) For pressures up to and including 500 lbs. per sq. in. pressure guage dials shall be graduated in pounds per square inch from zero to twice the pressure, as nearly as may be practicable.

(b) For pressures exceeding 500 lbs. per sq. in. the range of graduation shall be from zero to one and a half times the maximum permissible working pressure, as nearly as may be practicable, but in no case shall be maximum graduation on the guage be less than 1,000 lbs. per sq. in.

(c) The scale on the dial shall be clearly and permanently marked "lbs. per sq. in.".

(d) The dial of each pressure gauge shall have marked upon it in red the maximum permissible working pressure.

(e) Where the gauge is compensated for a head of water between the gauge and the boiler connection, the amount of such compensation shall be marked on the dial. Pressure gauges shall be calibrated within an accuracy of ± 1 per cent. of the working pressure. Boiler pressure gauges shall be not less than 6 inches in diameter except in the case of small boilers where a guage not less than 4 inches in diameter may be used.

(f) The travel of the pointer of dial gauges shall not exceed 325°.

328. Connections.—All pressure gauges shall be fitted with a syphon pipe and a cock or valve integral with, or adjacent to, the gauge in such manner that the gauge may be shut off and removed whilst the boiler is under steam.

329. Gauge Cocks.—The handles of the gauge cocks shall be parallel to the pipes in which they are located when the cocks are open and marks shall be cut on the shank of the cock indicating open position.

TEST CONNECTIONS

330. Inspector's Pressure Gauge Attachment.—Every boiler shall be fitted with a valve or cock carrying in a vertical position a receiving screw for the attachment of the inspector's pressure gauge. The receiving socket shall be tapped with $\frac{3}{4}$ in. British Standard Whitworth screw thread and shall be fitted with an easily removable cap.

FUSIBLE PLUGS

331. General.—Fusible plugs shall be of sufficient height and fitted in such a position as to give early protection to all parts of the boiler liable to damage by the direct application of furnace heat in the event of shortness of water.

NOTE.—For example : In Lancashire Boilers the fusible plugs should be in the crowns of the furnaces from 12 inches to 18 inches in front of the brickwork fire bridge.

332. Type.—Fusible plugs shall consist of an outer body with a central conical passage, the smallest part to be not greater than $\frac{1}{2}$ inch for plugs suitable for pressures up to 100 lbs. per sq. in. and not greater than 3/8 inch for plugs for pressures exceeding 100 lbs. per sq. in. The passage shall be closed by a plug secured by an annular lining of fusible alloy so that the plug may drop clear if the lining melts.

The portion of the body carrying the fusible metal should preferably be detachable from the base to allow of easy replacement without removing the whole fitting from the boiler.

333. Material.—The non-fusible portions of the plug shall be of bronze except where the nature of the boiler water precludes the use of a non-ferrous material. The fusible metal shall be an alloy melting readily at a temperature not less than 150° F in excess of the saturated steam temperature at the maximum permissible working pressure of the boiler.

334. Attachment to Boiler.—Wherever practicable fusible plugs shall be screwed into the boiler plates from the waterside. The screwed portion shall have threads or Whitworth form not more than 11 per inch.

FEED VALVES

335. General.—(a) Feedcheck valves shall be of the non-return type.

(b) Where the valve is not of screw-drown non-return type a separate screw-down valve shall be provided.

(c) The discharge from the feed check valve or from the internal feed pipe (if provided) shall be above low water level and in the case of Lancashire and Cornish boilers shall be at least 5ft. beyond the fire bridge.

336. Operating position.—Feed check valves or regulating valves shall be so arranged as to enable them to be satisfactorily operated from the boiler floor.

CHAPTER VII

SUPERHEATERS

TUBES

337. Material and Construction.—See Reg. 151.

338. (a) The Working Pressure of tubes shall be determined by the following formula :—

$$WP=\frac{2f}{D}(T-C) \quad \text{.....} \quad \text{(Eqn. 87).}$$

Where T=Minimum thickness of tube in inches.

W.P.=Boiler drum working pressure in lb. per sq. in.

D=Outside diameter of tube in inches.

f=Permissible working stress in lb. per sq. in. at working metal temperature See Table below.

C=Constant as follows :—

	Cold Drawn Tubes.	Hot Drawn Tubes.
For generating tubes and unprotected furnace wall tubes	C=0·06	C=0·08

The working metal temperature shall be taken as :

(*a*) For boiler tubes, the saturation temperature corresponding to pressure W.P. plus 25° F.

(*b*) For convection superheater tubes, the maximum steam temperature for which the tube is designed plus 50°F.

(*c*) For radiant superheater tubes the designed maximum steam temperature plus more than 50°F, the amount depending upon the superheater design.

Permissible Working Stresses for Tubes.

Table.

Working metal temperature	Low carbon steel tubes to Reg. 36 and 43	Molybedenum ½% steel tubes	1% chrome ½% molybdenum steel tubes
Upto			
650°F	10,000 lbs./sq. in.		
700°F	9,600 " " "		
750°F	9,000 " " "	12,000	12,000
800°F	8,000 " " "		
850°F	6,800 " " "		
900°F	5,500	11,600	11,600
950°F		8,400	9,800
975°F		6,100	8,400
1000°F		4,500	7,000
1025°F			5,750
1050°F			4,500

Intermediate values may be interpolated.—

(b) In no case, however, shall the (standard wire gauge) of tube as supplied be less than those given in the following table—

[Subject to the tolerances Regs. 36 (*d*), 43 (*d*), 48 (c) and 53 (c).]

Table.

Outside diameter in inches	Weldless tubes	
	Hot finished	Cold drawn
	SWG	SWG
Upto and including 2	10	13
Over 2, up to and including 3	10	12
Over 3, up to and including 3½	10	10
Over 3½, up to and including 4½	9	9

(c) Where tubes are bent the resulting thickness of the tubes at the thinnest part shall be not less than that required for plain tubes.

HEADERS AND SIMILAR PRESSURE PARTS

339. Material and Construction.—See Regs. 154 & 244(b).

340. Rectangular Headers Symmetrical in Form.— (a) The Working Pressure shall be determined by the following formula :—

$$W.P. = \frac{f\ (t-1)2}{b^2 \times C} \qquad \text{Eqn. (88)}$$

Where W.P.=The working pressure in lbs. per sq. in.

t=The thickness in 1/32 in.

b=The breadth in inches between the supporting sides of the header less one inside corner radius 'r', this being the corner radius of the rectangular box from which the header is pressed or of the header casing, which shall be not less than 1/4 in. In no case, however, shall 'b' be taken as less than 0·9 of the breadth between the supporting sides.

C=300 for wrought steel and 350 for steel castings : where the sides are corrugated or otherwise reinforced by substantial supports so that the length of the flat portion between the corrugations or supports does not exceed ' b '. ' C ' shall be taken as 175 for wrought steel and 200 for steel castings.

f=The permissible stress at working metal temperature lbs. per sq. in. see table below.

(b) If the faces of the headers are machined locally at the tube holes or hand holes the thickness at that part may be as much as 6/32 in. less than given by Equation 88 but irrespective of the thickness obtained by the use of the formula, the thickness of the headers at the tube holes in 1/32 in. shall be not less than :

$$t = 3 \times \sqrt{d} + 8 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (89).}$$

Where d=The diameter of the hole in inches, and in no case shall the thickness be less than 10/32 in., except that in small patches not exceeding one-half a sq. in. in area, the thickness may be 50 per cent. of the thickness used in Equation 88.

(c) The permissible stress at working metal temperature shall be as given in the table below.

TABLE

Working metal temperature	Permissible stress in lb/sq. in.					
	Wrought steel having an ultimate tensile stress in tons per sq. in. of :—					Cast Steel 28-35 tons sq. in.
	24-28	26-30	28-32	32-36	34-38	
Upto 550°F . . .	12300	13300	14300	16300	17300	10000
600°F . . .	12300	13300	14300	16300	17300	9000
650°F . . .	12300	13300	14300	16300	17300	8000
700°F . . .	11800	12800	13800	15800	16800	7560
750°F . . .	10600	11600	12300	14000	14800	7200
800°F . . .	9300	10000	10500	11800	12400	6700
850°F . . .	7800	8300	8500	9200	9000	6300
900°F . .	6300	6300	6300	6300	6300	4400

Intermediate values may be interpolated.

The working metal temperature shall be taken as :—

(d) For saturated steam, water drums, muddrums and headers, the saturation temperature corresponding to the pressure WP plus 50°F.

(e) For superheater headers the designed maximum steam temperature for that header plus 50°F.

(f) Where headers are adequately protected from the gases of combustion or swept by such gases in the third or subsequent pass of a boiler, the working metal temperature shall be taken as the saturation or designed maximum steam temperature as defined above, whichever applies. A covering of refractory or insulating

material which may be liable to become dislodged shall not be deemed adequate protection.

341. Headers Irregular in Form.—In cases where the headers are of such irregular form as to render impracticable the application of a formula for the determination of thickness, the manufacturer shall show the suitability of the headers for the working conditions by indicating practically the maximum internal hydraulic pressure which a header, made to the same design and of similar material, will withstand without permanent deformation. The maximum working pressure for similar headers may then be determined by the following formula :—

$$W.P. = P_1 \times \frac{\text{Permissible stress at working metal temperature}}{F \times C} \quad \text{Eqn. (90).}$$

Where W.P.=The working pressure in lbs. per sq. in.

P_1=The maximum internal hydraulic pressure withstood without permanent deformation.

F=1·75 for wrought steel and 2 for cast steel,

C=15 500 for wrought steel of 24 tons per sq. in. minimum ultimate tensile stress,

=16 500 for wrought steel of 26 tons per sq. in. minimum ultimate tensile stress,

=18 000 for wrought steel of 28 tons per sq. in. minimum ultimate tensile stress,

=21 000 for wrought steel of 32 tons per sq. in. minimum ultimate tensile stress,

=22 000 for wrought steel of 34 tons per sq. in. minimum ultimate tensile stress, and

=15 500 for cast steel of 28 tons per sq. in. minimum ultimate tensile stress.

342. Cylindrical Headers.– Where cylindrical headers are provided their working pressure shall be determined by Equation 72.

CHAPTER VIII

STEAM PIPES AND FITTINGS

343. Steam pipes may be wrought iron, wrought steel, cast steel and in some cases of copper. Steel pipes may be solid drawn (cold or hot finished) or lap welded. Wrought iron pipes may be lap welded. Copper pipes shall be solid drawn and no pipe made from the electrode position of copper on a mandril shall be used for steam delivery.

MATERIAL

344. Steel pipes.—(a) These pipes shall be made by the open hearth or an electric process acid or basic. Where the material is used for designed steam temperatures above 750°F, the steel shall be of non-segregated or fully killed type.

(b) The material from which these pipes are made shall conform to the following requirements :—

See Table 1.

TABLE 1

Kind of pipes	Ultimate tensile stress in tons per sq. in.		Min. elongation per cent.				Sulphur Maximum %	Phosphorus maximum %
			On 8 in.		On 2 in.			
	Not less than	Not more than	¼″ thick and over	Less than ¼″ thick	¼ in. thick and over	Less than ¼″ thick		
Cold drawn Weldless Steel Pipes								
Strips cut from the pipes and tested in their curved condition.	23	30	20	18	32	30	·05	·05
Test lengths taken from finished pipes (ends of pipes to be plugged for grips)	23	30	25	23	..	..		
Hot-finished Weldless Steel Pipes								
Strips cut from the pipes and tested in their curved condition	23	30	20	18	32	30	·05	·05
Test lengths taken from finished pipes (ends of pipes to be plugged for grips).	23	30	25	23	..	..		
Roll Lapwelded Steel Pipes								
Strips cut from the pipes clear of the welds and tested in their curved condition.	22	28	20	18	32	30	·06	·06
Test lengths taken from finished pipes (ends of pipes to be plugged for grips)	22	28	25	23	..	..		

Hydraulic (water gas) Lapwelded Steel Pipes

Selected samples cut transversely	Ultimate tensile stress in tons per sq. in.		Min. Elongation per cent. on 8 in.			Sulphur maximum %	Phosphorus maximum %
	Not less than	Not more than	$\frac{1}{8}$″ thick and over	Less than $\frac{1}{8}$″ thick and not less than $\frac{1}{4}$″ thick	Less than $\frac{1}{4}$″ thick		
	22	28	23	20	18	·05	·05

345. Condition of pipes.—All Pipes shall be commercially straight free from longitudinal seaming, grooving, blistering or other injurious surface marks. The ends of the pipes shall be cut square.

MECHANICAL TEST

346. –Flattening test (For pipes upto and including 4-in. nominal bore).—A ring not less than 2″ in length cut from one end of each selected pipe shall when cold withstand, without showing either crack or flaw , being flattened between two parallel flat surfaces until when the pressure is released the interior surfaces of the test piece remain at the middle a distance apart equal to 4 times the thickness of the pipe.

347. Cold bend test (For pipes over 4-in. nominal bore).—(a) A strip 1½″ wide cut circumferentially from one end of each selected pipe shall when cold withstand, without showing either crack or flaw, being doubled over in the direction of original curvature round a bar, the diameter of the bar being :—

For pipes upto and including 3/8″ thick . 3 times the thickness,

For pipes over 3/8″ thick . . . 4 times the thickness.

Bend Test on the Weld.—(b) A strip 1½″ wide cut circumferentially from one end of each selected pipe with the weld near the middle of the strip, shall when cold withstand, without showing either crack or flaw, being doubled over in the direction of original curvature round a bar, the diameter of the bar being equal to eight times the thickness of the test piece, the weld being placed at the point of maximum bending.

Additional test.—(c) Should a pipe selected for testing fail in any one or more of the tests specified above, two further tests of the same kind may be made from the same or other pipe. Should either of these fail, the pipes represented may be reheat treated and then retested. If the repeat test are satisfactory, the pipes shall be accepted provided they comply with other requirements but if failure again occurs, the pipes which the test pieces represent shall be rejected.

348. (a) The process of welding lap jointed seams shall be by hammering or rolling the joint.

(b) On completion of any work which involves heating, whether for welding the joint, welding on flanges, hot bending the pipe or for any other purpose, the pipe shall be carefully annealed.

349. The pressure and temperature limits within which pipes, tees, branches etc., shall be used shall be in accordance with Table 2.

WORKING PRESSURE OF STEAM PIPES

350. Steel and Wrought Iron Pipes.—The maximum working pressure allowed on steel or wrought iron pipes shall be determined by the following formula :—

$$W.P. = \frac{2Se.\ (t-9)}{100\ D} \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (91)}$$

t=minimum thickness in hundredths of an inch.

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

D=Outside diameter of pipes in inches.

S=Allowable stress in lbs. per sq. inch as specified in Table 3.

e= efficiency factor—

1 for weldless steel pipes,

·9 for welded steel or iron pipes for values of t up to and including 7/8″,

·85 for welded steel pipes for values of t over 7/8″ and upto and including 1-1/8″,

·8 for welded steel pipes for values of t over 1-1/8″.

351. Cast steel Pipes.—(*a*) The material shall comply with Regulations 73 to 80, *i.e.*, 28 tons minimum tensile stress.

(*b*) The maximum working pressure allowed on cast steel pipes shall be determined by the following formula :—

$$W.P. = \frac{2S(t-\cdot 015\ d_1-\cdot 25)}{d_1} \quad . \quad . \quad . \quad . \quad \text{Eqn. (92)}$$

t=minimum thickness in inches.

W.P. =Working pressure in lbs. per sq. in.

d=internal diameter of pipe in inches.

d_1 =external diameter of pipe in inches.

S = allowable working stress in lbs. per sq. in. as specified in Table (4).

352. Copper Pipes.—(*a*) The material shall comply with Regulation 35.

(*b*) Copper pipes may be used for a working pressure not exceeding 180 lbs. The external diameter shall not exceed 5-in.

(*c*) Copper pipes shall not be used for superheated steam.

(*d*) The maximum working pressure on such pipes shall be determined by the following formula :—

$$W.P. = \frac{50\ (t-3)}{D} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (93)}$$

= minimum thickness in hundredths of an inch.

W. P. = working pressure in lbs. per sq in.

D = outside diameter of pipe in inches.

TABLE 2

(Maximum permissible W. P. and Temperature)

Material	Method of manufacture	Maximum permissible pressure in lbs. per sq. in.	Maximum permissible temperature in °F.	Form
Mild steel . .	Cold drawn weldless.	No restrictions	900	Straights, bends or tees, etc.
	Hot finished weldless.	Do.	900	
	Hydraulic Watergas lap-welded.	Do.	900	Do.
	Roll lap-welded	300	500	Do.
Wrought Iron . .	Roll lap-welded	250	425	Straights, bends or tees, etc.
Cast Steel . .	Castings .	No restriction	900	Straights, bends or tees, etc.
Copper . . .	Solid drawn .	Upto and including 5"..180.	..	Straights and bends.

TABLE 3

Maximum permissible working Stress in lbs. (Values of S)

Pipes	Permissible Working Stress in lbs. per sq. in. for design temperature in °F.										
		Over									
		425°	500°	550°	600°	650°	700°	750°	800°	850°	875°
		Up to and including									
	425°	500°	550°	600°	650°	700°	750°	800°	850°	875°	900°
Cold drawn Weldless Steel, Hot finished Weldless Steel.		11200	11200	10000	8900	8400	8000	7500	7000	5860	4880
Hydraulic (Watergas) lap-welded steel.		10000	10000	9000	8000	7560	7200	6750	6300	5280	4400
Roll lap-welded Steel.		10000	..	..	Not used for these temperatures.						
Lap-welded Iron.	7500	..	..	..	Not used for these temperatures.						

TABLE 4

Maximum permissible working stress in lbs. for cast steel (Values of S)

Permissible working stress in lbs. per sq. in. for design temperature in °F								
Over								
	550°	600°	650°	700°	750°	800°	850°	875°
Up to and including								
550°	600°	650°	700°	750°	800°	850°	875°	900°
10000	9000	8000	7560	7200	6750	6300	5280	4400

ATTACHMENT OF FLANGES

353. Flanges of Iron and Steel Pipes.—(*a*) Flanges of iron and steel pipes may be made of cast steel wrought iron or wrought steel made without a weld. They may be secured to the pipes by screwing, riveting or welding.

(*b*) No flange or blank flange of cast iron shall be attached directly to main steam pipes or form part of main steam piping.

(*c*) Blank flanges shall be of mild steel or cast steel and shall be not less in thickness than the flanges to which they are attached.

354. Screwed on flanges.—The pipes may be screwed into flanges with a disappearing thread and expanded. Such screwed and expanded flanges may be used for steam for a maximum pressure of 450 lbs. per sq. in. and/or a maximum temperature of 750°F and for feed pipes for pressures up to 600 lbs/sq. in. Screwed and expanded flanges may in addition be seal welded.

355. Loose Flanges.—Loose flanges may be used where the joints are made by metal to metal faces integral with the ends of the pipes. Alternatively these joints may be welded or seal welded. The loose flange shall conform to the table given in Appendix E.

Where the joint is formed by integral flanges, these after machining shall be not less in thickness than the designed thickness of the pipe as calculated by Equation (91).

356. Riveted on flanges.—(*a*) Riveted on flanges shall only be used for pipes of 7″ bore and above and for a maximum pressure of 350 lbs. per sq. in. and/or a maximum temperature of 750°F.

(*b*) The shear stress in the rivets shall not exceed 6000 lbs. per sq. in. when calculated by the following formula :—

$$Sr = \left(\frac{A_o \times P}{AN} \right) \qquad \text{Eqn. (94)}$$

Where Sr = the shear stress in the rivets in lbs. per sq. in.

A_o = cross sectional area, calculated on outside diameter of pipe in sq. inches.

P = working pressure in lbs. per sq. in.

N = number of rivets.

A = Area of one rivet hole in sq. in.

(*c*) The stress in the pipe shall not exceed that specified in Table 3 when calculated by the following formula:—

$$Sp = \frac{(A_o \times P)}{(A_o - A1) - (N \times d \times t)} \quad . \quad . \quad . \quad . \text{ Eqn. (95)}$$

Where Sp = the stress in the pipe in lb. per sq. in.,

A_o, P and N have the values given above, and

A1 = crosss sectional area, calculated on inside diameter of pipe in sq. inches.

d = diameter of rivet hole in inches.

t = minimum thickness of pipe in inches.

(*d*) The flange hub thickness shall not be less than 0·2 in. thicker than the minimum thickness of the pipe.

(*e*) The distance from the edge of the hub to the centre line of the rivets shall be not less than one and a half times the diameter of the rivet hole.

(*f*) The pipes shall first be properly expanded into the flanges or alternatively the flanges shrunk on to the pipes the rivet holes shall then be drilled through the pipe and hub, and the holes afterwards countersunk to remove burrs.

(*g*) After riveting the flange hub shall be fullered at the back.

357. Welded on flanges.—(*a*) Where flanges are welded on, the welding shall be carried out by the oxy-acetylene or electric process.

(*b*) The proportions of the welds in the case of metallic arc welding shall be as indicated in Figs. 28-32, the respective working condition for each type being as follows :

Figs. 28, 29 and 32: for all pressure and temperature conditions

Fig. 30: for pressure condition up to 250 lbs. and temperature not exceeding 700°F.

Fig 31 : for pressure conditions up to 150 lbs. and temperature not exceeding 500°F.

(*c*) (*i*) Electric Welds made in accordance with figure 32 shall be stress relieved.

(*ii*) Similar welds made in accordance with Fig. 28 or 29 shall be stress relieved when practicable.

(*iii*) Flanges for use at temperatures over 700°F. which are welded by the oxy-acetylene process shall be normalised.

(*d*) For sizes up to and including 12″ bore bossed or hubbed flanges may be used in Figs. 30 & 31.

(*e*) Welded on flanges may be screwed on to the pipes prior to welding.

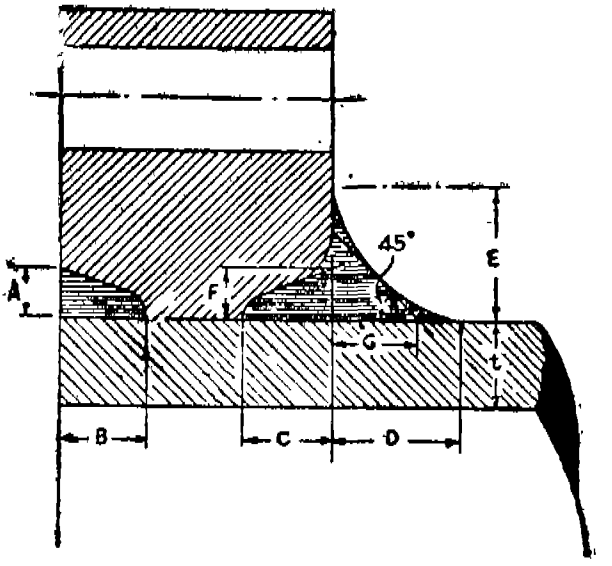

Fig. 28. For all pressure and temperature conditions.

A	t but not less than $\frac{1}{4}$ in and not more than 3/4 in.
B	t
C	t but not less than 3/8 in.
D	$1\frac{1}{8}$ t but not less than 3/8 in.
E	$1\frac{1}{8}$ t but not less than 3/8 in.
F	t but not less than 3/8 in. and not more than 3/4 in.
G	t but not less than 1/4 in.

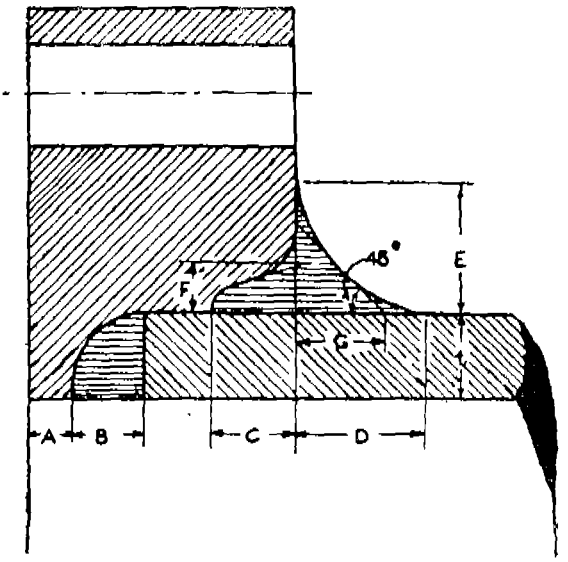

Fig. 29. For all pressure and temperature conditions.

A	1/2 t but not less than 3/16 in.
B	1/4 in. Min. for Tubes up to and including 5/16 in. thick. t – 1/16 in. for Tubes over 5/16 in. thick and up to and including 9/16 in. t – 1/8 in. for Tubes over 9/16 in. thick and up to and including 7/8 in. t – 1/4 in. for Tubes over 7/8 in. thick and up to and including 1 in.
C	t but not less than 3/8 in.
D	1½ t but not less than 3/8 in.
E	1¼ t but not less than 3/8 in.
F	t but not less than 3/8 in. and not more than 3/4 in.
G	t but not less than 1/4 in.

A	$1\frac{1}{4}$ t but not less than 3/8 in.
B	$1\frac{1}{4}$ t but not less than 3/8 in.
C	t
D	t but not less than $\frac{1}{4}$ in.

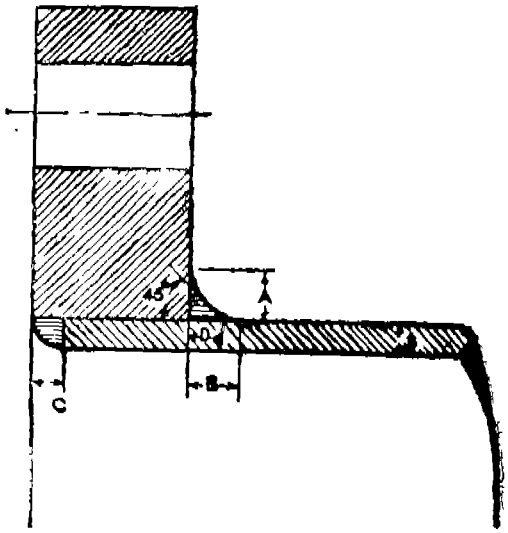

Fig. 30. For pressure conditions up to 250 lbs. and temperature not exceeding 700° F.

A	$\frac{1}{4}$ t but not less than 1/16 in.
B	2 t
C	t
D	t

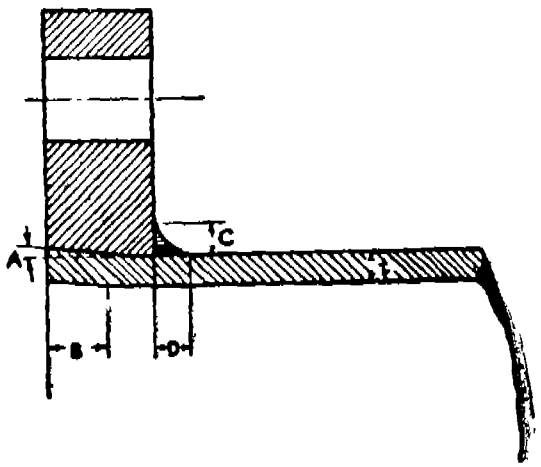

Fig. 31. For pressure conditions upto 150 lbs. and temperature not exceeding 500°F.

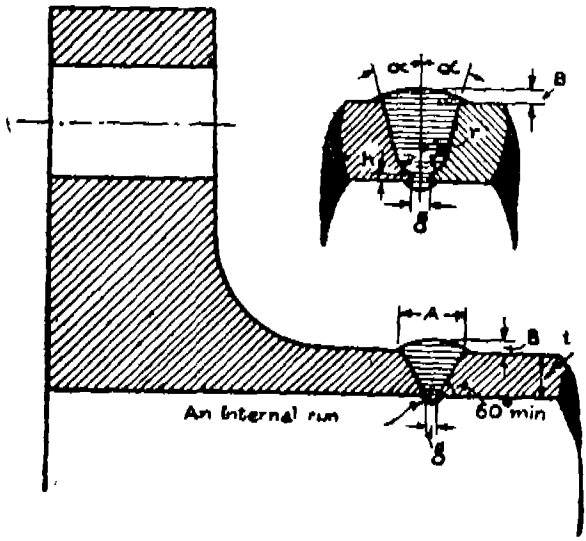

Fig. 32. For all pressure and temperature conditions.

A	t+1/16 in.	where t is not greater than 1/2 in.
B	1/16 in. min.	
G	1/16 in. min.	

Where t is greater than 1/2 inch. 'U' shaped groove as shown may be used.

α	15° min.
r	1/8 in.
h	1/8 in. max.
g	1/8 in. min. ¼ in. max.
B	1/16 in. min.

358. Flanges of copper pipes.—Flanges of copper pipes may be made of brass or bronze. When flanges are attached to copper pipes by brazing they shall be secured in such additional way (*e.g.* by riveting the ends or forming a conical end so as to fit into a conical bore in the flange that the resistance to withdrawal from the flange does not depend wholly on the brazing).

359. Standard Flanges.—The size and thickness of flanges and the number and size of their bolts should be as shown in Appendix E.

360. Joints—(*a*) These Regulations provide for ordinary bolted flange joints. Special types of joints may be used, subject to the approval of the Chief Inspector.

(*b*) All steam pipes with butt welded circumferential joints having a wall thickness of 3/8" and above or carrying a pressure of over 50 lbs. shall be effectively stress relieved.

(*c*) Such butt welded joint shall conform to standard specification.

STEAM PIPE FITTINGS AND CONNECTIONS

361. Wrought Bends.—(*a*) Wherever practicable the radii of bends (on centre line) shall be not less than those given below :—

Bore	up to and including 6 in.	$R=3\times d$
,,	over 6 in. up to and including 9"	$R=3\cdot5\times d$
,,	over 9 in. up to and including 12"	$R=3\cdot5\times d$
,,	over 12 in. up to and including 15"	$R=4\cdot5\times d$
,,	over 15 in up to and including 18"	$R=5\times d$
,,	over 18 in. up to and including 20"	$R=5\cdot5\times d$

Where d=the bore of the pipe,

R=Radius of bend to centre line of pipe.

(*b*) The thickness of pipes from which such bends are made shall be not less than 12½ per cent. greater than the minimum thickness required by Equation 91. Where smaller radii are necessary further allowances shall be made for thinning at the back of the bend. Alternatively some special form of construction shall be adopted to prevent undue thinning.

362. Branches, Tees, etc.—Branches, bosses and drain pockets shall be welded to the pipes. Where a branch is equal size to the main pipe an approved type of reinforcement shall be employed. For pressures over 350 lb./sq. in. and/or temperatures of 750°F or over, branches of 6 in. bore and larger shall be welded inside as well as outside. Alternatively to the welding on the inside of the pipe, an approved type or re-inforcement or mechanical lock may be provided.

363. Blow-down pipes.—(*a*) Blow-down pipes which can be subjected to full boiler pressure shall be considered as saturated steam pipes at that pressure.

(*b*) "Blow-down pipes which cannot be subjected to full boiler pressure shall be considered as saturated steam pipes at half the working pressure of the boiler."

364. Valve Chests.—(*a*) Chests of stop-valves, isolating valves, reducing valves steam traps etc., forming parts of wrought iron or wrought steel main steam piping when for use with saturated steam up to a gauge pressure of 160 lbs. per square inch or a temperature of 400°F. may be made of cast iron, cast steel or wrought steel in accordance with the requirements of Regulation 290.

(*b*) When superheated steam is used above 400°F. or when pressures are above 160 lbs. per sq. in. gauge, such chests shall be made of cast or wrought steel or other approved material in accordance with the requirement of Regulation 290.

365. Steam Receivers, separators, etc., for temperature exceeding 500°F.—(*a*) If such vessels are fusion welded the manufacture and tests shall conform to Chapter V.

(*b*) The working pressure of all parts shall be determined by the appropriate formulae given in Chapter V.

(*c*) All mountings for the above and for connected steam pipe ranges shall be of cast steel or other approved material.

366. Steam Receivers, separators, etc. for temperature not exceeding 500°F.—(*a*) The shells of steam receivers, steam separators, steam driers, catch waters, drop legs, interceptors, etc. may be made of steel plates or steel castings.

(*b*) (*i*) When fabricated of steel plates the seams may be riveted or welded.

(*ii*) When riveted the working pressure for the parts shall be determined by the formulae prescribed for corresponding parts of boilers and the hydraulic test pressure to which the vessel shall be subjected on completion shall be that prescribed for boilers.

(*iii*) Except where such vessels are fusion welded in accordance with Chapter V the longitudinal weld of vessels exceeding 15" internal diameter shall be covered by a butt strap.

(*iv*) For such welded seams the standard co-efficient C of Regulation 176 to be used in determining the working pressure shall be 3·0 for both welded and welded and strapped seams. The strength percentage to be allowed for the weld shall be 50 and J, the strength percentage to be allowed for welded and strapped seams shall be determined in accordance with Regulation 180.

(*v*) Branches for attachment of steam piping shall be flanged and be either flanged and riveted or welded to the vessel.

When welded this shall be done inside as well as outside where practicable. Alternatively to the welding on the inside of the vessel an approved type of reinforcement or mechanical lock may be provided.

Where a branch is of equal size to the vessel the opening shall be reinforced.

(*vi*) All welded vessels shall be stress relieved.

(*c*) (*i*) Where made of cast steel the shell shall comply with the requirements of Regs. 73 to 80.

(*ii*) The working pressure for flat end plates of cast steel shall be determined by the formulae for flat end plates of wrought steel.

(*d*) Suitable arrangements for drainage shall be fitted to all vessels intended for use in the separation of condensed steam. Where automatic drainage is not provided a glass water gauge of substantial make to indicate the water level in the vessel and a substantial drain cock or valve shall be fitted.

367. Screwed and socketed Joints.— Couplings or sockets may be used on pipe up to 4 in. internal diameter with pressures up to 120 lbs. per square inch gauge and up to 5 in. diameter with pressures up to 100 lbs. per square inch gauge. In all other cases, flanges with bolts and nuts shall be used.

368. Other fittings and Mountings.—(*a*) Valve chests of bronze for stop valves up to 3 in. diameter of bore may be attached directly to iron and steel steam pipes when pressures do not exceed 120 lbs. per sq.in. gauge and temperature not exceeding 425° F. The attachment may be by direct screwing to the steam pipe or by means of flanges.

(*b*) Drain cocks and valves may be attached to steam pipes either by flange and bolts or be screwed into a boss formed on the pipe.

369. Reducing Valve.- Where a reducing valve is installed in a pipe line, the pipe line and accessories on the low pressure side of the reducing valve shall be protected by a suitable safety valve or valves so adjusted as to permit the steam to escape as soon as the safe working pressure is exceeded or by a suitable appliance for cutting off automatically the supply of steam as soon as the safe working pressure is exceeded.

370. Flexibility.—(*a*) The use of sliding expansion joints is prohibited. The necessary degree of flexibility shall be obtained by the use of special expansion joints, or the pipes shall be pre-stressed initially when cold by leaving gaps at appropriate joints and pulling these up when erecting the piping. The amount of the cold spring

shall be not less than 50% of the total expansion of the length under consideration and may be greater than this in cases where it is necessary in order to keep within the permissible stress value shown in tables 3 and 4.

(*b*) The allowance for expansion per 100 ft. of piping at various temperatures shall be based on Table 5.

TABLE 5

EXPANSION ALLOWANCE

Range of temperature Degrees Fahrenheit	Expansion Inches per 100 ft.
60-250	1·56
60-300	1·99
60-350	2·43
60-400	2·89
60-450	3·35
60-500	3·83
60-550	4·31
60-600	4·81
60-650	5·31
60-700	5·83
60-750	6·36
60-800	6·89
60-850	7·44
60-900	7·99

371. Pipe work supports.—All pipe work shall be adequately supported in order to permit free movement for expansion and contraction, and the amount of such movement shall be proportioned throughout the whole of any main by the provision of anchors at suitable points. Where pipes may be subject to vertical movement, spring supports designed to carry the load under all conditions shall be provided. It is desirable that points of supports should, as far as practicable, be arranged adjacent to the pipe joints. Slings are in general preferable to roller supports, and these latter should be used only where necessary. All pipe supports should, as far as practicable, be of mild steel and pipe anchors either of mild steel or cast steel.

372. Drainage.—(*a*) In the case of steam mains, attention should be paid to the adequate provision of drainage points in the form of drain pockets. Drainage points connected to steam traps, shall be provided wherever water can collect under working conditions. Hand drains shall be provided at all points at which water can collect in any portion of the steam main, by valve leakage or other means, when shut down, or when warming up prior to use.

(*b*) Where practicable a suitable gradient shall be provided in the pipe work to ensure the passage of condensed water in the direction of flow of steam towards the drainage point.

(*c*) It is recommended that a by-pass should be fitted at each steam trap.

(*d*) Where the volume of water deposited is likely to be of serious proportions, separators should be installed. Each separator shall be furnished with a steam trap which shall be connected to it by means of a three-way cock one end of which is connected to a manually operated drain.

373. Freedom from rust and other foreign matter.—All pipes, valves and fittings shall be thoroughly cleaned as far as possible of rust and other foreign matter before erection and pipe lines shall be blown through with steam or air before being put into service.

374. Test Pressures.—(*a*) Each completed pipe and fitting shall be tested by hydraulic pressure at the Manufacturer's works to twice the maximum permissible working pressure. It is inadvisable to submit a completed steam pipe installation to any hydraulic test.

(*b*) Pipes and fittings with flanges for steam pressures exceeding 100 lbs. per sq. in. shall be tested with blank flanges bolted or clamped on. All other pipes, if straight may be tested between the heads of an ordinary hydraulic pipe testing machine.

(*c*) Special arrangements shall be made, according to circumstances, for testing bends and other fittings where not flanged.

CHAPTER IX

REGULATIONS FOR THE REGISTRATION AND INSPECTION OF BOILERS

375. *The procedure to be followed in connection with applications for the registration of a boiler and with examinations of boilers under the Act shall be regulated in accordance with the provisions of this Chapter read with the relevant Sections of the Act.

376. Preparation for Inspection.—(*a*) At every examination of a boiler for the grant or renewal of a certificate, the boiler shall be empty and thoroughly clean in all its parts. Except as provided for in sub-regulation (*f*) all doors of manholes, handholes and sightholes and cleaning plugs and all caps in the headers and mud drums of water-tube boilers, all firebars, bearers, front plates, bridge plates, firebridges, brick arches, oil fuel burners and mechanical stoker fittings shall be removed. All valves and cocks comprising the boiler mounting shall be opened up and taken apart and the valves or cocks ground, when necessary, before the Inspector's visit.

(*b*) Provision shall, if required by the Inspector, be made for the removal of lagging or brick-work or other concealing part and for the drilling of plates, and for verifying the pressure gauge and safety valve dimensions and weights.

(*c*) All smoke tubes, exterior of water tubes, smoke boxes, and external flues shall be swept clean.

(*d*) Provision shall be made for the effective disconnection of all steam and hot water communication with any other boiler under steam as prescribed in Chapter X of these Regulations. This shall be effected either by the removal of a length of pipe from the steam and feed piping or by the insertion of substantial blank flanges. Where blank flanges are employed, they shall be inserted between the flange of the chest and the pipe attached to it.

(*e*) No blank flange shall be inserted between a safety valve chest and the boiler.

(*f*) At alternative annual inspections and subject to a minimum of three bottom rows or all tubes subject to the first pass of heat being opened up for inspection, the Inspector may at his discretion relax the preparation for inspection called for under (*a*) above in favour of boilers having an evaporative capacity of 200,000 lbs. per hour and over, and fed with water treated to the satisfaction of the Inspector.

377. Hydraulic test of boilers for registration.—Every boiler shall be hydraulically tested in the presence of an Inspector or Inspecting Officer.

*NOTE.—In accordance with sections 7 and 8 of the Act Inspectors are required to measure and examine boilers for registration, to examine boilers for renewal certificates, to determine subject to the approval of the Chief Inspector, the pressure at which they may be allowed to work, to grant certificate therefor and generally to convey to the owners such orders as the Chief Inspector may issue.

378. Preparation for hydraulic tests.—(*a*) The chests of all mountings subject to steam pressure shall be in place and shut tight or blank flanged.

(*b*) The safety valves should invariably be removed and the chest opening blank flanged.

(*c*) The attachment for the Inspector's pressure gauge and the nipple for connecting the Inspector's test pump hose shall be in order.

(*d*) All doors shall be properly jointed and tightened up. The boiler shall be completely filled with water, care being taken to allow all air to escape and, if possible, a preliminary test not exceeding the working pressure of the boiler shall be taken before the Inspector's visit, to test the tightness of the joints.

(*e*) When a boiler is hydraulically tested for the first time, it shall be entirely cleared of lagging or brickwork; at subsequent tests the lagging or brickwork, or portions thereof, shall be removed if required by the Inspector.

379. Procedure of hydraulic tests.- (*a*) Subject to the provisions of sub-regulation (*e*) of Regulation 381 every boiler shall be hydraulically tested in the presence of an Inspector to not less than twice the approved working pressure, when such working pressure does not exceed 100 lbs. per square inch; when the approved working pressure is above 100 lbs. per square inch, the hydraulic tested pressure shall be 1½ times the working pressure *plus* 50 lbs. per square inch.

(*b*) The boiler shall satisfactorily withstand such pressure without appreciable leakage or undue deflection or distortion of its parts for at least ten consecutive minutes. If the test is not satisfactory, the working pressure allowable by calculation shall be suitably reduced, unless the owner desires to make such alterations as will enable the boiler to withstand satisfactorily the hydraulic test; in which case the boiler shall again be examined, after the alterations have been made, the pressure recalculated, if necessary, and the boiler tested to the satisfaction of the Inspector.

(*c*) *At the first hydraulic test of a boiler prior to the issue of an original certificate deflection measurements shall be made before, during and after test of each furnace length, fire-box and flat end or other plates.

(*d*) After the application of the hydraulic test the Inspector shall carefully examine the boiler inside and outside and satisfy himself that it has satisfactorily withstood the test.

(*e*) In any case in which the safe working pressure to be allowed for a boiler cannot, owing to peculiar construction of any of its parts, be determined by calculation in the ordinary way, the Inspector shall, under the direction of the Chief Inspector, subject the boiler to hydraulic test for the purpose of determining the fitness of such parts. The amount of the test pressure to be applied in such a case shall not exceed the test pressure prescribed for the least working pressure found by calculation for other parts of the boiler or the intended working pressure, whichever is less.

(*f*) Should any part of the boiler show undue deflection or indication of permanent set during the progress of the test, the pressure shall be released immediately such indications are observed. The working pressure for the part shall be 40 per cent. of the test pressure applied when the point of permanent set was reached. This procedure shall apply to any boiler at any test.

(*g*) Hydraulic tests of boilers at subsequent examinations shall, except when the Inspector expressly requires otherwise, be made after the inspection. The test pressure to be applied to boilers at such subsequent examinations shall be from one and a quarter to one and a half times the working pressure of the boiler.

*NOTE.- These deflection measurements should be entered in the Memorandum of Inspection Book before its submission to the Chief Inspector.

(*h*) When the internal construction of size of a boiler does not permit of the Inspector getting inside it or of examining closely all its parts, he shall see it tested by hydraulic pressure to one and a half times the working pressure at each inspection for the grant or renewal of a certificate.

(*i*) Water tube, locomotive type and all tubular boilers shall be hydraulically tested at each inspection for the grant or renewal of a certificate, unless such test is waived under the orders of the Chief Inspector.

(*j*) The Inspector may, if he considers it necessary, apply a hydraulic test to any boiler at any inspection.

(*k*) Except in the case of small, portable and vehicular boilers which do not require re-erection or building in brickwork, the hydraulic test of all boilers shall be conducted only after the erection of the boiler *in situ* and all boilers shall after re-erection in a position different from that in which they were last examined be hydraulically tested.

(*l*) A hydraulic test shall also be taken before granting an increased pressure certificate and after repairing a boiler, unless the Chief Inspector authorizes the Inspector to waive such test.

(*m*) When carrying out hydraulic test, Inspectors shall use pressure gauges supplied by the Chief Inspector.

380. *Steam tests.—(*a*) Every newly registered boiler and every other boiler of which the working pressure has been altered shall, before the issue of an original or renewal certificate for such boiler, be tested under steam to the satisfaction of the Inspector.

(*b*) At the time of test the safety valves shall be left free and capable of being adjusted to the approved working pressure.

(*c*) After adjustment of the valves to the correct blowing pressure the boiler shall be tried under full steam and firing with the feed water shut off and the stop valve closed, during which time the Inspector shall note the accumulation of pressure and other details of the test as well as the loading and adjustment of the safety valves.

In the case of water tube boilers, or boilers fitted with superheaters, the feed water connection and stop valve need not be shut off, and if the total safety valve area and lift are found to be adequate, the requirements of this clause may be assumed to have been satisfied if the valves are so adjusted that each blows at the approved pressure.

(*d*) On completion of the safety valve test the Inspector shall satisfy himself that the water gauges are in working order and that the feed apparatus is capable of supplying the boiler with sufficient water.

(*e*) Where the State Government does not require a person-in-charge of a boiler to hold a certificate of competency, the Inspector may when he thinks fit satisfy himself by questioning or by practical test whether the person-in-charge of the boiler understands the use and purpose of the water gauges, the pressure gauge, the safety valves, the feed water-supply and blowdown.

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*NOTE.—A steam test is primarily intended for the purpose of ascertaining by actual test whether the safety valves are sufficient to relieve the boiler effectively of excess steam and whether they operate at the time when the maximum working pressure is reached. Inspectors should always send to the owner due notice of the date fixed for the steam test.

On completion of the test the Inspector should enter all details in the Memorandum of Inspection Book.

(*f*) When witnessing safety valve tests, Inspectors shall use the standard pressure gauges supplied by the Chief Inspector unless the boiler pressure gauge has, since the time of inspection been tested and found correct with an authorized testing machine.

(*g*) No steam gauge shall be used without a syphon filled with water between it and the boiler.

(*h*) When the accumulation of pressure at a steam test exceeds ten per cent. of the maximum working pressure, the area of the safety valves shall be considered insufficient, and a certificate shall be refused until the safety valve area is increased.

(*i*) An Inspector may, when visiting a factory for any purpose, verify the correctness of the safety valves and pressure gauge of any boiler under steam by comparison with his standard pressure gauge.

381. Procedure for registration.—(*a*) On receipt of an application for registration under section 7(1) of the Act, the Inspector shall, when the boiler has been properly prepared for examination, proceed to measure in complete detail all its parts, ascertain the working pressure allowed by the Regulations by making a series of calculations of the strength of the various parts, such calculations being based on his measurement and if he is satisfied with the correctness of the maker's certificate, on the dimensions and other particulars relating to the material and construction as stated therein [*vide* Section 14(1) (*c*) of the Act and Regulation 4]. In making his calculations he shall after examination of the material, take due account of the workmanship and details of the construction of each part. In his examination the Inspector may, if he deems necessary, bore the plates or other parts to ascertain their thickness and in making his calculations he shall be guided by the requirements of Chapters IV and V of these Regulations.

(*b*) If no formulae or co-efficient applicable to any part is contained in Chapter IV or V of the Regulations, the Chief Inspector shall in his discretion determine the fitness of such part.

(*c*) The strength of the weakest part so calculated or determined, subject to any discretionary power exercised by the Chief Inspector, shall determine the permissible working pressure of the boiler. After inspecting the boiler and ascertaining by the prescribed calculations the maximum pressure at which the boiler may be worked, the Inspector shall hydraulically test and steam-test it in accordance with requirements of Regulations 379 and 380 and may issue a provisional order under Section 9 of the Act in Form V.

(*d*) The Inspector shall enter the above particulars and dimensions of the boiler and calculations of strength of the various parts, together with details of the hydraulic and of the steam tests, in a "Memorandum of Inspection" Book (*vide* Regulation 386) which, together with all the maker's papers for the boiler, shall be submitted to the Chief Inspector with the Inspector's report under sub-section (3) of Section 7 of the Act in Form I.

(*e*) Where a certificate in Form II and a memorandum of inspection book in Form I are furnished by an Inspecting Authority in accordance with sub-regulation (*c*) of Regulation 4, the Inspector shall, on receipt of an application for registration under Section 7 (1) of the Act, proceed to make such examination and measurement of the boiler as will satisfy him that the boiler is the one certified by the Inspecting Authority and that it has sustained no damage in transit for which purpose he may, if he considers it necessary, subject the boiler to hydraulic test in accordance with Regulation 379.

The Inspector shall, if he is satisfied with the condition of the boiler, accept the particulars and approved working pressure entered in Form I by the Inspecting

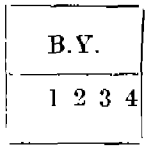
Authority as if they had been ascertained and entered by himself and shall issue a provisional order to enable the boiler to be worked.

He shall make such entries in respect of his examination of the boiler in the Memorandum of Inspection Book as may be required and shall submit the book and Inspecting Authority's certificate and drawing of the boiler with his report to the Chief Inspector as prescribed under sub-regulation (*d*).

382. *Engraving of registry number.—(*a*) The registry number of every boiler shall, within a period of one month after the registration thereof, be cut in the front plate thereof in such position as shall be pointed out by the Inspector. The device for each state shall be distinguished by the following letters :—

Ajmer	A.J.
Assam	A.
Bhopal	B.P.L.
Bihar	B.R.
Bilaspur	B.I.
Bombay	B.Y.
Coorg	C.
Delhi	D.
Himachal Pradesh	H.P.
Kutch	K.U.
Madhya Pradesh	M.P.
Madras	M.
Manipur	M.A.
Orissa	O.
Punjab (India)	P.I.
Tripura	T.R.
Uttar Pradesh	U.P.
Vindhya Pradesh	V.P.
West Bengal	W.B.L.

The distinguishing letters shall be engraved above a number and separated therefrom by a horizontal line two and a half inches in length. The letters and figures shall be one inch in height and of suitable breadth, provided that in the case of small boilers the letters and figures of the device may, in the discretion of the Chief Inspector, be reduced to 3/8″ in height. The whole shall be enclosed in a rectangle, the upper and lower sides of which shall be three inches apart and one quarter inch clear of the top of the letters and the bottom of the figures respectively as indicated below :—



The side lines shall beat equal distance clear from the figures. The engraving shall not be less than 1/64th inch in depth.

(*b*) The engraving shall be complete and ready for verification within thirty days of the first inspection of the boiler.

(*c*) Boilers having registry devices differing from those prescribed herein shall have such devices obliterated, altered or cut anew in conformity with those prescribed above. The original numbers of such boilers shall be retained in the new device. A number once allotted to a boiler shall not be used again for another boiler.

*NOTE.—Engraving slips for tracing the devices in the boiler will be supplied by the Chief Inspector ; the slip should be pasted on the part of the boiler pointed out by the Inspector.

383. Measurement of heating surface.—(*a*) For the purpose of regulating the area of the safety valves and the amount of registration and inspection fees the "heating surface" of a boiler shall be the total surface of all plates and tubes exposed to heat on one side and in contact with water on the other measured on the water side or the fire side, whichever is larger.

(*b*) For Lancashire and Cornish boilers the total heating surface shall include the wetted surface of the furnaces between the end plates, the fire surface of cross tubes where fitted, and the part of the external shell below the side flue covers. In estimating the areas furnaces shall be considered as plain cylinders ; the area of their wetted surface shall be taken as their mean external circumference × the length of the boiler between end plates. For the shell the width of that part of the circumference below the flue covers shall be taken as =2 D, and this width × the length between end plates shall be taken as the area of shell heating surface. The part of the surface of the back-end plate exposed to heat shall be omitted from the calculation.

Example.—The formula for the total heating surface of a Lancashire boiler having plain furnaces without cross tubes is as follows :—

H.S. in square feet =2L (3·14d+D). L is the length of the boiler between end plates in feet, d is the mean external diameter of the furnaces in feet and D is the internal diameter of the largest belt of shell in feet.

(*c*) For steam and water drums of water tube boilers the heating surface of the drum shall be taken as half the external mean circumference multiplied by the clear length of drum between the outer brick walls or centres of cross boxes, as the case may be. The heating surface of the tubes shall be taken as the external surface of the tubes between the tube plates or headers. The heating surface of the headers shall be omitted from the calculation. Integral economisers shall be deemed as component heating surface.

(*d*) For marine boilers of the fire-tube type the heating surface shall include the wetted surface of the furnaces between the tube plates (considered in the same way as for Lancashire boilers), the wetted surface of the combustion chambers (less the area of the tube holes) and the wetted surface of the tubes between tube plates. The parts of the front tube plate exposed to heat shall be omitted from the calculation.

(*e*) For locomotive type boilers the heating surface shall include the wetted surface of the fire-box above the foundation ring (less the area of the tube holes and the fire-hole and ring) and the wetted surface of the tubes between tube plates. The smoke box tube plate shall be omitted from the calculation.

(*f*) For vertical boilers of ordinary type the heating surface shall include the wetted surface of the fire-box above the foundation ring (less the area of fire-hole and ring and tube holes, if any) and the surface of any cross or other tubes and uptake below the lowest water level shown in the gauge glass.

(*g*) For any other heating surface not provided for in the foregoing instructions the same general procedure shall be observed.

(*h*) No deduction shall be made for stays, etc., in calculating the heating surface.

384. Boiler rating.—The boiler rating shall be the number of square feet (to the nearest whole figure) in the heating surface of the boiler as determined under Regulation 383.

385. Registration fee.—The fee required to accompany an application under sub-section (1) of section 7 of the Act shall be:—

	Rs.
For Boiler Rating not exceeding 100	40
For Boiler Rating exceeding 100 but not exceeding 300 . . .	50

	Rs.
For Boiler Rating exceeding 300 but not exceeding 500 . . .	60
For Boiler Rating exceeding 500 but not exceeding 700 . . .	70
For Boiler Rating exceeding 700 but not exceeding 900 . . .	80
For Boiler Rating exceeding 900 but not exceeding 1,100 . . .	90
For Boiler Rating exceeding 1,100 but not exceeding 2,000 . .	100
For Boiler Rating exceeding 2,000 but not exceeding 4,000 . .	120
For Boiler Rating exceeding 4,000 but not exceeding 6,000 . .	140
For Boiler Rating exceeding 6,000 but not exceeding 8,000 . .	160
For Boiler Rating exceeding 8,000 but not exceeding 10,000 . .	180
For Boiler Rating exceeding 10,000	200

Provided that the Chief Inspector may direct that no fees shall be payable in respect of a fresh application made in pursuance of sub-section (2) of Section 14 of the Act.

386. *Memorandum of Inspection Book.—(*a*) A Memorandum of Inspection Book shall be prepared for each boiler in Form I. In this book the Inspector shall enter in ink all particulars and dimensions of the boiler with the calculations for the various parts in detail, particulars of hydraulic test and steam test and his inspection notes.

(*b*) At subsequent inspections Inspectors shall enter the dates of the inspections, hydraulic tests and steam tests, when such are made with their notes thereon.

(*c*) Inspectors should also enter in the Memorandum of Inspection Book the general condition of the boiler and of repairs, to what extent boilers have been cleared of brick work, etc., a report of all casual visits, visits for inspection of repairs, for inspection of main steam pipes, and reports on accidents, etc., in this way the Memorandum of Inspection Book will provide a useful record of the boiler's history for the information and guidance of Inspectors at subsequent inspections.

(*d*) On submission of the Memorandum Book to the Chief Inspector he will in the case of newly registered boilers, check all particulars and calculations and approve of the working pressure that is to be permitted. In the case of old boilers, the Chief Inspector will examine the Inspector's notes of inspection and proposals made for repairs or reduction of pressure. A pressure once approved for the boiler should not be altered without the written authority of the Chief Inspector.

387. Registration Book.—(*a*) A Registration Book or copy of Memorandum of Inspection Book containing all the particulars required for registration shall be maintained in the office of the Chief Inspector in Form I and any orders passed by him regarding the boiler shall be entered in the Registration Book under his initials.

(*b*) The Chief Inspector should also see that the notes of subsequent inspections entered in the Memorandum of Inspection Book are copied in the Registration Book.

388. Transfer of Memorandum of Inspection Book and Registration Book.—On a boiler passing from one State to another, the Memorandum of Inspection Book and the Registration Book shall, on the request of the Chief Inspector of the State to which the boiler has been transferred, be forwarded to that officer who shall take over their custody and maintain them as hereinbefore prescribed.

389. †Grant of certificate.—(*a*) A certificate for the use of a boiler shall be granted in Form VI. In the certificate shall be entered the maximum pressure at which the boiler shall be worked, the load to be placed on the safety valves or the

* NOTE.—The Memorandum of Inspection Book should always be kept clean and up to date. Inspection Books, except when actually required by the Inspector, should be filed in the office of the Chief Inspector.

† NOTE.—The Inspector's remark should be as brief as possible.

thickness of washers or ferrules required as safeguard against overloading, the date and pressure of the last hydraulic test of the boiler and, when applicable, of the main steam pipes prescribed.

390. Procedure for inspection of installed boilers.—(a) **General Instructions.**—It is essential to have every part of a boiler, that is accessible, open and properly prepared for examination, internally and externally. All boilers have openings through which an examination may be made and which for operation are closed ; all such parts shall be opened whether for access to water surfaces, or heater surfaces. In cooling a boiler down for inspection or repairs, the water should not be withdrawn until the setting is sufficiently cooled to avoid damage to the boiler and when possible allowed to cool down naturally. It is not necessary, in order to comply with ordinary prudence, to remove insulation material, masonry, or fixed parts of the boiler, unless defects or deterioration peculiar to certain types or inaccessible parts of boilers are suspected and where there is moisture or vapour showing through the covering, the covering should be removed at once and a complete investigation made. Particular attention should be paid to the external parts of boilers in the way of seating blocks, especially when the situation is damp. Saddle tanks and engine fittings of locomotive type boilers should be removed to facilitate the inspection of the parts underneath at the first inspection, and at any reasonable period afterwards if the Inspector cannot otherwise satisfy himself as to the condition of those parts. Water walls, shall be bared at least once in every 24 months. Upon sufficient visible evidence or suspicion due to age or other causes, every effort shall be made to discover the true condition, even to the removal of insulating material, masonry or fixed parts of a boiler. Sometimes drilling or cutting away of parts is justifiable and necessary to positively determine this condition.

The Inspector should, whenever the size permits, go inside it and make a thorough inspection of all its internal parts. Before doing so, he should of course, satisfy himself that proper provision has been made for disconnecting the boiler from any other boiler under steam. Should he find that proper provision for disconnection has not been made or that the boiler has not been properly cleaned or scaled, or that is unreasonably hot, he should decline to proceed with the inspection and should report the facts to the Chief Inspector for orders. When a boiler is of such a size or its construction is such that the Inspector cannot go inside it, there should be sufficient sightholes or handholes provided to enable him to see the principal internal parts ; if any important part of a boiler is so constructed that the Inspector cannot examine it, he should report the facts to the Chief Inspector for orders.

(b) **Scale, Oil, etc.**—Upon entering a boiler, the Inspector shall examine all surfaces of the exposed metal to observe the action caused by the use of water, oil scale solvents, or other substances which may have intentionally or unintentionally gone in with the feedwater. Any evidence of oil is dangerous and immediate steps shall be taken to prevent any further entrance of oil into the boiler. Oil or scale in the tubes of water-tube boilers or on plates over the fire of any boiler is particularly bad, often causing them to rupture.

(c) **Corrosion, Grooving.**—A given amount of corrosion along or immediately adjacent to a seam is more serious than a similar amount of corrosion in the solid plate away from the seams. Grooving along longitudinal seams is especially significant as grooving or cracks are likely to occur when the material is highly stressed. Severe corrosion is likely to occur at points where the circulation of the water is poor and such places should be examined most carefully for evidences of corrosive action.

If the Inspector decides that a boiler in one or more of its parts is no longer fit for the pressure approved for it, he must without delay report his proposal for reducing the pressure to the Chief Inspector and at the same time submit his calculation for the wasted parts for check and approval of pressure.

With regard to the pitting and wasting of shell plates, the Inspector should bear in mind that shell plates may become reduced in thickness to an appreciable extent and still be stronger than longitudinal seams.

All flanging shall be thoroughly inspected and particularly the flanges of circular end plates that are not stayed. Internal grooving in the fillet of such heads and external grooving in the outer surfaces of heads concave to pressure is very common since there is slight movement in the heads of this character which produces this kind of defect. Some types of boilers have what is known as the OG or reversed flange construction in some of their parts that may be inaccessible to the eye, but the condition shall be determined by the insertion of a mirror which at a proper angle will reflect back to the eye the condition of such a place, or any other feasible manner.

(d) **Stays.**—All stays, whether diagonal or through, shall be examined to note that they are in even tension. All fastened ends shall be examined to note whether cracks exist where the stays are punched or drilled for rivets or bolts and, if not found in proper tension, the inspector should recommend their proper adjustment.

(e) **Manholes and other Openings.**—The manhole and other reinforcing plates, as well as nozzles or other connections flanged or screwed into a boiler, shall be examined internally as well as externally to see that they are not cracked or deformed, and wherever possible observation shall be made from the inside of the boiler as to the thoroughness with which its pipe connections are made to the boiler. All openings to external attachments, such as water column connections, openings in dry pipes and openings to safety valves, shall be noted to see that they are free from obstructions.

(f) **Fire Surfaces—Bulging, Blistering, Leaks.**—Particular attention shall be given to the plate or tube surfaces exposed to the fire. The Inspector shall observe whether any part of the boiler has become deformed during operation by bulging or blistering ; the former is a distortion of the entire thickness of the plate or tube where it takes place, while the latter is a lamination or separation of the plate due to foreign material being embedded in the ingot before the plate is rolled. If bulges or blisters are of such size as would seriously weaken the plate or tube, and especially when a leakage is noted coming from those defects, the boiler shall be discontinued from service until the defective part or parts have received proper repairs. Careful observation shall be made to detect leakage from any portion of the boiler structures, particularly in the vicinity of seams and tube ends. Fire tubes sometimes blister but rarely collapse ; the Inspector should look through the tubes for such defects and if they are found with a sufficient degree of distortion they should be removed.

(g) **Lap Joints, Fire Cracks.**—Lap-joint boilers are apt to crack where the plates lap in the longitudinal or straight seam ; if there is any evidence of leakage or other distress at this point, it shall be thoroughly investigated and, if necessary rivets removed or the plate slotted in order to determine whether cracks exist in the seam. Any cracks noted in shell plates are usually dangerous except fire cracks that run from the edge of the plate into the rivet holes of girth seams. A limited number of such fire cracks is not usually a very serious matter.

(h) **Testing Staybolts.**—The Inspector shall test staybolts by tapping one end of each bolt with a hammer and when practicable a hammer or other heavy tool should be held on the opposite end to make the test more effective.

(i) **Tubes—Their Defects etc.**—(*i*) Tubes in horizontal fire-tube boilers deteriorate more rapidly at the ends forward the fire, and they should be carefully tapped with a light hammer on their outer surface to ascertain whether there has been

serious reduction in thickness. The tubes of vertical tubular boilers are more susceptible to deterioration at the upper ends when exposed to the products of combustion without water protection. They should be reached as far as possible either through the handholes, if any, or inspected at the ends.

(*ii*) The surfaces should be carefully examined to detect bulges or cracks, or any evidences of defective welds. Where there is a strong draft the tubes may become thinned by corrosion produced by the impingement of particles of fuel and ash, or the improper use of soot blowers. A leak from a tube frequently causes serious corrosive action on a number of tubes in its immediate vicinity.

(*iii*) Where short tubes or nipples are employed in joining drums or headers, there is a tendency for waste products of the furnace to lodge in the junction points and such deposits are likely to cause corrosion if moisture is present. All such places should be thoroughly cleaned and examined.

(j) **Ligaments between tube holes.**—The ligaments between tube holes in the heads of all types of fire-tube boilers and in shells of water-tube boilers should be examined. If leakage is noted, it may denote a broken ligament.

(k) **Steam Pockets.**—Steam pockets on fire surfaces are sometimes found in new or replacement work, and wherever this is possible or likely the Inspector should make observation and, if any are found, recommend the necessary changes.

(l) **Pipe connections and Fittings.**—The steam and water pipes, including connections to the water column, shall be examined for leaks, and if any are found it should be determined whether they are the result of excessive strains due to expansion and contraction, or other causes. The general arrangement of the piping in regard to the provisions for expansion and drainage, as well as adequate support at the proper points, shall be carefully noted. The location of the various stop valves shall be observed to see that water will not be pocketed when the valves are closed and thereby establish cause for water-hammer action.

The arrangement of connections between individual boilers and the main steam pipes shall be especially noted to see that any change of position of the boiler, due to setting or other causes, will not produce an undue strain on the piping.

It shall be ascertained whether all pipe connections to the boiler possess the proper strength in their fastenings, whether tapped into the boiler, a fitting, or flange riveted to the boiler.

The Inspector shall determine whether there is proper provision for the expansion and contraction of such piping, and that there is no undue vibration tending to crystallize the parts subjected to it. This includes all steam and water pipe ; and especial attention should be given to the blowoff pipes with their connections and fittings, because the expansion and contraction due to rapid changes in temperature and water-hammer action create a great strain upon the entire blowoff system, which is more pronounced when a number of blowoff pipes are joined in one common discharge. The freedom of the blowoff connection on each boiler shall be tested whenever possible by opening the valve for a few seconds, at which time it can be determined whether there is excessive vibration. Blowoff pipes should be free from external dampness to prevent corrosion.

(m) **Water column.**—The piping to the water column shall be carefully noted to see that there is no chances of water being pocketed in the piping forming the steam connection to the water column. The steam pipe should preferably drain towards the water column. The water-pipe connection to the water column must drain toward the boiler.

The relative position of the water column to the fire surfaces of the boiler shall be observed to determine whether the column is placed in accordance with the

regulations. The attachments shall be examined to determine their operating condition.

(n) **Baffling—Water-Tube Boilers.**—In water-tube boilers, it should be noted, as far as possible, whether or not the proper baffling is in place. In many types of boilers the absence of baffling often causes high temperatures on portions of the boiler structure which are not intended to be exposed to such temperatures, from which a dangerous condition may result. The location of combustion arches with respect to tube surfaces shall be carefully noted. These are sometimes arranged so as to cause the flame to impinge on a particular part of a boiler and produces overheating of the material and consequent danger of the rupture of the part.

(o) **Localization of Heat.**—Localization of heat brought about by improper or defective burner or stoker installation or operation creating a blowpipe effect upon the boiler, shall be condemned.

(p) **Suspended Boilers—Freedom of Expansion.**—Where boilers are suspended the supports and setting shall be carefully examined especially at points where the boiler structure comes near the setting walls or floor. Often accumulation of ash and soot will bind the boiler structure at such points and produce excessive strains on the structure owing to the expansion of the parts under operating conditions.

(q) **Safety Valves.**—As the safety valves are the most important attachments on the boiler, they shall be inspected with the utmost caution. There should be no accumulations of rust, scale, or other foreign substances located in the casings so as to interfere with the free operation of the valves. The setting and freedom of the safety valves should be tested preferably by raising the steam pressure to the blowing-off point, or if this cannot be done, the valves shall be tested by means of the try levers to ascertain if they are free. Where the steam discharged from a safety valve is led through a pipe the Inspector shall determine at the time the valve is operating whether or not the drain opening in the discharge pipe is free and in accordance with the Regulations.

If the Inspector deems it necessary, in order to determine the freedom of discharge from a safety valve, the discharge connections should be removed. Under no circumstances should a stop valve be permitted between a boiler and its safety valve.

(r) **Steam Gauges.**—The steam gauges on all boilers shall be removed and the Inspector shall test them and compare their readings with a standard test gauge. The readings of the steam gauges shall be observed and compared when making an inspection with steam on the boiler, where several boilers are in service connected to a common steam main. The location of the steam gauges shall be noted to see whether or not it is exposed to high temperature either externally, as would be the case if placed close to the smoke flue or other highly heated part of the boiler or setting, or exposed to heat internally due to lack of protection of the gauge spring with a proper syphon or trap to prevent steam from coming in contact with the spring. The Inspector shall see that provisions are made for blowing out the pipe leading to the steam gauge.

391. Calculation of Wasted Shell.—*(a)* When any part is wasted and the Inspector is doubtful of its fitness for the pressure, he shall cause one or more small holes to be bored and from them ascertain the average thickness of the parts from which he can satisfy himself by calculation in accordance with the formula applicable to the part. Such gaugings and calculations he shall enter in the Memorandum of Inspection Book.

(*b*) In making calculations for a wasted part of a boiler shell, *e.g.*, along the line of seating blocks of a Lancashire boiler, the Inspector shall use the following formula:—

$$W.P. = \frac{2t' \times S}{D \times F} \quad \text{.....Eqn. (96)}$$

t'=thickness of wasted plate, where thinnest.

S=minimum tensile strength of material of shell in lbs. per sq. in.

D=internal diameter of shell in inches.

F=factor of safety, which shall not be less than 4.

392. Repairs to Boilers.—(*a*) Extensive reapairs such as, fusion welded or riveted patches to shells, fire boxes and end plates of boilers and extensive building up of wasted parts of boilers permitted under these Regulations, the renewal of furnaces and end plates, parts of shell, fire boxes, girders etc., shall only be entrusted to a Repairer who can satisfy the Chief Inspector regarding the quality of welding and other repair done by his Organisation.

Welding

(*b*) The Repairer shall satisfy the Chief Inspector,—

(*i*) that the electric arc or oxy-acetylene welding sets and all other tools and plant in his possession for carrying out repairs are suitable for the work undertaken,

(*ii*) that the quality of material used conforms to the specification that are prescribed,

(*iii*) that the supervisory and operational staff employed by him possess the necessary training and experience for the work undertaken,

(*iv*) all welding Operators employed by the Repairer shall be required to pass the tests in regard to vertical, horizontal, overhead and fillet welding prescribed by the Chief Inspector,

(*v*) standard of work should be of high order and comply with all the requirements and test that may be prescribed by the Chief Inspector

Riveting and other repairs

(*c*) The Repairer shall satisfy the Chief Inspector,—

(*i*) that he possesses the necessary equipment and tools and engages trained and experienced workmen and staff for the work undertaken.

(*ii*) standard of work should be of a high order and comply with all the requirements and test that may be prescribed by the Chief Inspector, and all material used shall be of boiler quality.

Minor repairs.

(*d*) Notwithstanding anything contained in (a) above, minor repairs as determined at the discretion of the Chief Inspector may be entrusted to any Repairer.

(*e*) The repairs should be supervised, so far as his other duties permit by the Inspector when the fireboxes and smoke tubes of locomotive tube boilers are withdrawn, the opportunity should be taken to inspect the internal parts which are otherwise inaccessible to close inspection.

(*f*) Repairs to boiler shells shall be effected either by patching or by removing a strip of worn or damaged plate and inserting the new strip with covering straps over the longitudinal butt ends, the strength of the riveted joints to be not less than that of the longitudinal joints of the shell.

(*g*) Patches for fire-exposed plates shall be fitted metal to metal without joint of any description. The affected part shall be cut out, leaving the corners of the hole well-rounded. Patches shall be secured, wherever possible, by properly spaced rivets with a width of plate at least equal to the diameter of rivet between the edge of the rivet hole and the edge of the plate. Where riveting is impracticable, the plate shall be secured by well fitting countersunk headed screw pins.

(*h*) The thickness of a patch plate shall not be less than the original thickness of the plate which it is used to patch.

(*i*) Bulged or distorted furnaces of circular section may, if the bulge or distortion is not too great, be pressed back to shape.

(*j*) Circular furnaces of horizontal boilers that have become distorted, may be suitably reinforced.

(*k*) Anti-collapse rings shall be of substantial section either of single or double angles bolted back to back with screw stays not less than 7/8th inch in diameter and about 7 inches in pitch passed through flat of angle and screwed into the Furnace, the ends being either rounded or riveted over on the fire side and fitted with nuts at the other. The stay bolts shall be fitted with ferrules not less than 1 inch in depth between furnace and angle ring.

(*l*) Welding shall not be accepted for the repair of any part of a boiler for which welding is forbidden for a new boiler under these regulations. Boiler shells shall not be repaired by welding beyond the filling up of a small isolated corroded or pitted part or the making up of wasted edges of openings.

(*m*) Cracks or grooving in dished or flat end plates of cylindrical shells or in the bends of furnace flanges in a circumferential direction may be veed out and welded.

Butt welding of smoke tubes.—Smoke tubes may be butt welded either by fusion welding, flash welding or oxy-acetelyne welding, and these should be tested hydraulically at the discretion of the Chief Inspector.

(*n*) Wasted parts of circular furnaces and fire-boxes and fire exposed flat plates as in rectangular fire-boxes and combustion chambers may be cut out and be replaced by new pieces welded in or they may be built up by welding. Longitudinal cracks in circular furnaces and fire-boxes and cracks in rectangular fire-boxes and combustion chambers may be welded.

(*o*) No stay shall be welded.

(*p*) For the purposes of these regulations renewed parts shall be deemed to be parts of a new boiler intended for use at the pressure at which the boiler under renewal is used.

393. Submission of plans of boilers.—(*a*) In the case of land boilers made in India or outside India for use in the States the Chief Inspector may, on receipt of a Treasury acknowledgment of the prescribed fee, receive for examination in advance the plans and particulars of materials, design and construction of boilers so as to avoid questions arising at the examination of the finished boilers.

(*b*) The fee required under sub-regulation (*a*) shall be half the fee which would be required to accompany an application for the registration of the boiler (*vide* Regulation 385).

(*c*) The Chief Inspector shall, after examination of the plans and particulars intimate to the proposers whether he is satisfied with the design and fitness of the parts for the intended pressure and, if not, what modification is necessary therein. When plans and particulars of boilers have been approved, the Inspector in making his examination shall see that the designs as approved have been carefully followed out and that the material corresponds with the approved particulars.

(*d*) The above procedure shall be followed in the case of extensive repairs or alterations to boilers, but no fee shall be leviable for the examination of such plans and particulars.

STEAM PIPES

394. Inspections of steam pipes.—(*a*) Steam pipes shall be inspected and by hydraulically tested before erection in place, the test pressure to be that prescribed in the Standard Conditions for steam pipes. A certificate from an Inspecting Authority or a recognised maker stating that this has been done may be accepted. If the Inspector is stisfied with the test, the pipes may be erected in position , at the steam test of the boiler he shall examine them under steam pressure. No separate certificate for the steam pipes shall be issued, nor shall a separate fee be charged for their inspection.

(*b*) At subsequent inspections of the boiler or at any other time, the Inspector may make an external inspection of the steam pipes and for this purpose may require a part of the lagging at the flanges to be removed, and the pipe made bare. If as a result of this inspection the Inspector is of opinion that the pipes or any portions of them are in an unsatisfactory condition he shall report the matter to the Chief Inspector, who may require the whole of the lagging to be removed and may require any pipe or pipes to be hydraulically tested. The test pressure at such hydraulic test shall be not less than twice the working pressure of the boiler.

(*c*) The date and hydraulic pressure to which steam pipes were subjected shall be entered in the certificate for the boiler and such entries shall be continued from time to time in the renewal certificates for the boiler.

395. Submission of plans of steam pipes.—Plans of steam pipes shall be submitted to the Chief Inspector before construction or at the time of registration of the boiler for his decision whether the pipes and their arrangement comply with the regulations.

CHAPTER X

SAFETY OF PERSONS INSIDE BOILERS

396. Safety of persons working inside boilers.—(*a*) No person shall be compelled or allowed, by the owner or person in charge, to go inside a steam boiler for any purpose whatsoever unless the boiler is effectively disconnected in the manner hereinafter prescribed from any steam or hot water communication with any other boiler.

(*b*) Effective disconnection shall be made either by the removal of the boiler stop valve or of a length of piping from all steam and hot water connections with any other boiler, vessel or pipe containing steam or hot water or by the insertion of substantial blank flanges between the boiler stop valves and piping. The shutting of a stop valve, stop cock or automatic isolating valve alone shall not be deemed to constitute compliance with this regulation.

(*c*) The owner of a boiler to which this regulation is applicable shall obtain the approval of the Chief Inspector in writing to the method of disconnection which he proposes to use and shall be responsible for ensuring that the method so approved is followed in practice.

CHAPTER XI

STANDARD CONDITIONS FOR THE DESIGN AND CONSTRUCTION OF ECONOMISERS AND FEED PIPES.

ECONOMISERS

500.—(*a*) An economiser shall not be registered under sub-section (4) of section 7 of the Act and a certificate shall not be issued under sub-section (5) of that section.

with reference to an economiser, unless the standard conditions in respect of material, design and construction, which are specified in this Chapter are satisfied in respect of such economiser. Where the economiser heating surface is designed to permit the generation of steam and there are no valves interposed between this heating surface and the boiler drum, then the economiser shall be designed in accordance with Chapters I to VIII of the Regulations where these apply:

Provided that an economiser in use at the time Chapter XI of these Regulations came into force, may be so registered and such Certificate may be issued in respect thereof notwithstanding that such standard conditions are not satisfied in respect of such economiser.

(*b*) Notwithstanding anything contained in sub-regulation (*a*) the Chief Inspector may, subject to the provisions of Regulation 502, register an economiser and order the issue of a certificate authorising the use thereof, although the standard conditions are not fully satisfied in respect of such economiser.

GENERAL REQUIREMENTS

501.—(*a*) All cast iron and steel headers and the parts used in the assembly of an economiser shall conform with the requirements of this Chapter in respect of material specification and test, workmanship and structural requirements.

(*b*) All economisers under construction shall be under the supervision of an Inspecting Authority and must be so certified by that Authority.

(*c*) For economisers imported into the States to which these Regulations extend, a certificate from the Inspecting Authority in Form VII certifying that the material was tested and the economiser built under its supervision shall be furnished to the Chief Inspector before or with the first application for registration.

(*d*) In advance of or along with an application for registration, the following shall be furnished : (*i*) a certificate in Form VIII of manufacture and test signed by the Maker or by a responsible representative of the Maker, containing the description of the economiser, particulars of the material used in its construction, and the dimensions of the several parts with the declaration that the limits of tensile breaking strength and tests comply with the standard conditions ; (*ii*) a certificate from the Maker of the material, stating the tensile breaking strength and the elongation provided that if the Maker and Manufacturer be the same, the Manufacturer's precise statement showing the above information shall be accepted.

(*e*) To suit owners convenience where possible it is recommended that economisers be installed in two or more sections.

502. Where no certificates are produced, the working pressure as found by formula will be reduced by 10% . When the workmanship is however in any way doubtful and the Chief Inspector is not satisfied that any of the foregoing conditions would be sufficient to meet the circumstances, he may at his discretion reduce the working pressure by such percentage as he deems fit.

503. Makers' certificates for steel economisers.—The Maker shall furnish the Inspecting Officer with a certificate in the following form:—

> "We hereby certify that the material described below has been made by the Open Hearth or an Electric process acid/basic and has been satisfactorily tested in the presence of the Inspecting Officer/our Test House Manager in accordance with the Standard Tests."

504. For all new economisers the hydraulic test must be applied as shown below :—

On components before assembly	Hydraulic test pressure
Cast iron tubes, headers & Bends	Twice working pressure: Minimum pressure 500 lb./sq. in.
Steel tubes, headers & Bends	Twice working pressure: Minimum pressure 1000 lb./sq. in. Max. pressure 1000 lb./sq. in. plus working pressure.

NOTE.—"Working pressure" shall be the highest pressure at which the economiser relief valves are to be set.

The above test pressure shall be held for a minimum period of ten minutes.

505. Material of construction, workmanship and manufacture.—All material used in the construction of pressure parts shall be tested and shall conform with the following requirements :—

(*a*) The workmanship throughout shall be of the highest standard. All castings shall be well finished, free from defects, porous places and blow holes, and true to dimensions without warping. Where chaplets are used, there must be satisfactory fusion with the metal. Chaplets must be properly tinned with metal free from lead.

(*b*) The screw threads of all bolts must be of British Standard Whitworth forms.

(*c*) All component parts shall where necessary be manufactured to limit gauges to secure interchangeability throughout.

CAST IRON TUBES AND HEADERS

506. Process of manufacture.—The minimum tensile strength shall be in accordance with the following table :—

Main cross sectional thickness of casting represented	Dia. of test bar as cast	Gauge dia. of test piece	Minimum tensile strength tons/sq. in.	
			Tubes	Headers
in.	in.	in.	tons	tons
Up to 5/8	0·875	0·564	14·0	16·0
Over 5/8 and not exceeding 1·1/8	1·2	0·708	13·0	15·0

On analysis, the sulphur and phosphorus content of the iron shall not exceed the following percentages :—

Component	Sulphur per cent max.	Phosphorus per cent max.
Tubes	0·12	1·20
Headers	0·10	1·00

507. Test bars. (*a*) When the test bars are cast separately, they shall be poured at the same time and from the same ladle of metal as the casting or castings they represent. The number of test bars specified in Regulation 508 shall be applicable to all castings of each melt.

(*b*) 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.

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

(*d*) The test bars shall not be subjected to any heat treatment after leaving the moulds except where the castings are heat treated.

508. Number of tensile tests.—(a) The number of tests required for each batch of castings shall be in accodance with the following table the various classes of castings being divided into 4 representative groups :—

Group	Weight of castings	Test requirements
1	Up to 28 lbs.	One test for each 30 cwts. 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 1 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 of same heat as the bar or bars provided for the test.

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

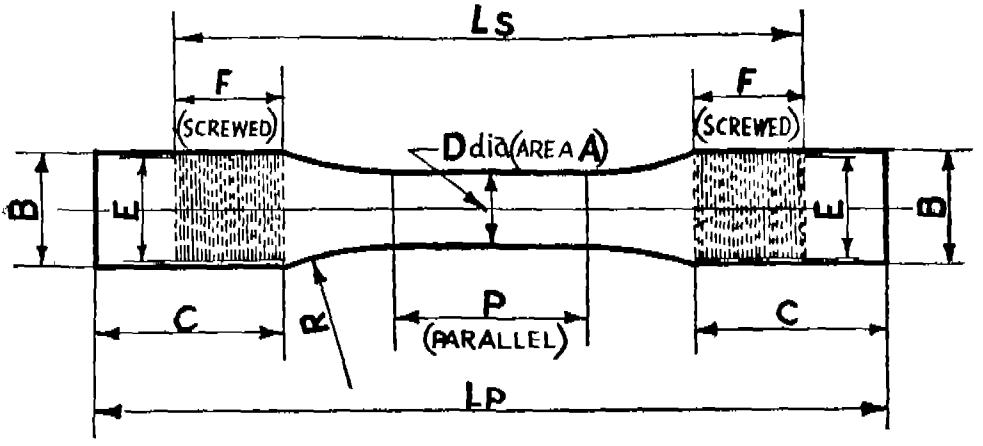
(*b*) The additional tests to be carried out before a casting or batch of castings is rejected shall be in accordance with the following table:—

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

(*c*) 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 test piece .	If this passes	The batch or separate castings represented shall be accepted.
	If this fails	The batch or separate casting represented may be rejected.

509. Standard test piece.—The tensile test bar shall conform to the dimensions shown in the following. Bars may be tested with either plain or screwed ends.



B	D	A	P	R	C	E	F	L_P	L_S	Main cross sectional thickness of casting represented.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0·875	0·564	0·25	2	3½	1½	¾	¾	7-1/16	4-13/16	Up to 5/8
1·20	0·798	0·50	2	3½	2	1·1/8 BSF (1-1/8) (BSW)	1-1/8	8¼	5-7/8	Over 5/8 and not exceeding 1-1/8

The test bars shall be cast as cylindrical bars of the diameters given in Col. B and machined to the dimensions given in Cols. D & P in the above Table.

CONSTRUCTIONAL REQUIREMENTS

CAST IRON ECONOMISERS

510. (*a*) The Manufacturer shall, on the basis of design details, satisfy the Inspecting Authority regarding the design and strength of all parts of Cast Iron Economisers for which, under these Regulations, specific design and stress limitation have not been imposed, subject to the following maximum working pressures :—

	Max. W.P.
(1) Ordinary Vertical Tube	250 lb./ sq. in.
(2) Ordinary Vertical Tube with strengthened tubes .	300 lb./ sq. in.
(3) Ring Stay Vertical Tube	350 lb./ sq. in.
(4) Gill Tube type of approved design . . .	450 lb./ sq. in.

(*b*) A certificate from the Inspecting Authority regarding the safe working pressure of such parts of Cast Iron Economisers for which design and stress limitations have not been imposed under these Regulations, should be furnished to the Chief Inspector.

511. "Joint bolts and studs for cast iron economisers.—(*a*) The maximum working pressure for the bolts and studs shall be calculated by Regulation 518.

(*b*) The use of studs tapped into cast iron is permissible where:—

(*i*) The studs and nuts are not in the path of the flue gases.

(*ii*) The studs are carefully threaded to gauge and fitted into tapped holes of ample depth".

512. Use of cast iron.—Where the water temperature is expected to exceed 425°F. the use of cast iron for pressure parts is prohibited.

STEEL ECONOMISERS WITH OR WITHOUT CAST IRON SLEEVES ON THE TUBES

513. Tubes, Construction.—(*a*) The tubes shall be manufactured in accordance with Regulation 151. (*b*) Suitable provision shall be made for supporting horizontal tubes at one or more intervals in their length to relieve bending stresses, and these supports as well as the end connections must permit free expansion.

514. Tubes Working pressure.—The working pressure of the tubes shall be calculated in accordance with Regulation 338.

515. Headers: Construction.—(*a*) The headers shall be constructed in accordance with Regulation 154.

(*b*) Branches shall be secured by one of the following methods:—

(1) Expanded, belled and welded.

(2) Strength welded with additional securing means.

(3) Full depth-strength weld.

(4) Branches less than 2 inch bore may be screwed and seal welded.

(*c*) Open ends of forged for seamless steel tube headers may be closed by forging, or the ends may be secured by bolting, screwing, or welding in an approved manner.

516. Headers: Working pressure. (a) Rectangular headers. The working pressure shall be calculated in accordance with Regulation 340.

(b) Cylindrical headers. The working pressure shall be calculated in accordance with Regulations 270 and 271.

517. Attachment of tubes to headers (a) Tubes shall be connected to the tube plates by one of the following methods:—

(1) Expanding with bell mouthing or seal welding.

(2) Strength welding.

(3) Mechanical bolted joint.

(b) Roller expanded tubes shall project through the neck or bearing part in the holes by at least a quarter of an inch and shall be secured from drawing out by being bellmouthed to the extent of 1/32" for each inch in diameter plus 2/32".

(c) Tubes expanded into headers may be seal-welded inside or outside the header. Where a seal weld is provided inside the header, the tube end projection and bellmouth specified in (b) is not required.

(d) In the case of roller expanded tubes the tube holes in the headers shall be formed in such a way that the tubes can be effectively tightened in them. There shall be a neck or belt of parallel seating of at least ½ inch.

(e) Where the tubes are strength welded direct to the headers, the technique followed shall be approved by the Inspecting Authority and all welds shall be suitably heat treated.

(f) Bolted joints shall be designed in accordance with Regulation 518.

(g) Tube spacers supporting clips and lugs may be welded to the tubes.

(h) The tubes shall be so arranged that they are accessible for cleaning internally and externally.

JOINT BOLTS AND STUDS

518. Joint bolts.—The maximum working pressure for the bolts shall be determined by the following formula:—

$$W.P. = \frac{N \times C}{A}\left(D - \frac{1 \cdot 28}{n}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (121).}$$

N = No. of bolts securing the parts.

n = No. of screw threads per inch.

D = Bolt diameter in inches measured over the threads.

A = the area exposed to pressure which is assumed to be bounded by a line midway between the pitch line of the bolts and the inner edge of the flange where flat joints are used with joint rings. Where conical joint faces are used with joint rings of curvilinear cross section, the area exposed to pressure shall be assumed to extend to the root of the thread where the tube ends are screwed, or to a corresponding boundary if the flanges are attached by other means.

C = 4,700 for steel bolts or studs of 28 tons/sq. in. minimum ultimate tensile stress where the diameter over thread is less than 3/4 inch.

C = 5,100 for steel bolts or studs of 30 tons/sq. in. minimum ultimate tensile stress where the diameter over thread is less than 3/4 inch.

C = 5,600 for steel bolts or studs of 35 tons/sq. in. minimum ultimate tensile stress where the diameter over thread is less than 3/4 inch.

C = 5,600 for steel bolts or studs of 28 tons/sq. in. minimum ultimate tensile stress where the diameter over thread is not less than 3/4 inch and not greater than 7/8 inch.

C = 7,000 for steel bolts for studs of 28 tons/sq. in. minimum ultimate tensile stress where the diameter over thread is greater than 7/8 inch.

VALVES AND MOUNTINGS

519. (*a*) **Thermometers.**– All economisers shall be provided with Thermometers or measuring water temperature adjacent to the inlet and outlet connections.

(*b*) **Relief valves.**—A valve which shall prevent increase of pressure beyond a predetermined limit shall be fitted to every economiser (except where economisers are designed to permit steam generation and have open connections to the boiler drum) and the design shall provide against unauthorised interference with the loading. Economisers with pressure parts of cast iron and arranged in groups of tiers connected by circulating piping shall have a relief valve fixed on each group or tier. Relief valves should have a minimum diameter of 2″.

(*c*) **Pressure Gauge.**—Means for indicating the pressure in the economiser shall be provided by a Pressure Gauge constructed on the lines of Regulation 327.

(*d*) **Air release valves.**—Means must be provided for the release of air at all points where air accumulation may occur.

(*e*) **Blow off drain valves.**—Means must be provided for draining the economiser completely of water.

(*f*) **Non-return valves.**—Economisers provided with means for heating the incoming feed by mixing it with hot water from the economiser outlet must have a non-return valve in the hot water return line.

(*g*) **Reserve Flues.**—In every case a reserve flue shall be provided for by-passing the flue gases when no water is being fed to the boiler through the economiser.

(*h*) **Explosion Doors.**—To relieve the economiser of excessive pressure accumulation due to internal explosions doors preferably of horizontally hinged 'self-sealing' type shall be fitted.

(*i*) **Hydraulic Tests.**—All valves and mountings shall be tested by hydraulic pressure to not less than twice the working pressure subject to a maximum of 1000 lb./sq. in. plus the working pressure.

NOTE.—The working pressure shall be the highest pressure at which the economiser relief valves are to be set.

FEED PIPES

520. General.—Feed pipes may be made of steel, cast iron or copper but cast iron pipes will not be accepted for a working pressure over 200 lbs per sq. in. or 425°F. Copper feed pipes shall be solid drawn and not exceed 8" external diameter and may be used for a working pressure not exceeding 350 lbs. or 300°F.

Design pressure for feed piping.—The design pressure shall be the maximum pressure generated in overcoming friction and other losses in the feed piping under ordinary working conditions, or the maximum pressure which can be generated by the boiler feed pumps unless special provision is made to prevent that pressure being communicated to the pipe line.

521. Steel feed pipes.—Steel feed pipes shall be in accordance with Chapter VIII.

522. Cast iron feed pipes.—(*a*) The standard conditions for material of construction and tests for cast iron pipes shall comply with Regulations 505 to 509.

(*b*) The maximum working pressure shall be determined by the following formula:—

$$W.P. = \frac{130\ (t - 6)}{d} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (122)}$$

t = thickness in thirty-seconds of an inch.
d = the external diameter of the pipe in inches.

523. Copper feed pipes.—(*a*) The standard conditions for material of construction and tests for copper pipes shall comply with Regulation 35.

(*b*) The maximum working pressure shall be determined by the following formula:—

$$W.P. = \frac{60(t - 3)}{d} \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (123)}$$

t = thickness in hundredths of an inch.
d = external diameter of the pipe in inches.

REGULATIONS FOR REGISTRATION AND INSPECTION OF ECONOMISERS.

524. Preparation for inspection.— (*a*) At each inspection the economiser shall be emptied and thoroughly cleaned internally and externally and in the flues. All mountings shall be opened up and caps removed to permit adequate inspection.

(*b*) The owner of an economiser to which this Regulation is applicable shall obtain the approval of the Chief Inspector in writing to the method of disconnection which he proposes to use and shall be responsible for ensuring that the method so approved is followed in practice.

525. Procedure for registration.— (*a*) On receipt of an application for registration the Inspector, shall, after the economiser has been prepared for examination, take full particulars of the design and ascertain the working pressure allowed by the Regulations.

(*b*) If as required under Regulation 510(a), a certificate from the Inspecting Authority has not been furnished, the Chief Inspector shall determine the fitness of such parts as per the following formulae subject to the limitation prescribed under Reg. 510(a) :—

(i) Economisers with pressed socket joints not reinforced.—

$$\text{W. P.} = \frac{\text{Area of Socket in contact,}}{\text{(width inside Header) (Pitch of tubes in Header)}} \times$$

$$\frac{\text{Friction Factor.}}{\text{W.P.=Working pressure in lbs. per sq in}} \qquad \text{Eqn. (124)}$$

Friction Factor = 300.

(ii) Headers for above Economisers :—

$$\text{W. P.} = \frac{20\,(t-6)^2}{b^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (125)}$$

t = Thickness of flat sides in thirty seconds of an inch.

b = Depth in inches of the [illegible]

(iii) Economisers with pressed socket joints reinforced.—

$$\text{W. P.} = \frac{\text{Area of Socket in contact,}}{\text{(width inside Header) (Pitch of tubes in Header)}} \times$$

$$\text{Where k} = \frac{\text{Friction Factor} + \text{k}}{\text{No. of stays per header}} \times \text{P} \quad . \quad . \quad . \quad \text{Eqn. (126)}$$

Where friction factor = 300.

and P=300 for approved design of reinforcing stay. In no case value of K shall be considered greater than 150.

(iv) Tubes for above Economisers :—

$$\text{W. P.} = \frac{200\,(t-6)}{d} \quad . \quad . \quad . \quad . \quad . \quad \text{Eqn. (127)}$$

Where t = Thickness in thirty seconds of an inch,

d = External diameter in inches.

(v) **Headers for Economisers with reinforced socket joints :—**

$$W.P. = \frac{200\,(t-9)}{d} \quad \text{Eqn. (128)}$$

t = thickness in thirty seconds of an inch.

d = External diameter in inches.

(vi) **Manifold Pipes for above Economisers :—**

$$W.P. = \frac{200\,(t-7)}{D} \quad \text{Eqn. (129)}$$

t = Thickness in thirty seconds of an inch.

d = External diameter in inches.

(vii) **Cast iron Economiser with gills or other extended surface Tubes :—**

$$W.P. = \frac{500\,(t-C)}{d} \quad \text{Eqn. (130)}$$

t = Thickness in thirty seconds of an inch.

C = 8 for portion where gills act as reinforcement ; 10 for portion not reinforced.

d = External diameter in inches.

(viii) **Bends and Manifold Pipes for above Economisers :—**

$$W.P. = \frac{200\,(t-10)}{d} \quad \text{Eqn. (131)}$$

t = Thickness in thirty seconds of an inch.

d = External diameter in inches.

(*c*) The Inspector shall enter full particulars of the economiser together with the required calculations of various parts in a Memorandum of the Inspection Book (Form IX) and submit it to the Chief Inspector.

(*d*) If no formula or co-efficient applicable to any part, other than what is mentioned above, is contained in the Regulations, the Chief Inspector shall at his discretion determine the fitness of the part.

(*e*) After Inspecting the Economiser and ascertaining, as prescribed, the maximum working pressure to which it may be worked, the Inspector shall witness the hydraulic test in accordance with Regulation No. 527 and may issue a Provisional Order in Form X.

526. Procedure at subsequent inspection.—(*a*) After the economiser has been cleaned the Inspector shall make a thorough examination so far as its construction permits. The external condition of the tubes should be carefully noted for wasting especially at the feed inlet end and all accessible tubes should be calipered. The internal surfaces of cast iron tubes should be closely observed for graphitic wasting as far as it is possible and in the event of any tube failure these should be broken up for scrutiny so that the general internal condition of the other tubes may be estimated.

(*b*) Where tubes or other parts are wasted, the strength should be re-calculated.

(*c*) The scraper gear should be examined to note if any parts are missing if the length of travel is adequate and if the scrapers are correctly adjusted.

(*d*) All cap bolts are to be inspected, also the condition and position of the dampers and baffles.

(e) The record of each inspection and calculations will be entered in the Memorandum of Inspection Book.

527. Procedure for Hydraulic test.—Every economiser for registration shall be hydraulically tested in the presence of an Inspector to 1½ times the working pressure. Subsequent hudraulic test may be carried out after repairs or when the Inspector considers it necessary.

During the test all parts externally and in the flues shall be noted for leakages.

528. Memorandum of inspection book.—In this book the Inspector shall enter all particulars and dimensions of the economiser with the required calculations for the various parts together with details of hydraulic test. At subsequent inspection the Inspector shall enter all notes pertaining to the condition of the various parts.

529. Registration Books will be maintained on the lines of Regulation 387.

530. Grant of certificate.—A certificate for the use of an economiser shall be granted in Form XI.

531. Casual visits.—(a) The Inspector shall note if the economiser is working satisfactorily, and if the relief valves, are correctly adjusted, if the scraper gear is operating and if the external brickwork is free from cracks.

(b) He shall also ascertain that the makers' instructions for working are being strictly followed by the owner.

NOTE.—It is recommended that the feed inlet temperature to the economiser should not be less than 100°F to prevent sweating and consequent external corrosion of the tube and bottom headers.

532. Economiser rating.—The rating shall be equivalent to the area of the heating surface in square feet which shall be computed from the tubes and the Headers.

533. Registration fee.—An application for registration shall be accompanied by appropriate fee.

		Rs.
For Economiser rating not exceeding 500		50
For Economiser rating exceeding 500	but not exceeding 1,000	60
For Economiser rating exceeding 1,000	but not exceeding 1,500	70
For Economiser rating exceeding 1,500	but not exceeding 2,000	80
For Economiser rating exceeding 2,000	but not exceeding 2,500	90
For Economiser rating exceeding 2,500	but not exceeding 3,000	100
For Economiser rating exceeding 3,000	but not exceeding 3,500	110
For Economiser rating exceeding 3,500	but not exceeding 4,000	120
For Economiser rating exceeding 4,000	but not exceeding 4,500	130
For Economiser rating exceeding 4,500	but not exceeding 5,000	140
For Economiser rating exceeding 5,000		150

534. Engraving of Registry Number.—(a) Each section, branch pipe or detachable part subject to the working pressure shall be marked for identification with a Registry Number and also the appropriate device as shown in Regulation 382.

(b) In the case of the ordinary vertical type of cast iron economisers, the device and number shall be stamped on the header flange connected to the top branch pipe. In each case the stamping shall be on some conspicuous part not affected by the gases or other corroding influence.

The letter "E" should be prefixed to the number in the denominator.

Example : $\frac{\text{U.P.}}{\text{E}}$

FORM I

(Regulations 386 and 387)



INDIAN BOILERS ACT, 1923

BOILER INSPECTION DEPARTMENT

BOILER

REGISTRY NUMBER

Memorandum of Inspection

OR

Registration Book

MISCELLANEOUS

District,.....
Owner, ...
Address of Factory, ...

Nearest Railway Station,.....
Factory is.....miles by.....from station.
Work or Factory,.....
Working season,.....

BOILER REGISTERED at..... on .....
REGISTER BOOK No.....PAGE.....
REGISTRY NUMBER,.....Verified on,.....
APPROVED WORKING PRESSURE,.....lbs.
BOILER RATING, ...INSPECTION FEE, ...Rs.
REGISTRATION BOOK filed at.....on.....

Remarks on transfers, etc.....

PROVISIONAL ORDER AND CERTIFICATE RECORD

Fee	Date of payment	Date of Inspection	Certificate No. and date	Period of Certificate	Working Pressure	Boiler Rating	Evaporation	Initials of Inspector

PARTICULARS AND DIMENSIONS

Type of boiler.....Leading dimensions.....

Maker,.....Intended working pressure.....lbs.

Place and year of make,.....Maker's number.....

Description of boiler,.....

Facsimile of maker's stamp

Position of stamp .....

MAKER'S CERTIFICATES

Boiler Maker — Name,.....

Manufacture, hydraulic test to.....lbs., drawing No. .....received.....

Inspecting Authority — Name,.....

Tests of material, construction, supervision, hydraulic test,.....received.....

Steel Makers — Plates — Name, ...

Process, ...received.....

Bars — Name,.....

Process, ...received.....

Rivets — .....

Process, ...received.....

PARTICULARS AND DIMENSIONS—contd.

MAKER'S CERTIFICATES—*contd.*

Rolling Mill

Plates, ... received .....

Bars, ... received .....

Rivets, ... received .....

Plates.

TEST RESULTS

Shell, ... T ..... to ..... tons. E. ..... to ..... % in ..... ins. .....

Gusset Stays . . . T ..... to ..... tons. E. ..... to ..... % in ..... ins. .....

Girders . . . . T ..... to ..... tons. E ..... to ..... % in ..... ins. .....

End and side . . . T ..... to ..... tons. E ..... to ..... % in ..... ins. .....

Fire and Flanged . . . T ..... to ..... tons. E ..... to ..... % in ..... ins. .....

.... T ..... to ..... tons. E ..... to ..... % in ..... ins. .....

.... T ..... to ..... tons. E ..... to ..... % in ..... ins. .....

Bar, ... T ..... to ..... tons. E ..... to ..... % in ..... ins. .....

Screw, ... T ..... to ..... tons. E ..... to ..... % in ..... ins. .....

Brand Bends Riveting.

Bars, ... T ..... to ..... tons. E ..... to ..... % in ..... ins. .....

Manufactured, ...

Plates, ...

Bars, ...

Plates, ...

Analysis

	Phos.	Sulph.
	%	%

PARTICULARS AND DIMENSIONS—contd.

CYLINDRICAL SHELL

	(a) Shell or Fire-box casing Crown	(b) Barrel or Mud Drum	(c) Steam & Water Drum or Dome
Names of parts			
Number and material of each			
Length between end plates			
Do. do. do. seam			
Diameter inside largest belt			
Thickness of plates			
Number of belts of plating			
First or top belt, inside or outside			
Longitudinal seams.			
Position (o'clock)			
Kind, L., S. B., D. B., W.			
Riveting, S., D., T., C., Z., H., M.			
No. of rivets per pitch			
Pitch of rivets			
Diar. of holes, outer rows			
Do. do. inner rows			
Distance between rows, outer			
Do. do. do. inner			
Do. rivet centre to edge			
Outer butt strap, width × thickness			
Inner do. do. do. × do.			
Circumferential seams.			
No. of seams (end and inner)			
Kind L., S. B., D. B., W., F & B.			
Riveting S., D. T., C., Z., H., M.			
No. of rivets per pitch			
Pitch of rivets			
Diar. of holes			
Distance between rows			
Do. rivet centre to edge			

PARTICULARS AND DIMENSIONS—contd.

SHELL ENDPLATES AND LONGITUDINAL STAYS

Parts and materials hereunder-,.....

Plates

Flat, dished, hemispherical (in.....pieces), not stayed, not flanged
Diameter (outside), front,.....back,.....crown,.....Largest circle, ...
Radius of curvature do.,.....do,.....do.,.....
Do. do, corner of flange, shell,.....furnace, ...uptake,.....
Plate thickness, front.....back.....crown,..... tube plate F., ...B,.....
Attacht, to shell, crown or front,.....
Do. do., back end,.....
Do. uptake or furnace crown or front,.....
Do., furnace flue, back end,.....
Shellangle,.....riveting, S., D., pitch .....holes.....
Furnace or uptake riveting, pitch circle,.....do.,.....do., ...
Heml. end sectors, no.,.....riveting S. D.,..do.,.....do.,.....
Steam space doubling plate, front.....back.....
Do. do. stiffener or bulb, do.,.....do.,.....

Stays

Gusset stays, No. F. E., top,.....bottom,.....B., E., top.,.....bottom.....
Longtl. stays No., ...diar.,.....threads,.....nutted,.....
Do. do. pitch, V.,.....H.,.....circle,.....washers,.....

Diagl. do.,.....

PARTICULARS AND DIMENSIONS—contd.

MANHOLES, HAND AND SIGHT HOLES, DOORS AND STAND BLOCKS

Parts and material hereunder,.....

Manholes.

No. and position			
Framed or plate flanged			
Boiler opening, length × width			
Frame opening, length × width			
Frame inside, outside, raised, pressed			
Frame solid, welded, cast			
Frame section on longtl. axis			
Door, type and thickness			
Door, if inside, spigot clearance			
Bolts, no., diar. threads nut			
Bolts, pitch circle			
Compensation ring, width × thickness			
Riveting, S. D., T., no., rivets diar. holes			

Sight Holes

No.....dimensions,.....positions.....

Compensation rings fitted,.....section,.....×.....

Doors, type,.....bolts, diar.,.....threads,.....spigot clearance.....

Cleaning plugs, no.....diar.,.....positon,.....

Blocks etc.

Height,.....diar.(outside), top,.....bottom,.....thickness,.....

Standpipe below stop valve,.....height,.....diar. (outside).....thickness,.....

Flanges .....

PARTICULARS AND DIMENSIONS—contd.

FIREBOX CASING

Parts and material hereunder,.....

Plates

Length over all, bottom,.....Width over all, bottom .....
Height, foundn. seam to inside of crown plate,.....
Crown, arched or flat, riveted to or one piece with sides, diar.,.....
Plate thickness, front,.....sides,.....saddle,.....crown,.....
Radius of corner of flange, front .....do,.....do,.....
Riveting, front to sides, S., D., pitch,.....holes,.....spacing.....
Do. saddle to sides, S. D., do.,.....do.,.....do.,.....
Cross stays, No.....Diar.,.....threads,.....nutted, rivetted, pitch,.....

RECTANGULAR FIREBOX, COMBUSTION CHAMBER, GIRDERS SMOKE OR WATER TUBES AND SCREW STAYS

Parts and material hereunder,.....

Firebox or Combustion Chamber

Length inside, bottom.....top,.....Width inside, bottom,.....top,.....
Height, foundn., seam or chbr. bottom to roof,.....Radius of curve, chbr. bottom,.....roof side,.....
Roof, flat, curved, cambered, corrugated, stayed to shell or girders, type,.....
Plate thickness, firehole or chbr. back,.....sides,.....roof,.....
Do. bottom,.....tubeplate, F.....B.,.....Roof and sides in one,.....
Attacht, to fire box casing at bottom,.....
Do. do. do. firehole,.....
Foundn. ring, section.....riveting, pitch,.....holes,.....
Firehole, do.....do. do. ,.....do.,.....
Do. opening,.....distance of centre above foundn. seam,.....
Side seams, distance between.....riveting, pitch,.....holes,.....

PARTICULARS AND DIMENSIONS—contd.

RECTANGULAR FIREBOX, COMBUSTION CHAMBER, GIRDERS, SMOKE OR WATER TUBES AND SCREW STAYS—*contd.*

Firegrate dimensions,.....type,.....

Girders

Type,.....Section.....no.,.....lengthwise, crosswise, rest on.....

Distance apart,.....Bolts, no.,.....pitch,.....diar.....threads,.....
nutted, screwed into girder.

Slings, no.....distance apart,.....×.....Section.....×.....pins, diar.,

Do. attacht. to shell,.....

Tubes

No. plain,.....stay,.....length between tube plates,.....make,.....

Plain, diar., (out).....thickness,.....F. E., expd., bead. frld. S. E., Expd., bead, or.....

Stay, do. ,.....do.,.....F. E., do., do., nutted, S. E., do. nutted.....

Do. do. , over threads, F. E.,.....S. E.,.....threads,.....nuts,.....

Pitch of plain tubes, V., ...H.,.....D,.....C. Z. straight curved. Lie,.....

Do. stay do.,.....×.....×.....×..... marginal pitch,.....

Screw Stays

Tube plate, no. of rows, V., ...H.,.....Pitch, V.,..... H.,.....

F. hole or back do., V.,.....H.,.....Pitch, V.,.....H.,.....

Sides, do., V.,.....H.,.....Pitch, V.,.....H.,.....

Roof, do., L. wise.....C. wise.....pitch, L.,..... C.,.....

Bottom, do., L. wise.....C. wise.....pitch, L.,..... C.,.....

Ordinary stays, diar.....threads,.....nuts.....riveted, bodies turned to.....in.

Marginal, do., ...do.,.....do.,.....do., do., do.,.....

Roof, do., ...do.,.....do.,.....do., do., do.,.....

PARTICULARS AND DIMENSIONS—contd.

CIRCULAR FURNACE, CROWN AND UPTAKE

Parts and material hereunder, ...

Horizontal and Vertical Furnaces

No. of furnaces, ... Type .....

No. of rings in each, ... Longtl., Seams, ...

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Length between centre.	R															
	L															
Inside diameter.	R															
	L															
Plate thickness.	R															
	L															
Positions of cross tubes.	R															
	L															

PARTICULARS AND DIMENSIONS—contd.

CIRCULAR FURNACE, CROWN AND UPTAKE—*contd.*

Horizontal and Vertical Furnaces

Flanges, type, ... riveting, pitch, ... holes, ...

Caulking ring, ... Radius of corner, ... Flange width, ...

Crosstubes, No. each furnace, ... longtl. seam, ... riveted, welded to Flue.

Do., diar. (outside), top ..... bottom, ... thickness, ...

Attacht. to shell at bottom, ...

Do. do. do. firehole, ...

Foundn. ring, section, ... riveting pitch, ... holes, ...

Firehole do., do., ... do., do., ... do. .....

Do., opening ..... × ..... distance of centre above foundn. seam .....

Screw Stays, No. of rows, ... pitch, V., ... H., ... nearest row to foundn. seam. .....

Do., do., diar, ... threads, ... nuts, ... , riveted, bodies turned to .. in.

Firegrate dimensions, ... type, ...

Crown

Flat, dished hemispherical, not stayed, not flanged, Diar. (outside), ...

Radius of curvature ..... corner of flange, furnace, ... uptake ..... Largest circle, ...

Plate thickness, crown, ... oges ring ..... Boltstay pitch circle, ...

Attacht. to furnace or ..... to uptake, ...

Uptake riveting, pitch circle, ... pitch, ... holes .....

Uptake

Cylindrical, tapered, flanged, ... Longtl. seam ..... Length between seams, ...

Thickness, ... Diar. (outside), top, ... bottom, ... Liner not fitted .....

PARTICULARS AND DIMENSIONS—contd.

WATER TUBES, HEADERS, BOXES AND SUPERHEATER

Parts and material hereunder,.....

Tubes

Main tubes, no.,.....make,.....

Diar, (outside),.....thickness,.....Length between headers or plates,.....

Pitch, V.,.....H.,.....D.,.....C. Z. Straight, curved, Lie,.....

Ends expanded, beaded belled to.....in.. in.....

Downtake tubes, no.....diar. (outside),.....thickness,.....Length (exposed).....

Header

Headers, no.....section (outside).....×.....thickness,.....solid, welded.

Staggered or straight, Lie.....no. tubes in each,.....

Caps round, oval, square, inside, outside, Bolts, Diar.,.....threads,.....nuts,.....

Boxes

Mudbox, Length,.....section (outside) .....×.....thickness,.....solid welded.

Crossboxes, no.,.....do.,.....×.....do.,.....do., do.

Superheator

Tubes, no.....diar. (outside).....thickness,.....make.....

Straight, curved, Lie.,.....Position,.....

Ends expanded, beaded, belled to.....in. in .....

Description of superheating system,.....

Firegrate dimensions,.....Type,.....

DESCRIPTION OF INTEGRAL ECONOMISERS

PARTICULARS AND DIMENSIONS—contd.

MOUNTINGS AND FITTINGS

	Number	Diameter	Type	Material	Bolted to
Valves, etc., Chests — Safety					
Do.					
M. Stop					
A. Do.					
Feed					
Blow Down					
Scum					
Injector					

Miscellaneous Fittings

Water gauges, No. ..... type ..... Test cocks No. .....
Do. Do. top of lower nut is ..... inches above .....
Test cocks, bottom cock is ..... do. .....
Pressure gauge, Type ..... diar, ... ins. range ..... lbs.
Do. Do. maker ..... no ..... red line at ..... lbs.
Tester attachment type ..... Screw ..... position .....
Hose Do. Do ..... do. ..... do. .....
Fusible plug, type ..... position, ...
Blow down elbow, material, ... waste pipe, separate, connected to .....
Centre of feed inlet is ..... inches above ..... on right, left side .....
Feed apparatus .....

Additional fittings .....

CALCULATIONS

SHELL, BARREL, S. & W. DRUM, F.C. CROWN, DOME, M. DRUM, RIVETED JOINTS

Parts	Joint Fig. No.	LONGITUDINAL	Joint Fig. No.	CIRCUMFERENTIAL
(A)		P...D...T..... N. C. S_1		P...D...T ... N. C. S_1
(B)				
(C)				
	Actual	Rule	Actual	Rule
Max. Pitch				
Outer Bows				
Inner Bows				
Edges				
Wide Strap				
Narrow Strap				
Plate %	$\frac{100\ (P-D)}{P}$ = %		$\frac{100\ (P-D)}{P}$ = %	
Rivet %	$\frac{100 \times A \times N \times C \times S_1}{P \times T \times S}$ = %		$\frac{100 \times A \times N \times C \times S_1}{P \times T \times S}$ = %	
Comb'd. %	$\frac{100\ (P-2D)}{P} + \frac{100 \times A \times C \times S_1}{P \times T \times S}$ = %			
Working Pressure	t....S....J....C....D....W.P.=		$\frac{(t-2) \times S \times J}{C \times D}$ = lbs.	

Least Pressure.....lbs.

CALCULATIONS—contd.

FLAT END PLATES AND GUSSET STAYS

PLATE STIFFNESS

Dimensions		Front	Back		FRONT END		
Thickness	t			W.P. =	$\frac{(t-1)^2}{D^2}$	=	lbs.
	t_1						
Diameter of Circles (D).	I—I						
	I—II				Around Manhole.		
	II—III			W.P. =	$\frac{[(t-1)^2+(t_1-1)^2]}{D^2}$	=	lbs.
	III						
	IV						
	IV—V				BACK END		
	Over Furnaces $\square$ or Below Do.			W.P. =	$\frac{(t-1)^2}{D^2}$	=	lbs.
	Manhole						

CALCULATIONS—contd.

GUSSET STAYS—*contd.*

AREAS (A) SUPPORTED BY GUSSET STAYS

	Dimensions	Front	Back	Gussets		Areas
				FRONT END		
Length of Lines	Mid			I.	=	Sq. in.
	I			II.	=	,,
	II			III.	=	,,
	III			IV.	=	,,
	IV			V.	=	,,
	V or Mid				BACK END	
Distance between Lines	I—I			I.	=	,,
	I—II			II.	=	,,
	II—III			III.	=	,,
	III—Apex			IV.	=	,,
	IV—Apex.			V.	=	,,
	IV—V or Mid					

PLATE MARGINS

W.P. .....

$\frac{3 \cdot 7\,(t-1)}{\sqrt{W.P.}}$ = ins. $\frac{3 \cdot 47\,(t-1)}{\sqrt{W.P.}}$ = = ins.

LEAST PRESSURE lbs.

CALCULATIONS—contd.

FLAT END PLATES AND GUSSET STAYS

GUSSET STAY PARTICULARS

Gussets plate, thickness.....tons .....angles.....×.....×....

Gussets

Number and Diameter of Rivets and Sections of Stays.

		N_1	N_2	N_3	N_4	D_1	D_2	D_3	D_4	G	G_1	Toe Rivets
I.	F.											
	B.											
II.	F.											
	B.											
III.	F.											
	B.											
IV.	F.											
	B.											
V.	F.											
	B.											

GAZETTE OF INDIA EXTRAORDINARY

GUSSET STAY CALCULATIONS

			I	II	III	IV	V	
Co-efficient	$N_1 \times A_1$	F.						
		B.						
	$N_2 \times A_2 \times 1{\cdot}875$	F.						
		B.						
	$N_3 \times A_3 \times 1{\cdot}875$	F.						
		B.						
	$N^4 \times A^4$	F.						
		B.						
	$(G - N_2 D_2)(t-2) \cdot 037$	F.						
		B.						
	$(G_1 - D_3)(t-2) \cdot 037$	F.						
		B.						
Working Pressure	$\frac{8500 \times C}{A}$	F.						Least Pressure.....lbs.
		B.						

CALCULATIONS

Least Pressure.

CALCULATIONS—contd.

SAFETY VALVES.

	(A)	(B)	(C)
No. valves each chest			
Type			
Diameter of valve			
Ditto neck			
Ditto outlet			

Balanced Lever ( )

$$\frac{[W.P.(A-a)-V]\ V \text{ to } F}{B} = \text{ins.}$$

Small Valve. ( )

W.P. × a( ) = lbs.

LEVER AND WEIGHT VALVES

High Steam and Low Water Type.

		( )	( )
Weights	B.		
	L.		
	V.		
Distances.	B. to F.		
	G. to F.		
	V. to F.		

Unbalanced Lever. ( )

$$\frac{[W.P\ (A-a)-V]\ V \text{ to } F-(G \text{ to } F)L}{B} = \text{ins.}$$

Ordinary Type. Unbalanced (Lever). ( )

$$\frac{[W.P. \times A-V]\ V \text{ to } F-(G \text{ to } F)\ L}{B} = \text{ins.}$$

DEAD WEIGHT VALVE. ( )

W.P. × A = lbs.

Weights { Plates..... / Casing..... = / Valve.....

CALCULATIONS—contd.

SAFETY VALVES—*contd.*

SPRING LOADED VALVE. ( )

Range of compression.....inches. Load compression.....inches

L=(A×W.P.) ; D= ; C= ; K= ; d= ;

B= ; H= ; W.P.= ; A= ;

Round Section	Square Section	Rectg. Section
$W.P. = \frac{10000 \times d^3}{DACK}$	$W.P. = \frac{33333 \times d^3}{DACK}$	$W.P. = \frac{160{,}000\ B^3 \times H^3}{DACK\ (3B+1{\cdot}8H)}$

REQUISITE AREA OF SAFETY VALVES.

For Saturated stem $A = \frac{E}{CP.}$ for Superheated steam. $AS = A\left(1 + \frac{1{\cdot}5\,T}{1000}\right)$

E= ; C= ; P= ; A=

AS= T= A=

NOTES ON WORKING OF BOILER

Boiler is used for.....

Constant, intermittent or seasonable work.....

Is boiler relieved by spare boiler ?.....

How long worked between cleanings ?.....

Most suitable time for inspection.....

Pump available for hydraulically testing boiler ?.....

Feed water used, town well, surface or jet condenser.....

Nature of water.....

Fuel used.....Are printed instructions kept near boiler ?.....

Period between cleanings approved by Inspector.....

CALCULATIONS—contd.

HEATING SURFACE

Total Heating Surface.....Sq. ft.

Boiler Rating.....

Calculations made by..... .....on..... submitted on..... .....

Do. checked by.....on.....

Least Pressure, that for..... lbs.

Approved working pressure..... lbs.

Chief Inspector's remarks and signature.....

HYDRAULIC TEST (REGISTRATION)

Inspector.....Date of test.....Test pressure.....lbs.

Duration of test.....mins. Boiler pressure, gauge No.....used at test .....

Boiler pressure gauge compared with.....on.....found.....

Position of boiler at test.....

Brickwork.....Lagging.....

Condition of boiler under test.....

Do. do. mountings under test.....

RIGHT HAND

	Ring	Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Furnace Gaugings	Before Test . . .	V															
		H															
	During Test . . .	V															
		H															
	After Test . . .	V															
		H															
	Bulging . . .	V															
		H															
	Permt. Set . . .	V															
		H															

HYDRAULIC TEST (REGISTRATION)—contd.

LEFT HAND

	Ring	Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Furnace Gaugings	Before Test	V															
		H															
	During Test	V															
		H															
	After Test	V															
		H															
	Bulging	V															
		H															
	Permt. Set	V															
		H															

FRONT END BACK END

Sketch position of gauge points

	Gauge Points	A	B	C	D	A	B	C	D
End Plate Gaugings	Before Test								
	During Test								
	After Test								
	Bulging								
	Permt. Set								

STEAM TEST (REGISTRATION)

Inspector .....Date of test. .....
Approved working pressure.....lbs. .....Test pressure .....lbs.
Inspector's pressure gauge.....Boiler pressure gauge No. .....
Boiler connections.....Condition of fire .....
Fuel used .....Draught .....
Safety Valves lifted at (A) .....lbs. (B) .....lbs. (C) .....lbs.

	Beginning	5 mins.	10 mins.	15 mins.	Difference.
Timing of test.					
Height of water in glass . . .					
Pressure by Inspector's gauge . .					
Do. Boiler Do. . . .					

Accumulation of pressure, 100 (——) = %

Do. safety valves efficiently relieve boiler ? .....
Condition of boiler under steam .....
Do. of mountings under steam.....
Loading of valves at blowing pressure (A) .....
Do. do. do. (B) .....
Do. do. do. (C) .....
Thickness of washers or ferrules .....

Feed pump or injector worked .....
Water gauges tested .....
Boiler attendant .....
Limit of load on safety valves to be entered in certificate .....

STEAM PIPES

PLAN OF BOILERS AND MAIN STEAM PIPES

PARTICULARS AND DIMENSIONS

Situation.....

Ry. Nos. of connected boilers .....

Main steam pipes include .....

Pipes, material .....diameter (outside) .....

Do. thickness .....ins., make .....

Do. attachment of flanges.....

Do. made by .....installed in .....

Drainage.....

Pipe covering .....

Provision for disconnection from other boilers .....

Main Steam .....

Auxy, do .....

Blow down .. ..

Feed delivery .....

CALCULATIONS

W.P. .....

STEAM PIPES—contd.

RECORDS OF INSPECTIONS AND TESTS

First inspection inside and outside by .....on .....

First hydraulic test (to lbs.) .....by .....on .....

Remarks .....

INSPECTOR'S NOTES

PARTICULARS OF BOILER ATTENDANTS

Grade	Name	No. and Year of Certificate	Date of Employment

FORM II

INSPECTING AUTHORITY'S CERTIFICATE
OF INSPECTION DURING CONSTRUCTION

[REGULATION 4 (c)]

DESIGNATION OF INSPECTING AUTHORITY

We hereby certify that the type, boiler ; length, feet inches ; diameter, feet, inches ; working pressure, lbs. built by Messrs. at under shop Number was constructed under our supervision and inspected at various stages of construction by the Inspecting Officer and that the construction and workmanship were satisfactory and in accordance with the Standard Conditions for the design and construction of land boilers under the Indian Boilers Act, 1923.

The boiler is stamped of the front end plate with our stamp as shown hereunder :—

Maker's Name Works number	Year of Make
Tested to lbs.	on
W. P. lbs.	Inspecting Officer's or Inspecting Authority's Official Stamp.

The boiler on completion was subjected to a water pressure test of lbs. ; per square inch in the presence of the Inspecting Officer on 19 and satisfactorily withstood the test.

Samples of the plates, stay, angle and rivet, bars used in the construction of the boilers were tested in the presence of the Inspecting Officer and were found to comply with the test prescribed in Chapters II & V of the Regulations relating to Standard Conditions for the design and construction of boilers under the Indian Boilers Act, 1923.

We have satisfied ourselves that the construction and dimensions of the boiler are as shown in the maker's drawing No. signed by us, and that the particulars entered in the maker's certificate of manufacture in Form III countersigned by us, are correct to the best of our knowledge and belief.

Signature of
Inspecting Authority.

Dated : this day of 19

FORM III

Works Address

CONSTRUCTOR'S CERTIFICATE OF MANUFACTURE AND TEST

[REGULATION 4 (*d*)]

Description

1 Type of boiler Length overall Diameter inside largest belt
Intended working pressure lbs. Shop number of boiler
Year of Manufacture Total heating surface sq. ft. Grate area sq. ft.
Description of boiler.
Total Evaporation lbs. P. H.

Inspecting Authority

2 Boiler constructed under supervision of
Boiler hydraulically tested and internally inspected after test by

Construction and Workmanship

3 *Shell Seams.*—The longitudinal seams are and have rows of rivets in inside strap and rows of rivets in outside strap. Rivet holes are inch diameter and number per pitch of inches.

Butt strap cut from plates and bent to required curve in . The circumferential seams joining rings of shell are and riveted.

Rivet holes are inch diameter and number per pitch of inches. The shell and seams are and riveted. Rivet holes are inch diameter and number per pitch of inches.

Details of seams as in drawing No.

Furnace Seams.—The longitudinal seams are . The cross seams joining rings are of type riveted.

Workmanship.—All rivet holes in cylindrical shell and furnace flues drilled in place after plates were bent; plates afterwards taken apart, burrs removed and rough edges of hole cleaned before riveting. Riveting wherever practicable done by machine. All fire-worked plates efficiently annealed after completion of operations. Welded parts of boiler are welding process.

No part of boiler proper including mouthpieces and stand blocks, is made of cast iron or malleable cast iron.

Fusion welded drums.—The construction is in accordance with Chapter V of Indian Boiler Regulations.

Number of longitudinal seams in each ring.

Number of circumferential seams.

Details of repairs to seams during construction, if any.

Details of heat treatment

FORM III—contd.

4	Boiler parts and fittings.	Material	Smelter	Make	Inspecting Officer	Remarks
	Plates Do. Rivet bars Stay Angle. Bolts Tubes Girders Manhole frames Manhole doors Manhole Compn. ring Sighthole doors Stand blocks Stop Valve Chests Safety Valve Chests Feed Valve Chests Blow down Blow down elbow pipe. Water gauge mountings					

NOTE.—Under "Material" enter against appropriate item :—"Steel, Siemes Martin, open hearth acid (or basic) process"; "Wrought Iron, Branch....." "Cast Steel, Process....." etc., etc., and under "Remarks" a brief explanation of process or manufacture where necessary, *e.g.*, "Solid drawn", "Lap welded"; "Solid pressed": Tested by makers.....lbs. per square inch, etc.

THICKNESS OF PLATES, ETC., AND TENSILE TEST LIMITS

5	Part of boiler	Thickness of plates in 32nd or Diameter in Inches	Tensile strength limits to tons	Elongation limits to %	Gauge length ins.	Brand and number on plate
Cylindrical Shell Plates	Shell Butt straps. Steam and water drawn Barrel (Loco) Firebox Casing Crown (Loco). Dome Mud drum					
Shell End Plates	Front End Back End Shell Crown Dome End Mud Drum End Saddle (Loco) Firebox casing sides (loco) Doubling plate					

FORM III.—concld.

THICKNESS OF PLATES ETC. AND TENSILE TEST LIMITS—*contd.*

5	Part of boiler	Thickness of plates in 32nd or Diameter in inches	Tensile strength limits to tons	Elongation limits to %	Gauge length ins.	Brand and number on plate
Flanged and fire-exposed plates	Furnace, Circular (plain) Furnace, Circular (plain) Furnace, Circular (corrugated) Firebox, Crown. Firebox Side. Firebox Front. Firebox Tube. Uptake. Smokebox tube.					
Tubes	Cross Tubes. Water Tubes. Smoke Tubes, (plain) Smoke Tubes (stay) Superheater. Headers. Cross boxes. Mud boxes.					
Stays and Bolts	Gusset Stay (plates) Longitudinal. Cross. Screw. Firebox Roof slings. Firebox Roof Pins. Girder Bolts. Shell Angle Bolts. Uptake Angle Bolts. Manhole Bolts. Sightholo Bolts.					
Miscellaneous	Firebox Girders. End plate Stiffeners. Shell Angle. Furnace Angle. Uptake Angle. Gusset Angle. Manhole Compn. Ring. Manhole Frame. Manhole Cover. Sightholo Compn. Ring. Sightholo Doors. Stand Blocks.					

(6) Certified that the particulars entered herein in manuscript by us are correct and that parts and fittings in sections 4 and 5, against the names of which entries are made, have been used in the construction and fittings of the boiler.

The particulars shown against the various part used are in accordance with the maker's certificates in our possession.

The design of boiler in section and end view with principal parts fully dimensioned is that show in drawing No.

The boiler has been designed and constructed to comply with the Regulations under the Indian Boilers Act, 1923, for a working pressure of lbs. per square inch at our works above named and satisfactorily withstood a water test of lbs. per square inch on the day of 19 . in the presence of our responsible representative whose signature is appended hereunder.

Maker.

Signature of Engineer. Signature of Maker or who witnessed test. Secretary of Firm.

Designation

Dated at the day of 19 .

Signature of Inspecting Authority.

NOTE.—The drawing of the boiler and steel maker's certificate of manufacture and results of plate tests for tensile strength elongation and bending must accompany this certificate and if boiler has been built under the supervision of an Inspecting Authority their certificate in Form II must also be attached.

FORM IV

STEEL MAKER'S CERTIFICATE OF MANUFACTURE AND RESULTS OF TESTS

[REGULATION 4 (c)]

DESIGNATION OF ROLLING MILL

We hereby certify that the material described below has been made by by the electric, open hearth, acid, basic process and rolled by us and has been satisfactorily tested in the presence of your Inspecting Officer, or Test House Manager, in accordance with the Standard tests.

Date of tests *19* .

Signature or Initials,
Test House Manager.

Ordered by

Order Number Date

Boiler Number

RESULTS OF TESTS

Charge Number	Number of plate	Part of boiler	Number of pieces	Size of Plate			Tensile breaking strength in tons per square inch	Elongation in inches per cent.	Bend tests
				Length Ft. In.	Breadth Ft. In.	Thickness in 32nds in.			

Counterfoil

No.

_____

_____

are hereby permitted to use the Boiler (Registry No.) Boiler Rating

made by

and bearing Maker's number at a maximum pressure of lbs.

per square inch pending the issue or refusal of a certificate within six months from the date hereof

after which period this order will become void.

Dated Inspector of Boilers.

No.

FORM V

[REGULATION 381 (c)

PROVISIONAL ORDER UNDER SECTION 9 OF THE INDIAN BOILERS ACT OF 1923.

_____

_____

are hereby permitted to use the Boiler (Register No.) Boiler Rating

made by

and bearing Maker's number at a maximum pressure of lbs.

per square inch pending the issue or refusal of a certificate within six months from the date hereof

after which period this order will become void.

Dated

Inspector of Boilers.

N.B.—This order must be produced on demand by any authorised person and surrendered to the Chief Inspector on receipt of orders.

FORM VI

———————BOILER INSPECTION DEPARTMENT

CERTIFICATE FOR USE OF A BOILER

(*Regulation 389*)

Registry Number of Boiler. Type of Boiler.

Boiler Rating. Place and year of manufacture.

Maximum Continuous Evaporation.

Name of Owner.

Situation of Boiler.

Repairs.

Remarks.

Hydraulically Tested on to lbs. per sq. inch.

I hereby certify that the above described boiler is permitted by me/the Chief Inspector under the provisions of Section 7/8 of the Indian Boilers Act, No. V of 1923, to be worked at a maximum pressure of lbs. to the square inch for the period from
to

The loading of the safety valve is not to exceed

I further certify that the main steam pipe was tested hydraulically to a pressure of lbs. per square inch last on

Fee Rs. paid on

Dated at

This day of 19

Inspector.

Countersigned.

Chief Inspector.

See Reverse for "conditions"

CONDITIONS

(Reverse of Form VI)

(1) No structural alteration, addition or renewal shall be made to the boiler otherwise than in accordance with Section 12 of the Act.

(2) Under the provisions of Section 8 of the Act this certificate shall cease to be in force:—

(*a*) on the expiry of the period for which it was granted ; or

(*b*) when any accident occurs to the boiler , or

(*c*) when the boiler is moved, the boiler not being a vertical boiler the heating surface of which is less than two hundred square feet, or a portable or vehicular boiler ; or

(*d*) when any structural alteration, addition or renewal is made in or to the boiler ; or

(*e*) if the Chief Inspector in any particular case so directs when any structural alteration, addition or renewal is made in or to any steam pipe attached to the boiler ; or

(*f*) on the communication to the owner of the boiler of an order of the Chief Inspector or Inspector prohibiting its use on the ground that it or any steam pipe attached thereto is in a dangerous condition.

Under Section 10 of the Act a boiler may continue to be worked beyond the period of the certificate issued for it provided the owner has applied for a renewal of the certificate before the expiry date and none of the cases specified in clauses (*b*), (*c*), (*d*), (*e*) and (*f*) apply to the boiler.

(3) The boiler shall not be used at a pressure greater than the pressure entered in the certificate as the maximum pressure nor with the safety valve set to a pressure exceeding such maximum pressure.

(4) The boiler shall not be used otherwise than in a condition which the owner reasonably believes to be compatible with safe working.

N.B —Details regarding this boiler are recorded in Registration Book No. . of which a copy may be obtained on payment on application to the Chief Inspector

FORM VII

INSPECTING AUTHORITY'S CERTIFICATE OF INSPECTION UNDER CONSTRUCTION
DESIGNATION OF INSPECTING AUTHORITY [Reg. 501 (c)]

We hereby certify that type, Economiser, consisting of sections, and tubes to each section was constructed for a working pressure of lbs. by Messrs

under our supervision and inspected at various stages of construction by the Inspecting Officer and that the construction and workmanship were satisfactory and in accordance with the standard conditions for the design and construction of Economiser laid down in Chapter XI of the Indian Boiler Regulations, 1950.

Identification mark on each section,
Branch Pipe or other pressure part.
Position of same.

The sections on completion were subjected to a water pressure of lbs per sq in. for ten minutes in the presence of the Inspecting Officer on and satisfactorily withstood the test

Samples of the material used in the constructions of the Economiser were tested in the presence of the Inspecting Officer and were found to comply with the tests prescribed in Chapter XI of the Indian Boiler Regulations, 1950.

We have satisfied ourselves that the construction and dimensions of the Economiser are as shown in the Makers' drawing No. signed by us and that the particulars entered in the Makers' certificate of manufacture in Form VIII countersigned by us are correct to the best of our knowledge and belief.

Dated at this day of 19 Signature of Inspecting Authority.

FORM VIII

Works Address

CONSTRUCTOR'S CERTIFICATE OF MANUFACTURE AND TEST [Reg 501 (*d*)]

1. Description	Type of Economiser	
	No. of Sections	No. of tubes
	Intended working pressure	lbs
	Year of manufacture	Total heating surface of tubes
	Description.	

2. Inspecting Authority .	Economiser constructed under supervision of Sections hydraulically tested for minutes and inspected after test by
3. Construction and workmanship.	Details are in Drawing No. All castings are well finished, free from external defects, porous places and blow-holes and true to dimensions without warping. Where chaplets are used, there is satisfactory fusion with the metal. Chaplets are properly tinned with metal free from lead. All screw threads are of British Standard Whitworth form. All component parts are manufactured to limit gauges to secure interchangeability throughout.

4. Economiser and fittings	Parts	Material	Maker	Inspecting Officer	Remarks
Particulars of material used		Headers Tubes and or Pipes Valve chests Bolts			

THICKNESS OF PARTS AND TENSILE TEST LIMITS

5. Part o Economiser	Thickness in 32nds	Tensile strength limits to tons	Elongation limits to %	Gauge length	Brand and No.
Headers					
Tubes					
Bolts					

Certified that the particulars entered herein are correct and that the parts and fittings mentioned above have been used in the construction and fittings of the Economiser.

The particulars shown against the various parts used are in accordance with the Maker's certificates in our possession.

The design of the economiser in section and end view with principal parts fully dimensioned is that shown in drawing No. The Economiser has been designed and constructed to comply with the Indian Boiler Regulations for a working of lbs. per sq. in., at our Works abovementioned and the sections satisfactorily withstood a water test of lbs. per sq. in. for minutes on day of in the presence of our responsible representative whose signature is appended hereunder.

Designation of Maker

Signature of Engineer who witnessed the test.

Dated at this day of 19

Signature of the Inspecting Authority.

NOTE.—The drawing of the Economiser and Maker's certificate of manufacture showing results of tests for tensile strength and elongation must accompany this certificate and if the economiser has been built under the supervision of an Inspecting Authority their certificate in Form VII must accompany.

FORM IX

(REGULATION 528)



INDIAN BOILERS ACT, 1923

BOILER INSPECTION DEPARTMENT
ECONOMISER
REGISTRY NUMBER

Memorandum of Inspection

OR

Registration Book

MISCELLANEOUS

District

Owners

Address of Factory

Nearest Railway Station

Economiser Registered at on

Register Book No. page

Registry Number verified on

Approved Working Pressure lbs.

Economiser Rating Inspection fee

Registration book filed at on

Remarks on transfer etc.

PROVISIONAL ORDER AND CERTIFICATE RECORD

Fee	Date of payment	Date of inspection.	Certificate No. and date	Period of Certificate	Working pressure	Economiser Rating	Remarks and inspector's initial

Type of economiser .....

Maker .....

Intended Working Pressure .....

Place and year of Make .....

Maker's No. .....

Description of Economiser .....

No. of tubes.....Length.....Dia.....

Thickness .....

Internal dimensions .....

No. of Headers .....

Thickness of Headers.....

Length of Top Branch Pipe.....Thickness .....

Length of Bottom Branch Pipe .....Thickness .....

Dimensions of cap openings .....

Diameter of cap bolts .....

MOUNTINGS'

No.	Diameter	Type	Position	Material
Relief Valve				
Stop Valve				
Blow Down				
Thermometers				
Pressure Gauge				

Additional Fittings .....

MAKERS, CERTIFICATES

Name of Maker .....

Maker's Hydraulic Test Pressure.....

Maker's Drawing No.....

Name of Inspecting Authority .....

Name of Maker of Material .....

Process { Tubes ..... / Headers ..... / Bolts .....

		Test Results
Tubes	T	E
Headers	T	E
Pipes	T	E
Bolts	T	E

%Sulphur.
%Phosphorus
Makers Identification Marks
Position

CALCULATIONS

HEADERS

TUBES

BRANCH PIPES

BOLTS

HEATING SURFACE

Total Heating Surface . . . . . .

Economiser Rating . . . . . .

Calculations made by submitted on

Calculations checked by on

Least pressure, that for lbs.

Approved working pressure lbs.

Chief Inspector's remarks and signature

INSPECTOR'S NOTES

Counter foil
No.

Name of person or firm to which provisional order is granted.

Description of Economiser

Makers No.

Rating.

Pressure permitted

Period

Date

Inspector

FORM X
[Regulation 525(e)]

PROVISIONAL ORDER UNDER THE INDIAN BOILERS ACT, 1923

_____

_____

are hereby permitted to use the Economiser RY No. and Economiser Rating made by and bearing Makers' No. at a maximum pressure of lbs. per sq. in./maximum temperature of °F. pending the issue or refusal of a certificate within six months from the date hereof after which period this order will become void.

Dated at this day

INSPECTOR.

FORM XI

_____-Boiler Inspection Department.

CERTIFICATE FOR THE USE OF AN ECONOMISER

(Regulation 530)

Registry Number of Economiser Type.

No. of tubes.

Number of Headers.

Economiser Rating. Place and year of manufacture

Name of Owner.

Situation of Economiser

Repairs.

Remarks.

I/We hereby certify that the above described Economiser is permitted by me/Chief Inspector under the provisions of Section of the Indian Boilers Act, 1923 (V of 1923) to be worked at a maximum pressure of lbs. per sq. in./maximum temperature of °F. for the period from to

The loading of the relief Value is not to exceed—lbs.

Fee Rs. paid on

Dated at

This day of

INSPECTOR

COUNTERSIGNED

CHIEF INSPECTOR

REVERSE OF FORM XI

CONDITIONS

(1) No structural alteration, addition or renewal shall be made to the Economiser without a written permission from the Chief Inspector.

(2) This certificate shall cease to be in force—

(*a*) on the expiry of the period for which it was granted, or

(*b*) when any accident occurs to the Economiser, or

(*c*) when any structural alteration, addition or renewal is made in or to the Economiser, or,

(*d*) if the Chief Inspector in any particular case so directs when any structural alteration, addition or renewal is made in or to the Economiser, or

(*e*) on the communication to the owner of the Economiser of an order of the Chief Inspector or Inspector prohibiting its use on the ground that it is in a dangerous condition.

(3) The Economiser shall not be used at a pressure greater than the pressure/temperature entered in the certificate as maximum pressure/temperature nor with the relief valve set to pressure temperature exceeding such maximum pressure/temperature.

(4) The Economiser shall not be used otherwise than in a condition which the owner reasonably believes to be compatible with safe working.

N.B.—Details regarding this Economiser are recorded in a Registration Book No. of which a copy may be obtained on payment on application to the Chief Inspector.

N. P. DUBE,
Secretary,
Central Boilers Board.

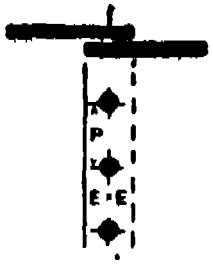
APPENDIX A

DIAGRAMS OF RIVETED JOINTS WITH FORMULÆ

SINGLE RIVETED JOINTS

LAP JOINT. ONE RIVET PER PITCH

FIG. 1



Max. Pitch $= 1{\cdot}31 \times T + 1{\cdot}625$. Eqn. (11)

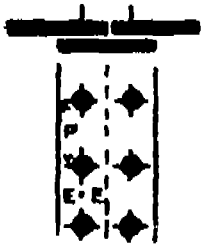
Plate % $= \dfrac{100\,(P-D)}{P}$ . . „ (2)

Rivet % $= \dfrac{100 \times A \times S_1}{P \times T \times S}$ . . „ (3)

E $= 1{\cdot}5 \times D$ . . . Reg. 184

FIG. 2

SINGLE BUTT STRAP. ONE RIVET PER PITCH



Max. Pitch $= 1{\cdot}53 \times T + 1{\cdot}625$ . . Eqn. (11)

Plate % $= \dfrac{100\,(P-D)}{P}$ . . . „ (2)

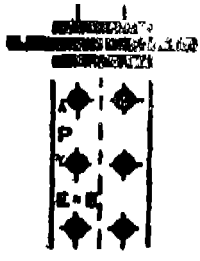
Rivet % $= \dfrac{100 \times A \times S_1}{P \times T \times S}$ . . „ (3)

E $= 1{\cdot}5 \times D$ . . . Reg. 184

BUTT STRAP $= 1{\cdot}125 \times T$ . . . Eqn. (5)

FIG. 3

DOUBLE BUTT STRAP. ONE RIVET PER PITCH



Max. Pitch $= 1{\cdot}75 \times T + 1{\cdot}625$ . . Eqn. (11)

Plate % $= \dfrac{100\,(P-D)}{P}$ . . . „ (2)

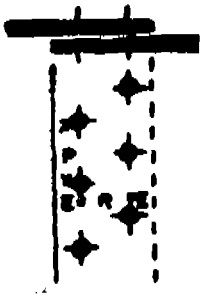
Rivet % $= \dfrac{100 \times A \times 1\ 875S_1}{P \times T \times S}$ . . „ (3)

E $= 1\ 5 \times D$ . . . Reg. 184

BUTT STRAPS $= {\cdot}625 \times T$ . . . Eqn. (7)

DOUBLE RIVETED JOINTS

FIG. 4



LAP JOINT. TWO RIVETS PER PITCH

Max. Pitch $=2\cdot62\times T+1\cdot625$ . . Eqn. (11)

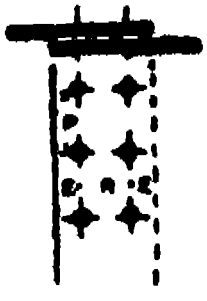
Plate % $=\dfrac{100\ (P-D)}{P}$ . . . „ (2)

Rivet % $=\dfrac{100\times A\times 2\times S_1}{P\times T\times S}$ . . „ (3)

R $=\cdot33P+\cdot67D$ . . . „ (12)

E $=1\cdot5\times D$ . . . Reg. 184

FIG. 5



LAP JOINT. TWO RIVETS PER PITCH

Max. Pitch $=2\cdot62\times T+1\cdot625$ . . Eqn. (11)

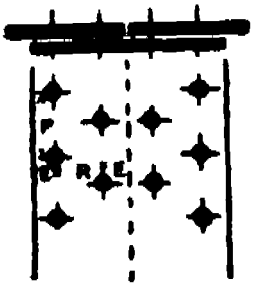
Plate % $=\dfrac{100\ (P-D)}{P}$ . . . „ (2)

Rivet % $=\dfrac{100\times A\times 2\times S_1}{P\times T\times S}$ . . „ (3)

R $=2\times D$ . . . . „ (13)

E $=1\cdot5\times D$ . . . Reg. 184

FIG. 6



SINGLE BUTT STRAP. TWO RIVETS PER PITCH

Max. Pitch $=3\cdot06\times T+1\cdot625$ . . Eqn. (11)

Plate % $=\dfrac{100\ (P-D)}{P}$ . . . „ (2)

Rivet % $=\dfrac{100\times A\times 2\times S_1}{P\times T\times S}$ . . „ (3)

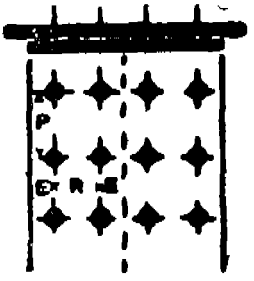
R $=\cdot33P+\cdot67D$ . . . „ (12)

E $=1\cdot5\times D$ . . . Reg. 184

BUTT STRAP $=1\cdot125\times T$ . . Eqn. (5)

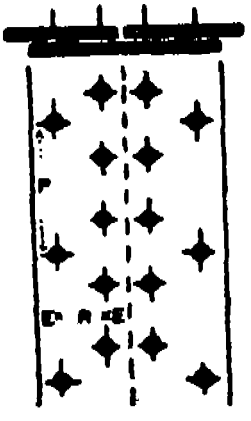
DOUBLE RIVETED JOINTS

FIG. 7 SINGLE BUTT STRAP. TWO RIVETS PER PITCH



Max. Pitch	$=3\cdot06\times T+1\cdot625$	Enq.	(1)
Plate %	$=\dfrac{100\,(P-D)}{P}$	,,	(2)
Rivet %	$=\dfrac{100\times A\times 2\times S_1}{P\times T\times S}$	,,	(3)
R	$=2\times D$	,,	(13)
E	$=1\cdot5\times D$	Reg.	184
BUTT STRAP	$=1\cdot125\times T$	Eqn.	(5)

FIG. 8 SINGLE BUTT STRAP. THREE RIVETS PER PITCH

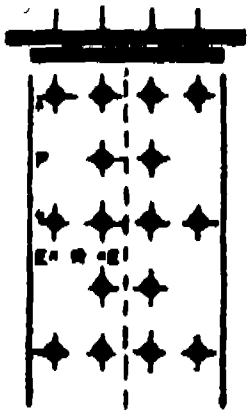


Max. Pitch	$=4\cdot05\times T+1\cdot625$	Eqn.	(11)
Plate %	$=\dfrac{100\,(P-D)}{P}$	,,	(2)
Rivet %	$=\dfrac{100\times A\times 3\times S_1}{P\times T\times S}$	,,	(3)
Combined %	$=\dfrac{100\,(P-2\,D)}{P}+\dfrac{100\times A\times S_1}{P\times T\times S}$	,,	(4)
R	$=\cdot2P+1\cdot15D$	,,	(14)
E	$=1\cdot5\times D$	Reg.	184
BUTT STRAP	$=1\text{-}125\,T\times\dfrac{(P-D)}{(P-2D)}$	Eqn.	(6)

DOUBLE RIVETED JOINTS

FIG. 9

SINGLE BUTT STRAP. THREE RIVETS PER PITCH



Max. Pitch $= 4 \cdot 05 \times T + 1 \cdot 625$ . . Eqn. (11)

Plate % $= \dfrac{100\ (P - D)}{P}$ . . . ,, (2)

Rivet % $= \dfrac{100 \times A \times 3 \times S_1}{P \times T \times S}$ . . ,, (3)

Combined % $= \dfrac{100\ (P - 2\ D)}{P} + \dfrac{100 \times A \times S_1}{P \times T \times S}$,, (4)

R $= \cdot 33\ P + \cdot 67D$ . . . ,, (12)

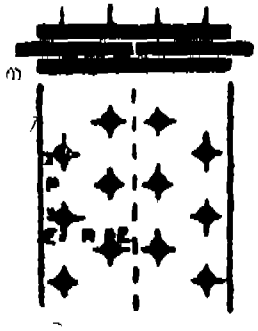
or $2 \times D$ whichever is greater ,, (13)

E $= 1 \cdot 5 \times D$ . . . Reg. 184

BUTT STRAP $= 1 \cdot 125T \times \dfrac{(P - D)}{(P - 2D)}$ Eqn. (6)

FIG. 10

DOUBLE BUTT STRAPS. TWO RIVETS PER PITCH



Max. Pitch $= 3 \cdot 5 \times T + 1 \cdot 625$ . . Eqn. (11)

Plate % $= \dfrac{100\ (P - D)}{P}$ . . . ,, (2)

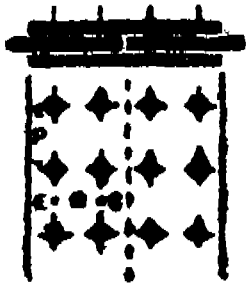
Rivet % $= \dfrac{100 \times A \times 2 \times 1 \cdot 875 \times S_1}{P \times T \times S}$,, (3)

R $= \cdot 33P + \cdot 67D$ . . . ,, (12)

E $= 1 \cdot 5 \times D$ . . . Reg. 184

BUTT STRAP $= \cdot 625 \times T$ . . . Eqn. (7)

FIG. 11 DOUBLE BUTT STRAPS. TWO RIVETS PER PITCH



Max. Pitch $= 3{\cdot}5 \times T + 1{\cdot}625$ . . Eqn. (11)

Plate % $= \dfrac{100\,(P-D)}{P}$ . . ,, (2)

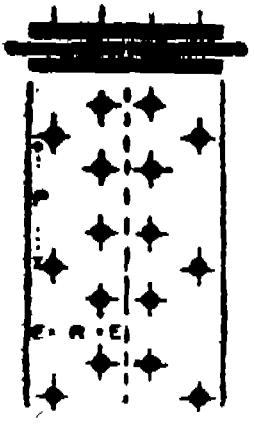
Rivet % $= \dfrac{100 \times A \times 2 \times 1{\cdot}875 \times S_1}{P \times T \times S}$. ,, (3)

R $= 2 \times D$ . . . ,, (13)

E $= 1{\cdot}5 \times D$ . . . Reg. (184)

BUTT STRAPS $= {\cdot}625 \times T$ . . . Eqn. (7)

FIG. 12 DOUBLE BUTT STRAPS. THREE RIVETS PER PITCH



Max. Pitch $= 4{\cdot}63 \times T + 1{\cdot}625$ . . Eqn. (11)

Plate % $= \dfrac{100\,(P-D)}{P}$ . . . ,, (2)

Rivet % $= \dfrac{100 \times A \times 3 \times 1{\cdot}875 \times S_1}{P \times T \times S}$. ,, (3)

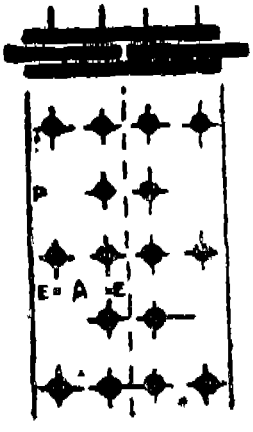
Combined % $= \dfrac{100\,(P-2D)}{P} + \dfrac{100 \times A \times 1{\cdot}875 \times S_1}{P \times T \times S}$,,(4)

R $= {\cdot}2\,P + 1{\cdot}15\,D$. . . ,, (14)

E $= 1{\cdot}5 \times D$ . . . Reg. 184

BUTT STRAPS $= {\cdot}625T \times \dfrac{(P-D)}{(P-2D)}$. Eqn. (8)

FIG. 13 DOUBLE BUTT STRAPS. THREE RIVETS PER PITCH



Max. Pitch $= 4 \cdot 63 \times T + 1 \cdot 625$ . . Eqn. (11)

Plate % $= \dfrac{100\,(P-D)}{P}$ . . ,, (2)

Rivet % $= \dfrac{100 \times A \times 3 \times 1 \cdot 875 \times S_1}{P \times T \times S}$. ,, (3)

Combined % $= \dfrac{100\,(P-2D)}{P} + \dfrac{100 \times A \times 1 \cdot 875 \times S_1}{P \times T \times S}$,, (4)

R $= \cdot 33\,P + \cdot 67\,D$ . . ,, (12)

or $2 \times D$ whichever is greater ,, (13)

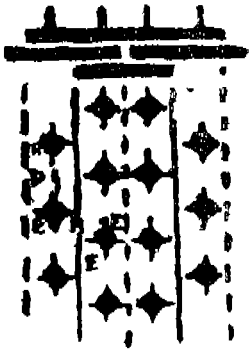
E $= 1 \cdot 5 \times D$ . . . Reg. 184

BUTT STRAPS $= \cdot 625T \times \dfrac{(P-D)}{P-2D)}$ Eqn. (8)

FIG. 14

DOUBLE BUTT STRAPS OF UNEQUAL WIDTH

TWO RIVETS PER PITCH



Max. Pitch $= 3 \cdot 5 \times T + 1 \cdot 625$ . . Eqn. (11)

Plate % $= \dfrac{100\,(P-D)}{P}$ . . ,, (2)

Rivet % $= \dfrac{100 \times A \times 1 \cdot 875 \times S_1}{P \times T \times S}$. ,, (3)

R $= \cdot 33\,P + \cdot 67\,D$ . . ,, (12)

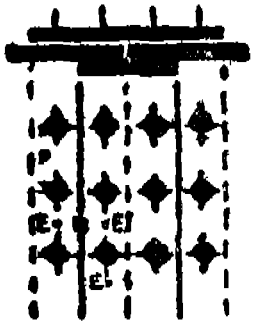
E $= 1 \cdot 5 \times D$ . . . Reg. 184

BUTT STRAP (WIDE) $= \cdot 75\,T$ . . . Eqn. (9)

BUTT STRAP (NARROW) $= \cdot 625\,T$ . . . ,, (10)

FIG. 15 DOUBLE BUTT STRAPS OF UNEQUAL WIDTH

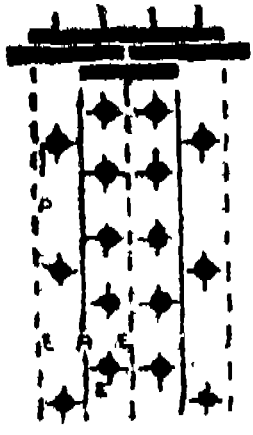
TWO RIVETS PER PITCH



Max. Pitch	$=3\cdot5\times T+1\cdot625$	Eqn.	(11)
Plate %	$=\frac{100\,(P-D)}{P}$	,,	(2)
Rivet %	$=\frac{100\times A\times 2\cdot875\times S_1}{P\times T\times S}$	,,	(3)
R	$=2\times D$	,,	(13)
E	$=1\cdot5\times D$	Reg.	184
BUTT STRAP (WIDE)	$=\cdot75\ T$	Eqn.	(9)
BUTT STRAP (NARROW)	$=\cdot625\ T$	,,	(10)

FIG. 16 DOUBLE BUTT STRAPS OF UNEQUAL WIDTH

THREE RIVETS PER PITCH

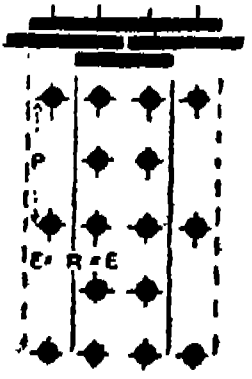


Max. Pitch	$=4\cdot63\times T+1\cdot625$	Eqn.	(11)
Plate %	$=\frac{100\,(P-D)}{P}$	,,	(2)
Rivet %	$=\frac{100\times A\times 4\cdot75\times S_1}{P\times T\times S}$	,,	(3)
Combined %	$=\frac{100\,(P-2D)}{P}+\frac{100\times A\times S_1}{P\times T\times S}$	,,	(4)
R	$=\cdot2\,P+1\cdot15\,D$	,,	(14)
E	$=1\cdot5\times D$	Reg.	184
BUTT STRAP (WIDE)	$=\cdot75\ T$	Eqn.	(9)
BUTT STRAP (NARROW)	$=\cdot625T$	,,	(10)

DOUBLE RIVETED JOINTS

FIG. 17 DOUBLE BUTT STRAPS OF UNEQUAL WIDTH

THREE RIVETS PER PITCH



Max. Pitch $= 4 \cdot 63 \times T + 1 \cdot 625$ . . Eqn. (11)

Plate % $= \dfrac{100\,(P - D)}{P}$ . . „ (2)

Rivet % $= \dfrac{100 \times A \times 4 \cdot 75 \times S_1}{P \times T \times S}$. „ (3)

Combined % $= \dfrac{100(P - 2D)}{P} + \dfrac{100 \times A \times S_1}{P \times T \times S}$ „ (4)

R $= \cdot 33P + \cdot 67D$ . . „ (12)

or $2 \times D$ whichever is greater „ (13)

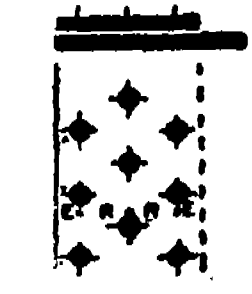
E $= 1 \cdot 5 \times D$ . . . Reg. 184

BUTT STRAP (WIDE) $= \cdot 75\ T$ . . . Eqn. (9)

BUTT STRAP (NARROW) $= \cdot 625\ T$ . . . . „ (10)

TREBLE RIVETED JOINTS

FIG. 18 LAP JOINT. THREE RIVETS PER PITCH



Max. Pitch $= 3 \cdot 47 \times T + 1 \cdot 625$ . . Eqn. (11)

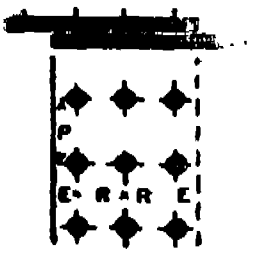
Plate % $= \dfrac{100\,(P - D)}{P}$ . . „ (2)

Rivet % $= \dfrac{100 \times A \times 3 \times S_1}{P \times T \times S}$ . . „ (3)

R $= \cdot 33\,P \times \cdot 67\,D$ . . „ (12)

E $= 1 \cdot 5 \times D$ . . . Reg. 184

FIG. 19 LAP JOINT. THREE RIVETS PER PITCH



Max. Pitch $= 3 \cdot 47 \times T + 1 \cdot 625$. Eqn. (11)

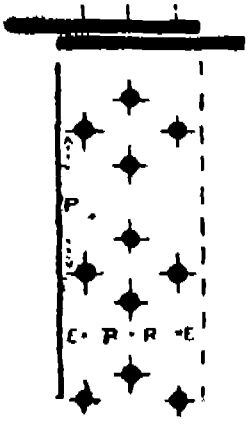
Plate % $= \dfrac{100\ (P - D)}{P}$ . . ,, (2)

Rivet % $= \dfrac{100 \times A \times 3 \times S_1}{P \times T \times S}$ . . ,, (3)

R $= 2 \times D$ . . . . ,, (13)

E $= 1 \cdot 5 \times D$ . . . Reg. 184

FIG. 20 LAP JOINT. FOUR RIVETS PER PITCH



Max. Pitch $= 4 \cdot 14 \times T + 1 \cdot 625$ . . Eqn. (11)

Plate % $= \dfrac{100\ (P - D)}{P}$ . . ,, (2)

Rivet % $= \dfrac{100 \times A \times 4 \times S_1}{P \times T \times S}$. ,, (3)

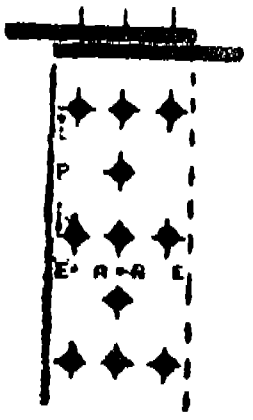
Combined % $= \dfrac{100\ (P - 2\ D)}{P} + \dfrac{100 \times A \times S_1}{P \times T \times S}$,, (4)

R $= \cdot 2\ P + 1 \cdot 15\ D$ . . ,, (14)

E $= 1 \cdot 5 \times D$ . . . Reg. 184

TREBLE RIVETED JOINTS

FIG. 21



LAP JOINT. FOUR RIVETS PER PITCH

Max Pitch $=4\cdot14\times T+1\cdot625$. . Eqn. (11)

Plate % $=\dfrac{100\ (P-D)}{P}$ . . ,, (2)

Rivet % $=\dfrac{100\times A\times 4\times S_1}{P\times T\times S}$. ,, (3)

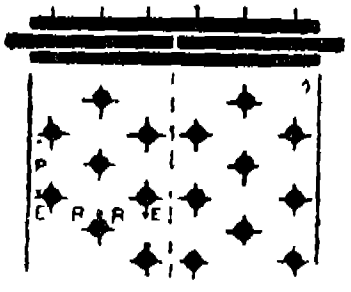
Combined % $=\dfrac{100\ (P-2D)}{P}+\dfrac{100\times A\times S_1}{P\times T\times S}$,, (4)

R $=\cdot33\ P+\cdot67D$ . . ,, (12)

or 2 D whichever is greater ,, (13)

E $=1\cdot5\times D$. . . Reg. 184

FIG. 22



DOUBLE BUTT STRAPS. THREE RIVETS PER PITCH.

Max. Pitch $=4\cdot63\times T+1\cdot625$. Eqn. (11)

Plate % $=\dfrac{100\ (P-D)}{P}$. ,, (2)

Rivet % $=\dfrac{100\times A\times 3\times 1\cdot875\times S_1}{P\times T\times S}$

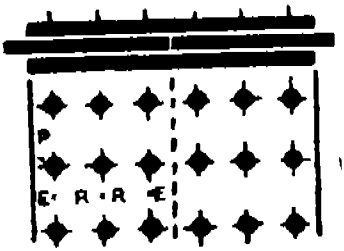
R $=\cdot33\ P+\cdot67\ D$. . ,, (12)

E $=1\cdot5\times D$ . . . Reg. 184

BUTT STRAPS $=\cdot625\ T$ . . Eqn. (7)

TREBLE RIVETED JOINTS

FIG 23 DOUBLE BUTT STRAPS. THREE RIVETS PER PITCH.



Max. Pitch $= 4.63 \times T + 1.625$ . . Eqn. (11)

Plate % $= \dfrac{100\ (P-D)}{P}$ . . (2)

Rivet % $= \dfrac{100 \times A \times 3 \times 1.875 \times S_1}{P \times T \times S}$. „ (3)

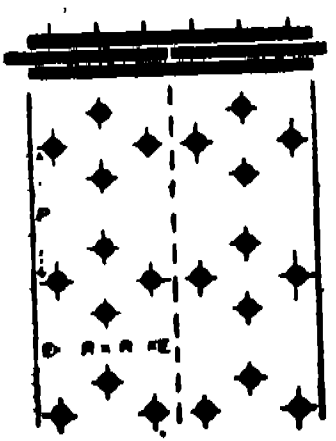
R $= 2 \times D$ . . . . „ (13)

E $= 1.5 \times D$ . . . Reg. 184

BUTT STRAPS $= .625\ T$ . . . Eqn. (7)

FIG. 24

DOUBLE BUTT STRAPS. FOUR RIVETS PER PITCH



Max. Pitch $= 5.52 \times T + 1.625$. . Eqn. (11)

Plate % $= \dfrac{100\ (P-D)}{P}$. „ (2)

Rivet % $= \dfrac{100 \times A \times 4 \times 1.875 \times S_1}{P \times T \times S}$ „ (3)

Combined % $= \dfrac{100(P-2D)}{P} + \dfrac{100 \times A \times 1.875 \times S_1}{P \times T \times S}$

„ (4)

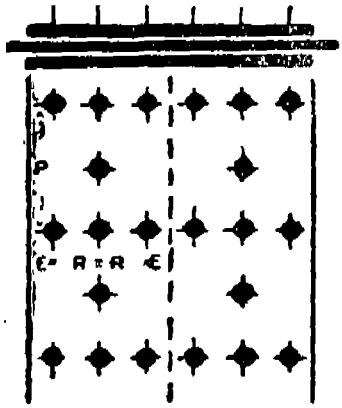
R $= .2P + 1.15D$ . . „ (14)

E $= 1.5 \times D$ . . . Reg. 184

BUTT STRAPS $= .625\ T$ . . . Eqn (7)

TREBLE RIVETED JOINTS

FIG. 25 DOUBLE BUTT STRAPS. FOUR RIVETS PER PITCH



Max. Pitch $= 5 \cdot 52 \times T + 1 \cdot 625$ Eqn. (11)

Plate % $= \dfrac{100(P-D)}{P}$ „ (2)

Rivet % $= \dfrac{100 \times A \times 4 \times 1 \cdot 875 \times S_1}{P \times T \times S}$ „ (3)

Combined % $= \dfrac{100(P-2D)}{P} + \dfrac{100 \times A \times 1 \cdot 875 \times S_1}{P \times T \times S}$ „ (4)

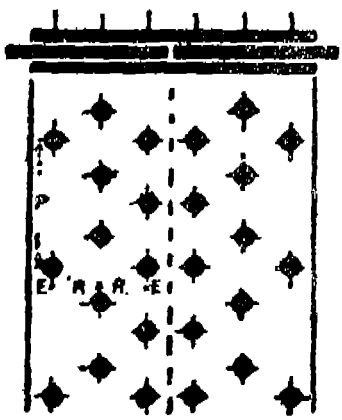
R $= \cdot 33P + \cdot 67D$. „ (12)
or 2 D whichever is greater „ (13)

E $= 1 \cdot 5 \times D$ . . Reg. 184

BUTT STRAPS $= \cdot 625\ T$ . . . Eqn. (7)

FIG. 26

DOUBLE BUTT STRAPS. FIVE RIVETS PER PITCH



Max. Pitch $= 6 \times T + 1 \cdot 625$ . . Eqn. (11)

Plate % $= \dfrac{100(P-D)}{P}$ . . . „ (2)

Rivet % $= \dfrac{100 \times A \times 5 \times 1 \cdot 875 \times S_1}{P \times T \times S}$ „ (3)

Combined % $= \dfrac{100(P-2D)}{P} + \dfrac{100 \times A \times 1 \cdot 875 \times S_1}{P \times T \times S}$ „ (4)

R_2 $= \cdot 2P \times 1 \cdot 15\ D$ . . „ (14)

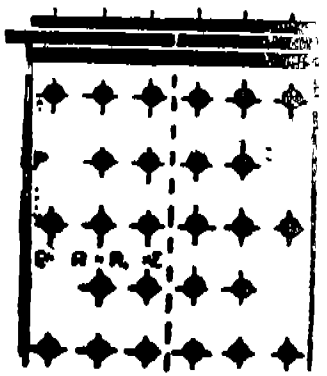
R_1 $= \cdot 165P \times \cdot 67D$ . . „ (15)

E $= 1 \cdot 5 \times D$ . . . Reg. 184

BUTT STRAPS $= \cdot 625\ T \times \dfrac{(P-D)}{(P-2D)}$ Eqn. (8)

TREBLE RIVETED JOINTS

FIG. 27 DOUBLE BUTT STRAPS. FIVE RIVETS PER PITCH



Max. Pitch $= 6 \times T + 1 \cdot 625$ . . Eqn. (11)

Plate % $= \dfrac{100(P-D)}{P}$ „ (2)

Rivet % $= \dfrac{100 \times A \times 5 \times 1 \cdot 875 \times S_1}{P \times T \times S}$ „ (3)

Combined % $= \dfrac{100(P-2D)}{P} + \dfrac{100 \times A \times 1 \cdot 875 \times S_1}{P \times T \times S}$ „ (4)

R $= \cdot 33P + \cdot 67D$ . . „ (12)

or 2 D whichever is greater „ (13)

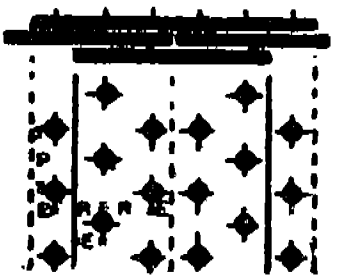
$R_1 = 2 \times D$ . . . . „ (13)

E $= 1 \cdot 5 \times D$ . . . Reg. 184

BUTT STRAPS $= \cdot 625T \times \dfrac{(P-D)}{(P-2D)}$. Eqn. (8)

FIG. 28

DOUBLE BUTT STRAPS OF UNEQUAL WIDTH THREE RIVETS PER PITCH



Max. Pitch $= 4 \cdot 63 \times T + 1 \cdot 625$ . . Eqn. (11)

Plate % $= \dfrac{100(P-D)}{P}$ „ (2)

Rivet % $= \dfrac{100 \times A \times 4 \cdot 75 \times S_1}{P \times T \times S}$ „ (3)

R $= \cdot 33P + \cdot 67D$ . . „ (12)

E $= 1 \cdot 5 \times D$ . . . Reg. 184

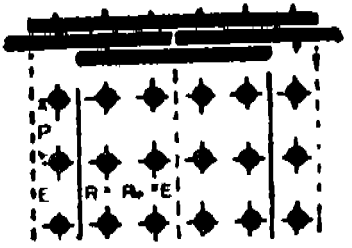
BUTT STRAP (WIDE) $= \cdot 75\ T$ . . Eqn. (9)

BUTT STRAP (NARROW) $= \cdot 625\ T$ . . . „ (10)

TREBLE RIVETED JOINTS

DOUBLE BUTT STRAPS OF UNEQUAL WIDTH THREE RIVETS PER PITCH

FIG. 29



Max. Pitch $=4\cdot63\times T+1\cdot625$. Eqn. (11)

Plate % $=\dfrac{100(P-D)}{P}$ . . ,, (2)

Rivet % $=\dfrac{100\times A\times 4\cdot75\times S_1}{P\times T\times S}$. ,, (3)

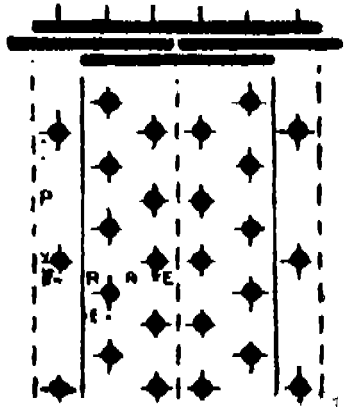
R $=2\times D$ . . . ,, (13)

E $=1\cdot5\times D$ . . . Reg. 184

BUTT STRAP (WIDE) $=\cdot75T$ . . . Eqn. (9)

BUTT STRAP (NARROW) $=\cdot625T$. . . ,, (10)

FIG. 30



DOUBLE BUTT STRAPS OF UNEQUAL WIDTH FIVE RIVETS PER PITCH

Max. Pitch $=6\times T+1\cdot625$. Eqn. (11)

Plate % $=\dfrac{100(P-D)}{P}$,, (2)

Rivet % $=\dfrac{100\times A\times 8\cdot5\times S_1}{P\times T\times S}$,, (3)

Combined % $=\dfrac{100(P-2D)}{P}+\dfrac{100\times A\times S_1}{P\times T\times S}$,, (4)

R $=\cdot2\,P+1\cdot15\,D$. ,, (14)

R_1 $=\cdot165\,P+\cdot67\,D$. ,, (15)

E $=1\cdot5\times D$ . . . Reg. 184

BUTT STRAP (WIDE) $=\cdot75\,T$ . . Eqn. (9)

BUTT STRAP (NARROW) $=\cdot625T$. . ,, (10)

Nominal thickness of test piece		(i)	(ii)	(iii) (*see* Note 3)	(iv)
		Up to but not including 3/8 in.			3/8 in. and thicker
		in.	in.	in.	in.
Width	W	½	1	1½ (max.)	1½ (max.)
Gauge length	G	2	4	8	8
Parallel length (minimum)	P	2½	4½	9	9
Radius at shoulder (minimum)	R	¼	½	1	1
Approximate total length		8	12	18	18

When the width of the material to be tested is insufficient to permit of the preparation of the standard tensile test piece, a piece of the full width of the material may be used.

NOTES.

1. For some materials it is convenient to use straight parallel test pieces.
2. For certain non-ferrous metals it is sometimes convenient to use the standard test piece that has a width of ½ in. and a gauge length of 2 in. for thickness exceeding ½ in.
3. A test piece of the dimensions given in Col. (iii) for material under 3/8 in. nominal thickness is intended for ferrous metals only.

Test Piece A_1

2. In tensile tests on special sheet and strip materials (*e.g.*, steel used for deep pressing operations) the following alternative test piece may be used.

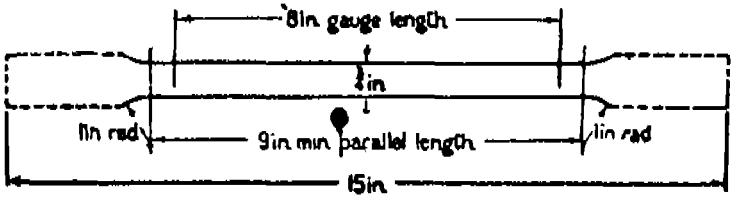


Fig. 2

BRITISH STANDARD ROUND TEST PIECES

Test Piece B

3. Chiefly for unmachined rods and bars not exceeding 1 in. diameter (excluding cast metals).

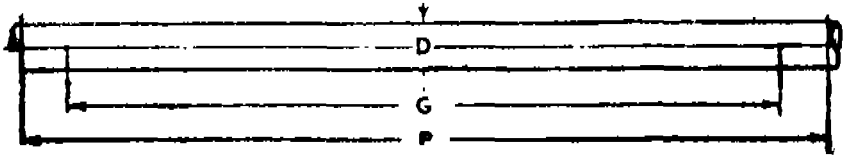


Fig. 3.

Gauge Length G=8D

Length between grips P to be not less than 9 D

All test pieces of form B are strictly similar and for the same material give the same percentage elongation. They give elongation figures nearly the same as those of standard flat test pieces 8 in. gauge length, 1½ in. wide and ½ in. thick.

NOTE.—When tensile tests are made on unmachined square and hexagonal bars (excluding cast metals) the gauge length shall be 8 times the distance between the flats and the length between the grips shall be not less than 9 times the distance between the flats.

Test Piece B_1

4. For rods and bars over 1 in. diameter (excluding cast metals).

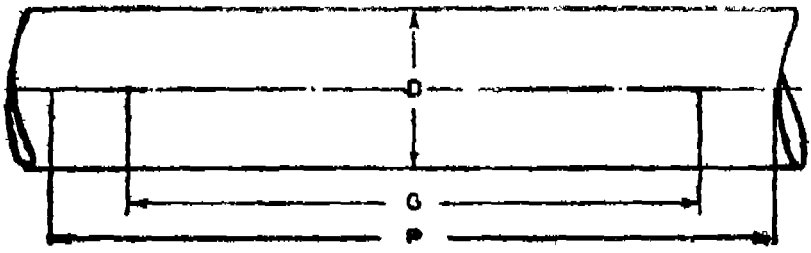


Fig. 4

Gauge length G=4 D

Length between grips P to be not less than 4·5 D

Test Piece C

5. Machined Round Test Piece for general purposes.

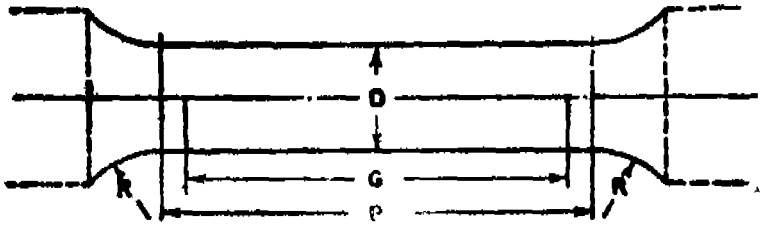


Fig. 5

Gauge length G=2 in.

Parallel length P to be not less than 2¼ in.

Diameter D=0·564 in.

Cross-sectional area A=¼ square in.

Radius at shoulder=⅛ in. minimum for wrought metals and 2/16 in. minimum for cast metals.

Subsidiary Standard Round Test Pieces

6. Machined Test Pieces for general purposes (excluding cast iron).

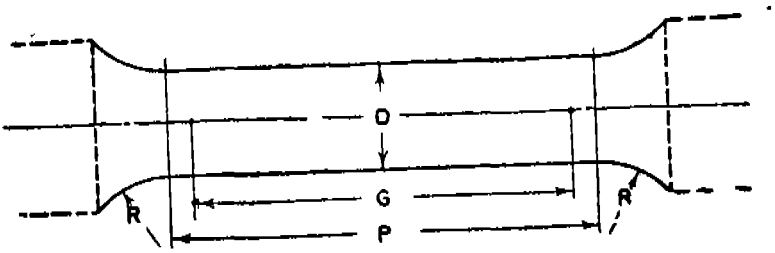


Fig. 6.

$$\text{Cross-sectional Area } A = \frac{D^2\pi}{4}$$

Gauge length $G = 4\sqrt{A} = 3{\cdot}54D$.

Parallel length $P = 9/8\ G$ minimum $= 3{\cdot}98$ D minimum.

Radius at shoulder for wrought metals $= G/4$ minimum.

(0·88 D minimum).

$$\text{Radius at shoulder for cast metals} = \frac{5C}{4} \text{ minimum.}$$

(4·40 D minimum).

All test pieces conforming to the above dimensions are similar to Standard Test Piece C with corresponding shoulder radius, and give the same percentage elongation as Test Piece C for the same material.

Recommended dimensions for Subsidiary Standard Round Test Pieces are tabulated below. Standard Test Piece C (0·564 in diameter) is included for comparison. Any test piece, however, in which the diameter is not less than 0·125 in., and the dimensions of which conform to the subsidiary standard form, is recognised as a subsidiary standard test piece.

Diameter D	Cross-sectional area A	Gauge length G	Parallel length P (minimum)	Radius at shoulder R (minimum)	
				Wrought metal	Cast metal
in.	in.	in.	in.	in.	in.
1·128	1·0000	4·00	4 50	1·00	5.00
0·977	0·7500	3 46	3·89	0·86	4.30
0·798	0 5000	2 82	3·18	0 70	3.50
0 564	0·2500	2·00	2·25	0·50	2.50
0·424	0·1412	1 50	1·69	0·37	1.85
0·399	0 1250	1 41	1·58	0·35	1.75
0·357	0·1000	1·26	1 42	0·31	1.55
0·282	0·0625	1·00	1·12	0·25	1.25
0·226	0·0400	0·80	0·90	0 20	1.00
0·159	0·0200	0·56	0 63	0·14	0.70
0 125	0·0122	0·44	0·50	0·11	0 55

APPENDIX C

List of Inspecting Authorities recognised as competent under Regulation 2 (b) of the Indian Boiler Regulations, 1950.

No.	Names
1.	Lloyd's Register of Shipping, London.
2.	The Ocean Accident and Guarantee Corporation Ltd., London.
3.	The Authorized Boiler Testing and Inspection Association, (Praha)—Prague (Czechoslovakia).
4.	The Scottish Boiler and General Insurance Co., Glasgow.
5.	Messrs. Kennedy and Donkin, Consulting Engrs., London.
6.	The National Boiler and General Insurance Co., Manchester.
7.	The Vulcan Boiler and General Insurance Co., Ltd., Manchester.
8.	The British Engine Boiler and Electrical Insurance Co., Ltd., Manchester.
9.	Messrs. Preece Cardew & Rider, London.
10.	Messrs. Eagle Star Insurance Co., Ltd., London.
11.	Bureau Veritas, International Register of Shipping, Paris.
12.	Insurance Engineers, Ltd., London.
13.	The Ocean Accident and Guarantee Corporation, Ltd., U.S.A., New York.
14.	India Store Dept., London.
15.	Messrs. Merz and Mclellan, Consulting Engineers, England.
16.	Messrs. Rendel Palmer and Tritton, Consulting Engineers, England.
17.	The London and Lancashire Insurance Co., Ltd., England.
18.	Chief Inspector of Boilers, Assam.
19.	Chief Inspector of Boilers, West Bengal.
20.	Chief Inspector of Boilers, Bihar and Orissa.
21.	Chief Inspector of Steam Boilers, Bombay.
22.	Chief Inspector of Boilers, Madhya Pradesh.
23.	Chief Inspector of Boilers, Delhi and Ajmer.
24.	Chief Inspector of Steam Boilers, Madras and Coorg.
25.	Chief Inspector of Boilers, Punjab (I)
26.	Chief Inspector of Boilers, Uttar Pradesh.
27.	Chief Inspector of Boilers, Department of Labour, Sydney, New South Wales, Australia.
28.	Chief Inspector of Boilers, Mines Department, Melbourne, Victoria, Australia.
29.	Chief Inspector of Machinery, Brisbane, Queensland, Australia.
30.	Chief Inspector of Machinery, Mines Department, Perth west Australia.
31.	Chief Inspector of Machinery, Hobart, Tasmania, Australia.
32.	Chief Inspector for Factories & Boilers Department, Adelaide, South Australia.
33.	American Employers Insurance Company, Mass.
34.	Employers Liability Assurance Corporation Limited, Mass.
35.	Mutual Boiler Insurance Company of Boston, Mass.
36.	Columbia Casualty Company, New York.
37.	London Guarantee and Accident Company Limited, New York.
38	Phenix Indemnity Company, New York.

APPENDIX D

Proof Test for Creep Quality of Carbon Steel plate of Boiler Plate Qaality

SPECIFICATION

NATURE OF TEST

1. The test shall consist of a tensile creep test carried out over a period of at least 48 hours at a temperature of 450°C. and with a stress of 8 tons per sq. in. Under these conditions the slope of the chord to the creep curve between the 24th and 48th hour shall not exceed 50×10^{-6} strain per hour.

CONDITION OF MATERIAL

2. The test shall be made on the material in the normalised condition. The normalising temperature shall be bewteen 875°C.—925°C., and the plate sample shall be maintained at the normalising temperature for one hour per inch of thickness and cooled freely in still air.

TEMPERATURE OF TSET

3. (a) *Temperature measurement.*—The temperature of the specimen shall be measured by thermocouples suitable for the temperature specified. Two thermocouples situated one at each end of the gauge length shall be used in the case of test pieces having gauge lengths up to 2 in., and for longer gauge lengths an additional thermocouple situated at the middle of the gauge length shall be used.

Thermocouples shall make good thermal contact with the test piece and be protected from the direct heat of the furnace by being covered with astestos tape or equivalent insulation.

The cold junction shall be maintained at a known temperature which shall be registered by a mercury thermometer. Alternatively, a suitable means shall be provided for correcting automatically errors in reading due to changes in temperature of the cold junction.

(b) *Temperature control.*—The two (or three) thermocouples specified in clause 3 (a) shall agree with one another within 3°C. and the average of these readings shall be taken as the test temperature which shall not vary from 450°C. by more than $\pm$ 2°C. throughout the test.

Either a continuous record or sufficient readings of the temperature shall be made to indicate that the temperature conditions have been satisfactory.

(c) *Heating period before loading.*—The specimen shall be maintained at the specified temperature for at least an hour prior to the application of the load.

STRESS

4. The load required to produce the specified stress shall be gradually applied without shock during a period not exceeding five minutes and the stress shall be accurate to $\pm 2\frac{1}{2}$ per cent.

SENSITIVITY OF STRAIN-MEASURING EQUIPMENT

5. The sensitivity of the extensometer must be such that strains can be measured to the nearest 0·00002.

READINGS

6. A sufficient number of strain readings shall be taken clearly to define the creep curve up to 48 hours, and the chord slope shall be measured from a chord drawn between points on the curve at the 24th and 48th hours.

REPEAT TEST

7. If the material fails to pass the test, but the chord slope does not exceed 60×10^{-6} strain per hour, a re-test may be made at the request of the manufacturer and shall be accepted if satisfactory, or at the Inspector's discretion a pass test at a stress 5 per cent less than that specified may be accepted.

APPENDIX E

STANDARD PIPE FLANGES.

Pipe Flanges

(For Land use)

TABLE D.—FOR WORKING STEAM PRESSURES UP TO 50 LBS.

(This table does not apply to boiler feed pipes, or to other water pipes subject to exceptional shocks.)

TABLE E.—FOR WORKING STEAM PRESSURE ABOVE 50 LBS. AND UP TO 100 LBS. PER SQUARE INCH.

Nominal Intl. Dia. of Pipe	Diameter of Flange	Diameter of Bolt Circle.	Number and Diameter of Bolts (Off centre lines)		Thickness of Flange.				
					Cast Iron	Cast Steel and Bronze		Stamped or Forged or Wrought Iron or Steel (*See* Notes)	
	Up to 50 l b. 100 lb.	Up to 50 lb. 100 lb.	Up to 50 lb.	Up to 100 lb.	Up to 50 lb. 100 lb	Up to 50 lb	Up to 100 lb.	Up to 50 lb.	Up to 100 lb.
In.	In.	In.	In.	In.	In.	In.	In	In.	In.
¼	3¾	2-5/8	4—1½	4—½	½	3/8	3/8	3/16	¼
⅜	4	2-7/8	,,	,,	½	3/8	3/8	3/16	¼
½	4½	3¼	,,	,,	½	3/8	3/8	3/16	9/32
¾	4¾	3 7/16	,,	,,	5/8	½	½	¼	5/16
1	5¼	3-7/8	,,	,,	5/8	½	½	¼	11/32
1¼	6	4½	4—5/8	4—5/8	¾	9/16	9/16	5/16	3/8
1½	6½	5	,,	,,	¾	9/16	9/16	5/16	13/32
2	7¼	5¾	,,	,,	¾	9/16	9/16	3/8	7/16
2½	8	6½	,,	8 -5/8	¾	9/16	9/16	3/8	15/32
3	8½	7	,,	,,	7/8	11 16	11/16	3/8	½
*3½	9	7½	8—5/8	,,	7/8	11 16	11/16	7/16	½
4	10	8¼	,,	,,	7/8	11 16	11/16	½	9/16
5	11	9¼	,,	8—¾	7/8	11 16	11/16	½	11/16
6	12	10¼	,,	,,	1	¾	¾	½	¾
7	13¼	11½	,,	,,	1	¾	¾	½	¾
8	14½	12¾	,,	12—¾	1	¾	13/16	5/8	13/16
9	16	14	8—¾	,,	1	¾	7/8	5/8	7 8
10	17	15	,,	,,	1-1/8	7/8	15/16	5/8	15/16
*11	18	16	12—¾	12—7/8	1 1/8	7/8	1	5/8	1
12	19½	17½	,,	,,	1-1/8	7/8	1	¾	1
*13	20¾	18½	12—7/8	,,	1¼	1	1	¾	1
14	21¾	19¼	,,	,,	1¼	1	1	¾	1
15	22¾	20¼	,,	,,	1¼	1	1	¾	1
16	24	21½	,,	,,	1 3/8	1-1 8	1-1/8	7 8	1 1/8
17	25¼	23	,,	16—7/8	1-3/8	1 1/8	1-1/8	7/8	1-1/8
*18	26¼	24	,,	,,	1-3/8	1-1 8	1¼	7/8	1½
19	27½	25¼	16—7/8	,,	1½	1¼	1¼	1	1½
20	29	26¼	,,	16—1	1½	1¼	1-3/8	1	1 3/8
21	30	27½	16—1	,,	1½	1¼	1-3/8	1	1-3/8
*22	31	28½	,,	,,	1-5/8	1-3 8	1½	1-1/8	1-3/8
*23	32½	29½	,,	,,	1-5/8	1-3 8		1-1/8	1½
24									

*See Notes at end of T bles regarding these, also for other particulars.

Pipe Flanges

(For Land use)

TABLE F.—FOR WORKING STEAM PRESSURES ABOVE 100 LBS. AND UP TO 150 LBS. PER SQUARE INCH.

TABLE H.—FOR WORKING STEAM PRESSURES ABOVE 150 LBS AND UP TO 250 LBS. PER SQUARE INCH.

Nominal Intl. Dia. of Pipe	Diameter of Flange	Diameter of Bolt Circle	Number and Diameter of Bolts (off centre lines)		Thickness of Flange		
					Cast Iron	Cast Steel and Bronze Steel (stamped or forged) (See Notes)	
	Up to 150 lb. 250 lb.	Up to 150 lb. 250 lb.	Up to 150 lb.	Up to 250 lb.	Up to 150 lb. only	Up to 150 lb.	Up to 250 lb.
In.	In.	In.	In.	In.	In.	In.	In.
150 lb. only ½	3¾	2-5/8	4—½	—	½	3/8	—
¾	4	2-7/8	,,	—	½	3/8	—
250 lb. only ½	4¼	3¼	—	4—5/8	—	—	½
¾	4½	3¼	—	,,	—	—	½
				In.			
1	4¾	3-7 16		4—5/8	½	3/8	9/16
1¼	5¼	3-7/8		,,	5/8	7/10	11/16
1½	5½	4-1 8		,,	5/8	½	11/16
2	6½	5		,,	¾	5/8	¾
2½	7¼	5¾		8—5/8	¾	5/8	¾
3	8	6½		,,	¾	5/8	7/8
3½	8½	7		,,	7/8	¾	7/8
4	9	7½		,,	7/8	¾	1
*4½	10	8¼		8—¾	7/8	¾	1
5	11	9¼		,,	1	7/8	1 1/8
6	12	10¼		12—¾	1	7/8	1 1/8
7	13½	11½		,,	1	7/8	1¼
8	14½	12¾		,, ;	1 1/8	1	1¼
9	16	14		12— 7/8	1 1/8	1	1 3/8
10	17	15		,,	1 1/8	1	1 3/8
*11	18	16		16—7/8	1¼	1 1/8	1½
12	19½	17½		,,	1¼	1 1/8	1½
*13	20½	18½		16—1	1½	1 1/8	1 5/8
14	21¾	19½		,,	1-3/8	1¼	1 5/8
15	22¾	20½		,,	1-3/8	1½	1¾
16	24	21½		20—1	1-3/8	1½	1¾
*17	25¼	23		,,	1½	1 3/8	1 7/8
18	26½	24		20—1 1/8	1½	1 3/8	1 7/8
*19	27¾	25¼		,,	1½	1 3/8	2
20	29	26½		24—1,1/8	1 5/8	1½	2
21	30	27½		,,	1 5/8	1½	2 1/8
*22	31	28½		,,	1 5/8	1½	2 1/8
*23	32½	29¾		24—1¼	1¾	1 5/8	2¼
24	33½	30¾		,,	1¾	1 5/8	2¼

*See Notes at end of Tables regarding these, also for flanges for pipe lines and other particulars.

Pipe Flanges

(*For Land use*)

TABLE J.—FOR WORKING STEAM PRESSURES ABOVE 250 LBS. AND UP TO 350 LBS. PER SQUARE INCH.

Nominal Intl. Dia. of Pipe	Actual Extl. Dia. of Wrot. Pipe	Diameter of Flange	Diameter of Bolt Circle	Number and Diameter of Bolts (off centre lines)	Thickness of Flange: Cast Steel and Bronze; Steel (stamped or forged) (See Notes)
In.	In.	In.	In.	In.	In.
¼	27/32	4½	3¼	4—5/8	5/8
⅜	1-1/16	4½	3¼	"	5/8
1	1-11/32	4¾	3-7/16	"	¾
1¼	1-11/16	5¼	3-7/8	"	¾
1½	1-29/32	5½	4-1/8	"	7/8
2	2-3/8	6½	5	4—¾	1
2½	3	7¼	5½	8—¾	1
3	3½	8	6½	"	1¼
3½	4	8½	7	"	1¼
4	4½	9	7½	"	1 3/8
*4½	5	10	8¼	8—7/8	1 3/8
5	5½	11	9¼	"	1½
6	6½	12	10¼	12—7/8	1½
7	7½	13½	11½	"	1 5/8
8	8½	14½	12¾	"	1 5/8
9	9½	16	14	12—1	1¾
10	10½	17	15	"	1 7/8
*11	11½	18	16	16—1	1 7/8
12	12½	19½	17¼	"	2
*13	14	20½	18½	16—1 1/8	2
14	15	21½	19¼	"	2 1/8
15	16	22½	20¼	"	2 1/8
16	17	24	21½	20—1 1/8	2¼
*17	18	25½	23	"	2 3/8
18	19	26½	24	20—1¼	2 3/8
*19	20	27½	25½	"	2½
20	21	29	26½	24—1¼	2½
21	22	30	27½	"	2 5/8
*22	23	31	28½	"	2 5/8
*23	24	32½	29½	24—1 3/8	2¾
24	25	33½	30½	"	2¾

*See Notes at end of Tables regarding these, also for flanges for pipe lines and other particulars.

The actual external diameters of wrought pipes given above apply equally to all tables.

Pipe Flanges

(For Land use)

TABLE K.—FOR WORKING STEAM PRESSURES ABOVE 350 LBS. AND UP TO 450 LBS. PER SQUARE INCH

Nominal Intl. Dia. of Pipe	Actual Extl. Dia. of Wrot. Pipe	Diameter of Flange	Diameter of Bolt Circle	Number and Diameter of Bolts (off centre lines)	Thickness of flange
					Cast Steel and Bronze Steel (stamped or forged) (See Notes.)
In.	In.	In.	In.	In.	In.
½	27/32	4½	3½	4—5/8	¾
¾	1-1/16	4½	3¼	"	¾
1	1-11/32	5	3¾	"	7/8
1¼	1-11/16	5¼	3-7/8	"	7/8
1½	1-29/32	6	4½	4—¾	1
2	2-3/8	6½	5	8—5/8	1
2½	3	7½	5¾	8—¾	1 1/8
3	3½	8	6½	"	1¼
3½	4	9	7¼	8—7/8	1¼
4	4½	9½	7¾	"	1-3/8
*4½	5	10	8¼	"	1½
5	5½	11	9¼	12—7/8	1 5/8
6	6½	12	10½	"	1 5/8
7	7½	13½	11½	12—1	1¾
8	8½	14½	12¾	"	1 7/8
9	9½	16	14	16—1	2
10	10½	17	15	"	2
*11	11½	18½	16¼	16—1 1/8	2 1/8
12	12½	19½	17	"	2¼
*13	14	21½	19	16—1¼	2 3/8
14	15	22½	20	"	2 3/8
15	16	23¾	21¼	20—1¼	2½
16	17	24¾	22¼	"	2 5/8

NOTES.—It is recommended that the use of sizes marked * should be avoided.

The thicknesses of flange given in the tables include a raised face of not more than 1/16 in. high if such be used.

For ½-in. and 5/8 in. bolts the diameters of the holes to be 1/16 in. larger than the diameters the bolts, and for larger sizes of bolts 1/8 in.

Iron or Steel flanges (stamped or forged) may be screwed or riveted on with boss, or welded with fillet, the flanges being of steel for pressures above 150 lb. per square inch.

Special welded-on flanges (stamped or forged) for pipe lines 2-in. nominal diameter of pipe and upwards (without valves or fittings) are made as stated below, the flange selected in all cases being that given for the next smaller size of pipe in the corresponding table or as specially stated:—

Table L.—For Working Steam Pressures up to 150 lb. per square inch, corresponds with, table F modified as above.

Table M.—For Working Steam Pressures above 150 lb. and up to 250 lb. per square inch, corresponds with Table H modified as above.

Table P.—For Working Steam Pressures above 250 lb. and up to 350 lb. per square inch, corresponds with Table J modified as above.

APPENDIX F

Transverse rupture stress (Modulus of Rupture).

The transverse strength of cast iron may be expressed by a figure known as the Transverse Rupture Stress; this figure is obtained by dividing the maximum bending moment at failure by the modulus of the section. Thus, the Transverse Rupture Stress is the maximum stress which would have existed if the material had behaved in accordance with the assumptions made in the ordinary theory of bending, and in that event it would be independent of the size and shape of the section. Bars fractured in transverse, however, are stressed beyond the elastic limit, and under these conditions the theory of bending no longer holds good. Furthermore, the influence of rate of cooling in cast metals is such that the Transverse Rupture Stress of a thick bar is less than that of a thinner bar of the same metal. The Transverse Rupture Stress, therefore, is not strictly independent of the size and shape of the section, but nevertheless forms a convenient way of expressing the results of transverse tests without the necessity for giving full details of bar dimensions. The formula required is obtained as follows :—

A bar supported at both ends and centrally loaded with a load W is subject to a bending moment $\frac{WL}{4}$, L being the distance between supports. The resistance offered by the bar may be expressed as fZ, f being the stress and Z the modulus of the section. At fracture, f becomes the breaking stress or Transverse Rupture Stress, and $\frac{WL}{4}=fZ$, whence $f=\frac{WL}{4z}$. If W is in tons and L in inches, f is in tons per square inch. For a round bar, $Z=0{\cdot}0982d^3$, where d= diameter in inches.

Since for a Standard round bar L and Z are constant, the value $\frac{L}{4Z}$ is fixed, and hence the Transverse Rupture Stress $f = KW$, where k is a constant.

The factors k for converting actual breaking loads into Transverse Rupture Stresses are given in the following table both for the Standard test bars and the test bars varying within the limits of Regulation 88. In the same table are given factors for converting actual breaking loads into equivalent breaking loads on the bars of Standard diameter.

Factors X for converting Actual Breaking Loads into Equivalent Breaking Loads on Bars of Standard Diameter.
(Equivalent Breaking Load on Bar of Standard Diameter = X × Actual Breaking load.)
and
Factors K for converting Actual Breaking Loads into Transverse Rupture Stresses.
(Transverse Rupture Stress in tons per sq. in. = K Actual Breaking Load in lb.)

0·6 in. Test Bar			0·875 in. Test Bar			1·2 in. Test Bar			1·6 in. Test Bar			2·1 in. Test Bar		
Dia.	X	K	Dia.	X	K	Dia.	X	K	Dia.	X	K	Dia.	X	K
in.			in.			in.			in.			in.		
..	..	..	..	..	..	.			1·50	1·214	0·00606	2·00	1·158	0·00341
..	..	..	..	..	..	1·11	1·264	0·0150	1·51	1·190	0·00594	2·01	1·140	0·00336
..	..	..	..	..	..	1·12	1·230	0·0146	1·52	1·166	0·00583	2·02	1·124	0·00331
..	..	..	0·81	1·261	0·0257	1·13	1·198	0·0142	1·53	1·144	0·00571	2·03	1·107	0·00326
..	..	..	0·82	1·215	0·0247	1·14	1·166	0·0138	1·54	1·121	0·00560	2·04	1·091	0·00321
..	..	..	0·83	1·172	0·0239	1·15	1·136	0·0135	1·55	1·100	0·00549	2·05	1·075	0·00317
0·56	1·230	0·0582	0·84	1·130	0·0230	1·16	1·107	0·0131	1·56	1·079	0·00539	2·06	1·059	0·00312
0·57	1·166	0·0552	0·85	1·091	0·0222	1·17	1·079	0·0128	1·57	1·058	0·00529	2·07	1·044	0·00308
0·58	1·107	0·0524	0·86	1·053	0·0214	1·18	1·052	0·0125	1·58	1·038	0·00519	2·08	1·029	0·00303
0·59	1·052	0·0498	0·87	1·017	0 0207	1·19	1 025	0·0121	1·59	1·019	0·00509	2·09	1·014	0·00299
0·60	1·000	0·0474	0·875	1·000	0·0204	1·20	1·000	0·0118	1·60	1·000	0·00499	2·10	1·000	0·00295
0·61	0·952	0·0451	0·88	0 983	0·0200	1·21	0·975	0·0115	1·61	0·981	0·00490	2·11	0·986	0·00290
0·62	0·906	0·0429	0·89	0·950	0·0193	1·22	0·952	0·0113	1·62	0·963	0·00481	2·12	0·972	0·00286
0·63	0·864	0 0409	0·90	0 919	0·0187	1·23	0·929	0·0110	1·63	0·946	0·00472	2·13	0·958	0·00282
0 64	0·824	0 0390	0·91	0 889	0·0181	1·24	0·906	0·0107	1·64	0·929	0·00464	2·14	0·945	0·00278
..	..	..	0·92	0·860	0·0175	1·25	0·885	0·0105	1·65	0·912	0·00455	2·15	0·932	0·00274
..	..	..	0 93	0·833	0·0170	1·26	0 864	0·0102	1·66	0·895	0·00447	2·16	0·919	0·00271
..	..	..	0 94	0·807	0·0164	1·27	0·844	0·0100	1·67	0·879	0·00439	2·17	0·906	0·00267
..	..	..	..	..	..	1·28	0 824	0·0098	1·68	0·864	0·00431	2·18	0·894	0·00263
..	..	..	..	..	..	1·29	0·805	0·0095	1·69	0·849	0·00424	2·19	0·882	0·00260
..	..	..	..	..	..	..	..	..	1·70	0·834	0·00416	2·20	0·870	0·00256

[No. E 1-II/304(40).]

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