

BRITISH STANDARD SPECIFICATION

ELECTRODE BOILERS

of Riveted, Seamless, Welded and Cast Iron Construction

FOR WATER HEATING
AND STEAM GENERATING

B.S.1894:1952



BRITISH STANDARDS INSTITUTION

Incorporated by Royal Charter

British Standards House, 2 Park Street, London, W1Y 4AA

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THIS BRITISH STANDARD, having been approved by the Mechanical Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 22nd December, 1952.

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 5000, indexed and cross-indexed for reference, together with an abstract of each standard, will be found in the Institution's Yearbook, price 20s.

This standard makes reference to the following British Standards :—

- B.S. 10. Parts 1—5. Tables of pipe flanges (for land use).
- B.S. 21. Pipe threads. Part 1 : Basic sizes and tolerances.
- B.S. 84. Screw threads of Whitworth form.
- B.S. 116. Oil circuit-breakers, oil switches and oil isolating-switches for alternating-current circuits.
- B.S. 131. Forms of notched bar test pieces.
- B.S. 425. Forms and dimensions of boiler rivets (as manufactured) ($\frac{1}{2}$ in. to 2 in. diameter).
- B.S. 639. Covered electrodes for metal arc welding wrought iron and mild steel.
- B.S. 759. Valves, gauges and similar fittings for land boilers installations.
- B.S. 806. Ferrous pipes and piping installations for and in connection with land boilers.
- B.S. 862. Air-break circuit-breakers (including totally-enclosed and flameproof types) for voltages not exceeding 660 volts.
- B.S. 916. Black bolts and nuts. Hexagon and square, B.S.W. and B.S.F.
- B.S. 936. Oil circuit-breakers for alternating current circuits up to and including 660 volts.
- B.S. 1083. Bolts, nuts and set screws (machine bolts) B.S.W. and B.S.F.
- B.S. 1271. Proof test for creep quality of carbon steel plate of boiler plate quality.
- B.S. 1452. Grey iron castings.

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions. The current edition of any British Standard supersedes the previous editions and is itself modified by any amendment subsequently issued.

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CO-OPERATING ORGANIZATIONS

The Mechanical Engineering Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations :—

- Admiralty
- Air Ministry
- *Associated Offices Technical Committees
- *Association of Consulting Engineers (Incorporated)
- *British Chemical Plant Manufacturers' Association
- British Compressed Air Society
- *British Electrical & Allied Manufacturers' Association
- *British Electricity Authority and Area Boards
- *British Engineer's Association
- British Internal Combustion Engine Manufacturers' Association
- *British Iron & Steel Federation
- *British Railways, The Railway Executive
- *Crown Agents for the Colonies
- D.S.I.R.—Mechanical Engineering Research Organization
- Engineering Equipment Users' Association
- *Institute of Marine Engineers
- Institute of Petroleum
- *Institution of Civil Engineers
- *Institution of Gas Engineers
- *Institution of Heating & Ventilating Engineers
- *Institution of Mechanical Engineers
- Institution of Mechanical Engineers (Automobile Division)
- Institution of Production Engineers
- Locomotive Manufacturers' Association
- Machine Tool Trades Association
- *Ministry of Fuel and Power
- *Ministry of Labour and National Service (Factory Department)
- Ministry of Supply
- *Ministry of Transport
- *Ministry of Works
- National Physical Laboratory
- *Office of the High Commissioner for India
- War Office

The Government Departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard :—

- Association of Heating, Ventilating and Domestic Engineering Employers
- British Coal Utilization Research Association
- British Welding Research Association
- Combustion Engineering Association
- Engineer Surveyors' Association
- Institute of Welding
- Institution of Electrical Engineers
- Insurance Engineers Ltd.
- Lloyds Register of Shipping
- Individual manufacturers of electrode boilers

BRITISH STANDARD SPECIFICATION FOR
ELECTRODE BOILERS
OF RIVETED, SEAMLESS, WELDED AND CAST IRON
CONSTRUCTION
FOR WATER HEATING AND STEAM
GENERATION

FOREWORD

This British Standard forms one of a series for land boilers, the preparation of which was authorized by the Mechanical Engineering Industry Standards Committee.

The standard applies to boilers for design temperatures not exceeding 650°F., and is concerned solely with boilers for water heating or for the generation of steam, in which the water is heated by the passage of an alternating electric current through the water, the resistance of which to the passage of the current increases the temperature of the water or generates steam under pressure. Electrode boilers differ from fuel fired boilers in that there are no flame-swept surfaces, and no danger results if the current is switched on when the boiler is empty. Apart from radiation and convection losses, the whole of the electrical energy is converted into heat.

Safety valves have been dealt with at length in this standard. Although electrical safety devices are specified, safety valves are to be regarded as the safety protection against excess pressure.

The formulae in this standard give in all cases the minimum scantlings and apply to boilers constructed throughout under competent supervision.

Attention is drawn to the Institution of Electrical Engineers (I.E.E.) Regulations for the Electrical Equipment of Buildings, the appropriate paragraphs of which are reproduced in Appendix B.

Other British Standards in the series of standards for land boilers are :

B.S. 537. Lancashire and Cornish boilers.

B.S. 609. Multitubular horizontal boilers (dryback and waste heat).

B.S. 665. Vertical cross tube boilers.

B.S. 761. Cylindrical vertical multitubular boilers.

B.S. 779. Cast iron boilers for central heating and hot water supply.

B.S. 854. Welded steel boilers for steam central heating.

B.S. 855. Welded steel boilers for hot water central heating and hot water supply.

B.S. 931. Loco-type multitubular boilers.

SPECIFICATION

PART 1. GENERAL

SCOPE

1. This standard covers the following types of electrode boilers:—

- (i) Steel water-heating boilers.
- (ii) Steel steam boilers.
- (iii) Cast-iron water-heating boilers.

The boilers shall include mountings unless they are specifically excluded by the enquiry and order. The type of mountings shall be agreed between the purchaser and the manufacturer. In the absence of specific instructions to the contrary (in the enquiry and order) the mountings shall be suitable for the boiler when working as an independent unit.

Where welding is referred to in this standard it shall be the metal arc process using Class A electrodes complying with B.S. 639, 'Covered electrodes for metal arc welding wrought iron and mild steel,' or the submerged arc process.

INFORMATION TO BE SUPPLIED BY THE MANUFACTURER

2. The manufacturer shall, on request, supply to the purchaser or his representative dimensioned sectional drawings showing in full detail the construction of all pressure parts of the boiler.

INFORMATION TO BE SUPPLIED BY THE PURCHASER

3. The purchaser shall inform the manufacturer at the time of the enquiry and order of any special statutory or other regulations with which the boiler is required to comply. The manufacturer shall undertake that the boiler will comply in all respects with such statutory or other regulations.

INSPECTION

4. Where the purchaser requires independent supervision of manufacture, he or his representatives shall have access to the works of the manufacturer at all reasonable times and shall be at liberty to inspect the manufacture at any stage and to reject any part that does not comply with the requirements of this standard. The fees and expenses of the representative of the purchaser shall be borne by the purchaser.

PART 2. ELECTRODE WATER-HEATING BOILERS :

RATING AND FITTINGS

SECTION ONE : GENERAL

SCOPE

5. Part 2 of this standard applies to electrode water-heating boilers for all voltages and any design pressure and also to their electrical controls and switch gear.

NOTE. The mountings, controls and switch gear may be supplied separately and not necessarily by the manufacturer of the boiler.

DEFINITION

6. An electrode water-heating boiler is a vessel in which water is circulated through the boiler and heated by the passage of an alternating electric current through the water.

RATING

7. The nominal rating (or load) of an electrode water-heating boiler shall be taken as the kilowatts (kW) absorbed at the stated voltage when the water has a specific resistance of not less than 200 ohms per inch cube when at 150°F. and flows through the boiler at a mean temperature between inlet and outlet of $150 \pm 10^\circ\text{F}$.

NOTE. In certain instances it may be necessary to treat the raw water to obtain the desired resistance.

HEAT OUTPUT

8. The nominal output of an electrode water-heating boiler shall be taken as 3410 British Thermal Units (B.Th.U.) per hour per kW of the rating. The net output will be less than the nominal output by reason of radiation and convection losses under working conditions.

LOAD ADJUSTMENT

9. a. Means shall be provided by which the kilowatt loading can be adjusted between the agreed minimum load and the nominal rating, at any water temperature between 150°F. and 20°F. below the boiling point at the design pressure, the water in the boiler having the specific resistance stated in Clause 7.

b. It is recommended that the load adjustment should also be such as to permit of satisfactory operation when the specific resistance of the water in the boiler is up to 50 per cent greater than that stated in Clause 7.

c. Where means are provided to control the load automatically, a manual control shall also be fitted.

d. Automatic load adjustment shall be capable of maintaining the load between the limits of plus and minus 10 per cent of the set load.

SECTION TWO : MOUNTINGS, FITTINGS AND CONNECTIONS

SAFETY VALVES

10. a. The boiler shall have a safety valve or valves arranged vertically and attached directly or as close as possible to the boiler shell by means of the shortest possible length of pipe used solely for that purpose and without any intervening cock or valve. The internal diameter of such pipe shall in no case be smaller than the nominal bore of the valve and its length shall not exceed twelve times its nominal bore.

b. Safety valves shall be of the direct spring-loaded or direct dead-weight type. Safety valves shall be loaded according to the following formula:—

$$\text{The valve load in pounds per square inch} = \frac{\text{Head of water in feet}}{2.3} + 10$$

Spring-loaded valves are recommended where the pressure exceeds 80 ft. head and also where the boilers may be affected by external vibration.

In hot water heating systems with accelerated circulation the valve load shall be 10 lb/sq. in. in excess of the pressure at the outlet side of the pump where the pump delivers to the boiler.

c. Safety valves shall be so designed and constructed as to comply with the following requirements:—

(i) The nominal size of the valve shall be the same as its clear bore, and this size shall be stamped or cast on the body of the valve.

(ii) Valves shall be so constructed that they cannot be inadvertently overloaded beyond the pressure to which they have been set.

(iii) Means shall be provided for turning the valves on their seats or, if they are not readily accessible, easing gear shall be provided.

(iv) The seats and disks of valves shall be metal-to-metal, and shall be made of non-corrodible metal.

Fibrous or other material which may become distorted under working conditions shall not be used.

NOTE. By non-corrodible metal is meant metal specially resistant to corrosion and erosion.

(v) The moving parts shall be efficiently guided and there shall be sufficient clearance between the working parts to ensure freedom of movement under all conditions of service. The spindle shall not be fitted with a stuffing box.

(vi) The valves shall have sufficient clearance to allow a lift of $\frac{D}{5}$, where D is the actual bore of the valve.

(vii) Means shall be provided for draining each enclosed valve chest. The drain pipe shall be open-ended and laid with a fall.

downward gradient clear of the boiler to a place where the discharge is visible and cannot harm anyone.

d. The size of the safety valve shall be determined by the following formula, but in no case shall a valve of less than $\frac{1}{2}$ in. bore be fitted :—

$$A = \frac{kW}{C(P + 15)}$$

where

A = for ordinary and high lift safety valves : aggregate area, in square inches, of the orifices through the seatings of the valves.

A = for full lift safety valves : the net area in square inches through the seats, after deducting the area of guides or other obstructions when the valves are fully lifted.

kW = maximum output of the boiler in kilowatts.

P = design pressure in pounds per square inch.

C = constant, as in Table 1.

TABLE 1. SAFETY VALVE CONSTANTS

Type of safety valve	Direct spring-loaded valves	Direct dead weight loaded valves
	Constant C	Constant C
Ordinary	1.3	1.6
High lift	2.6	3.2
Full lift	5.2	5.2

SAFETY SWITCH

11. Boilers of over 20 kW rating shall be fitted with an excess-temperature or excess-pressure switch, attached directly to the boiler shell or as close to it as possible without any intervening valve or cock.

The switch shall be of the circuit-opening type and controlled by rise of temperature or pressure. It shall be set to operate at a lower pressure than the safety valve (see Clause 10). It shall be electrically connected to open a main switch cutting off the supply to the boiler. The switch shall be re-closed manually.

THERMOMETER

12. It is recommended that the boiler be fitted with a thermometer.

The thermometer shall be of such a type and so fitted as to permit of being readily replaced without emptying the boiler. It shall be so located as to be easily readable, and shall indicate the temperature of the water at or near the outlet.

DRAIN

13. The boiler shall have a drain cock or draw-off plug connected with the lowest water space.

The cock or plug shall be operated by means of a loose key.

AIR RELEASE

14. The boiler shall be provided with means to release air from the highest water space.

PIPE CONNECTIONS

15. The minimum size of inlet and outlet connections shall be as shown in Table 2.

TABLE 2. PIPE CONNECTIONS

Rating	Minimum size of connections
kW	in.
Up to 10	1½
Over 10 up to 30	1¾
Over 30 up to 100	2
Over 100 up to 200	2½
Over 200 up to 300	3
Over 300 up to 600	4
Over 600 up to 1000	5

The size of connections for boilers of over 1000 kW rating shall be the subject of agreement between the purchaser and the manufacturer.

ELECTRICAL CONTROLS

16. *a. Circuit-breaker.* Each boiler of over 20 kW rating shall be controlled by a circuit-breaker which, when opened, disconnects all phase electrodes from the supply.

The circuit-breaker shall have over-current protection such that a load of 120—150 per cent of the normal full load current in any phase conductor will cause the circuit-breaker to open. It is recommended that normally the over-current setting should be 125 per cent. An inverse time-lag device may be used in conjunction with the foregoing protection if desired.

If the boiler is for use on a high-voltage supply, the circuit-breaker shall be so set as to operate if the phase currents become unbalanced to the extent of not more than 15 per cent of the normal full load current.

An inverse time-lag device may be used in conjunction with the foregoing out-of-balance protection if desired.

The circuit-breaker shall comply with B.S. 116, Part 1*, B.S. 862† or B.S. 936‡.

b. Other electrical controls. All other electrical control apparatus shall comply with the relevant British Standards.

c. Ammeters. At least one ammeter shall be provided to indicate the current taken by the boiler and each ammeter shall have a red line at the full current mark.

THERMOSTAT TESTS

17. Provision shall be made for the operating temperature of any thermostat controlling the boiler to be verified by means of a thermometer included in the system. Alternatively, provision shall be made for installing, temporarily and without interrupting the working of the system, a test thermometer so that it gives a true reading of the heated medium surrounding the thermostat bulb.

SECTION THREE : ELECTRICAL REQUIREMENTS

INSULATION

18. All electrical clearances other than electrode spacings shall comply with Clauses 71 and 80 of B.S. 116, and the boiler, when empty of water and dry, shall pass the insulation tests specified in that standard.

ENCLOSURE

19. Mechanical protection of all parts above earth potential shall comply with the relevant standards, such as B.S. 116, for the working voltage.

CONDUCTORS

20. All electrical conductors shall be of such cross section that the temperature rise due to their resistance at maximum temperature when carrying full load shall not exceed the maximum water temperature by more than 100°F. They shall be of material which will not deteriorate at this temperature.

CONNECTIONS

21. *a.* The contact area of all electrical connections shall be such that there is no greater rise in temperature than that specified in Clause 20. The mechanical pressure between the surfaces shall be maintained irrespective of temperature, thermal expansion and normal vibration.

* B.S. 116, 'Oil circuit-breakers, oil switches and oil isolating switches for alternating-current circuits'.

† B.S. 862, 'Air-break circuit-breakers (including totally-enclosed and flameproof types) for voltages not exceeding 660 volts'.

‡ B.S. 936, 'Oil circuit-breakers for alternating current circuits up to and including 660 volts'.

b. The incoming conductors shall not deteriorate because of the temperature of, and around, the terminals to which they are connected.

c. A separate earthing terminal shall be provided, equal in cross section to the largest main terminal, and in direct contact with the boiler shell.

d. Where plugs and sockets are provided for any connections they shall have mechanical locking devices.

e. Insulated connections brought-through the shell shall be subjected to the hydraulic test pressure specified.

ELECTRODES AND INTERNAL PARTS

22. Electrodes shall be of material suitable for use under the working conditions of the boiler.

Moving parts liable to wear shall be of material resistant to corrosion and erosion.

The electrical insulating materials used shall not be liable to deteriorate on account of the conditions to which they are exposed when the boiler is in operation.

CURRENT BALANCE

23. Each boiler shall be so designed that, when operating on multiphase systems under normal conditions, the current is equally balanced between the phases, with a variation of not more than plus or minus 5 per cent of full load current.

ACCESS

24. Openings shall be provided for inspection, cleaning and removal of electrodes and shall be of such sizes and in such positions as to give access to all internal parts of the boiler shell.

PART 3. ELECTRODE STEAM BOILERS : RATING AND FITTINGS

SECTION ONE : GENERAL

SCOPE

25. Part 3 of this standard applies to electrode steam boilers for all voltages, for any design pressure, and for temperatures not exceeding 650°F.; and provides for their electrical controls and switch gear.

NOTE. The mountings, controls and switch gear may be supplied separately, and not necessarily by the manufacturer of the boiler.

DEFINITION

26. An electrode steam boiler is a vessel in which steam is produced under pressure by the passage of an alternating electric current through the water.

RATING

27. The nominal rating (or load) of an electrode steam boiler shall be taken as the kilowatts (kW) absorbed at the stated voltage, when the water in the boiler has a specific resistance of not less than 200 ohms per inch cube at 150°F., and while the boiler is delivering its normal output of steam at its operating pressure, with the feed water at a temperature of 60°F.

NOTE. In certain instances it may be necessary to treat the raw water to obtain the desired resistance.

STEAM OUTPUT

28. The nominal duty of an electrode steam boiler shall be taken as 3.5 lb. of steam at 212°F. per hour per kW of the rating. The net output will be less than the nominal duty by the amount of the radiation and convection losses under working conditions.

If continuous blow-down is employed, allowance for this shall be made before calculating the output.

LOAD ADJUSTMENT

29. a. Means shall be provided by which the kilowatt loading can be adjusted between the agreed minimum load and the nominal rating at the operating pressure, the water in the boiler having the specific resistance stated in Clause 20.

b. It is recommended that the load adjustment should also be such as to permit of satisfactory operation when the specific resistance of the water in the boiler is up to 50 per cent more than that stated in Clause 20.

c. Automatic load adjustment shall be capable of maintaining the load between the limits of plus or minus 10 per cent of the set load.

SECTION TWO : MOUNTINGS, FITTINGS AND CONNECTIONS

SAFETY VALVES

30. a. The boiler shall have a safety valve or valves arranged vertically and attached directly or as closely as possible to the boiler shell by means of the shortest possible length of pipe used solely for that purpose and without any intervening cock or valve. The internal diameter of such pipe shall in no case be smaller than the nominal bore of the valve and its length shall not exceed twelve times its nominal bore.

b. Safety valves shall be of the direct spring-loaded, or direct dead-weight type and shall be so constructed as to permit the steam to escape without increasing the pressure by more than 10 per cent above the pressure at which the valve is set to lift.

Unless otherwise agreed between purchaser and manufacturer the valves shall shut down at a pressure of not more than 10 per cent less than the pressure at which the valve is set to lift.

Safety valves shall be so set as to prevent the boiler being worked at a pressure greater than the design pressure.

c. Safety valves shall be so designed and constructed as to comply with the following requirements:—

(i) The nominal size of the valve shall be the same as its clear bore, and shall be stamped or cast on the body of the valve.

(ii) Valves shall be so constructed that they cannot be inadvertently overloaded beyond the pressure to which they have been set.

(iii) Valves shall be so arranged that they can be eased off their seats under pressure and the easing lever shall lift the valve positively.

(iv) The seats and disks of valves shall be metal-to-metal and shall be made of non-corrodible metal.

Fibrous or other material which may become distorted under working pressure shall not be used.

NOTE. By non-corrodible metal is meant metal specially resistant to corrosion and/or erosion.

(v) The valves and spindles shall be efficiently guided and means shall be provided to prevent them from lifting out of their guides. There shall be sufficient clearance between the working parts to ensure freedom of movement under all conditions of service. The spindle shall not be fitted with a stuffing box.

(vi) The 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 (see sub-clause d).

(vii) Means shall be provided for draining each enclosed valve chest. The drain pipe shall be open-ended and laid with a continuous downward gradient clear of the boiler to a place where the discharge is visible and cannot do injury to any person or persons.

d. The size of the safety valve shall be determined by the following formula, but in no case shall a valve of less than $\frac{3}{4}$ in. bore be fitted:—

$$A = \frac{kW}{C(P + 15)}$$

where

A = for ordinary and high lift safety valves: the aggregate area in square inches of the orifices through the seatings of the valves.

A = for full lift safety valves: the net area in square inches through the seats, after deducting the area of guides or other obstructions when the valves are fully lifted.

kW = maximum output of the boiler in kilowatts.

P = design pressure in pounds per square inch.

C = constant, as in Table 3.

TABLE 3. SAFETY VALVE CONSTANTS

Type of safety valve	Direct spring-loaded valves	Direct dead-weight loaded valves
	Constant C	Constant C
Ordinary	1.3	1.6
High lift	2.6	3.2
Full lift	5.2	5.2

PRESSURE OPERATED DEVICE

31. Boilers of over 20 kW rating shall be fitted with a pressure-operated device attached directly to the boiler shell or as close to it as possible. This device shall operate on rising pressure and shall be set to operate at a lower pressure than the safety valve.

The operation of this device shall so control the output of the boiler that there will be no appreciable rise in pressure after the device has operated.

PRESSURE GAUGE

32. The boiler shall have a pressure gauge which shall be in accordance with B.S. 759,* and shall also be fitted with a siphon. The siphons of boilers for design pressures of 20 lb/sq. in. and over shall be provided with a cock.

BLOW-DOWN COCK

33. The boiler shall be fitted with a blow-down cock.

WATER LEVEL

34. The boiler shall be provided with suitable means for determining the water level. Boilers rated above 20 kW with a design pressure exceeding 40 lb/sq. in. shall be provided with a tubular water-level gauge glass in accordance with B.S. 759.

FEED CHECK VALVE

35. Boilers rated at over 20 kW or of over 20 lb/sq. in. design pressure shall be fitted with a check-valve of the non-return type.

INSPECTOR'S PRESSURE GAUGE ATTACHMENT

36. The boiler shall be provided with an attachment to receive an inspector's pressure gauge.

* B.S. 759, 'Valves, gauges and similar fittings for land boilers installations.'

37. *a. Circuit-breaker.* Each boiler of over 20 kW capacity shall be controlled by a circuit-breaker which, when opened, disconnects all phase electrodes from the supply.

The circuit-breaker shall have over-current protection such that a load of 120—150 per cent of the normal full load current in any phase conductor will cause the circuit-breaker to open. It is recommended that normally the over-current setting should be 125 per cent. An Inverso time-lag device may be used in conjunction with the foregoing protection if desired.

If the boiler is for use on a high-voltage supply, the circuit-breaker shall be so set as to operate if the phase currents become unbalanced by not more than 15 per cent of the normal full load current. An Inverso time-lag device may be used in conjunction with the foregoing out-of-balance protection if desired.

The circuit-breaker shall comply with B.S. 116, Part 1*, B.S. 862† or B.S. 936‡.

b. Other electrical controls. All other electrical control apparatus shall comply with the relevant British Standards.

c. Ammeters. At least one ammeter shall be fitted to indicate the current taken by the boiler and each ammeter shall have a red line at the full load current mark.

THEMOSTAT-CHECKING

38. Provision shall be made for the operating temperature of any thermostat controlling the boiler to be verified by means of a thermometer included in the system. Alternatively, provision shall be made for installing, temporarily and without interrupting the working of the system, a test thermometer so that it gives a true reading of the heated medium surrounding the thermostat bulb.

SECTION THREE : ELECTRICAL REQUIREMENTS

INSULATION

39. All electrical clearances other than electrode spacings shall comply with Clauses 71 and 80 of B.S. 116, and the boiler, when empty of water and dry, shall pass the insulation tests specified in that standard.

* B.S. 116, 'Oil circuit-breakers, oil switches and oil isolating switches for alternating-current circuits'.

† B.S. 862, 'Air-break circuit-breakers (including totally-enclosed and flameproof types) for voltages not exceeding 660 volts'.

‡ B.S. 936, 'Oil circuit-breakers for alternating current circuits up to and including 660 volts'.

ENCLOSURE

40. Mechanical protection of all parts above earth potential shall comply with the relevant standards, such as B.S. 116*, for the working voltage.

CONDUCTORS

41. All electrical conductors shall be of such cross section that the temperature rise due to their resistance at maximum temperature when carrying full load shall not exceed the maximum water temperature by more than 100°F. They shall be of material which will not deteriorate at this temperature.

CONNECTIONS

42. *a.* The contact area of all electrical connections shall be such that there is no greater rise in temperature than that specified in Clause 20. The mechanical pressure between the surfaces shall be maintained irrespective of temperature, thermal expansion and normal vibration.

b. The incoming conductors shall not deteriorate because of the temperature of, and around, the terminals to which they are connected.

c. A separate earthing terminal shall be provided, equal in cross section to the largest main terminal, and in direct contact with the boiler shell.

d. Where plugs and sockets are provided for any connections they shall have mechanical locking devices.

e. Insulated connections brought through the shell shall be subjected to the hydraulic test pressure specified.

ELECTRODES AND INTERNAL PARTS

43. Electrodes shall be of material suitable for use under the working conditions of the boiler.

Moving parts liable to wear shall be of material resistant to corrosion and erosion.

The electrical insulating materials used shall not be liable to deteriorate on account of the conditions to which they are exposed when the boiler is in operation.

CURRENT BALANCE

44. Each boiler shall be so designed that, when operating on multiphase systems under normal conditions, the current is equally balanced between the phases, with a variation of not more than plus or minus 5 per cent of full load current.

ACCESS

45. Openings shall be provided for inspection, cleaning and removal of electrodes and shall be of such sizes and in such positions as to give access to all internal parts of the boiler shell.

* B.S. 116, 'Oil circuit-breakers, oil switches and oil isolating-switches for alternating-current circuits'.

PART 4. CONSTRUCTION, WORKMANSHIP AND SCANTLINGS

SECTION ONE : MATERIALS

NOTE. The materials used in the construction of the boilers shall comply with B.S. 1633, 'Steel for land boilers and other pressure vessels,' the relevant provisions of which are recapitulated below in Clauses 46 to 58 for ready reference.

PROCESS OF MANUFACTURE

46. The steel shall be made by the open hearth or electric process, acid or basic, as may be agreed between the purchaser and manufacturer.

CHEMICAL COMPOSITION

47. The steel shall contain not more than 0.05 per cent of sulphur or of phosphorus.

When the material is required for flame-cutting and/or welding, this shall be stated in the enquiry and order, in which case the carbon content shall not exceed 0.30 per cent.*

When steels are intended for service at temperatures in excess of 700°F., this shall be stated in the enquiry and order, and the silicon content shall then be 0.10 per cent minimum, or alternatively, the material shall comply with B.S. 1271, 'Proof test for creep quality of carbon steel plate of boiler plate quality.'

HEAT TREATMENT

48. All plates over 1½ in. in thickness and not intended for hot forming shall be supplied in the normalized condition, unless otherwise specified in the order. (See also Clause 53a.)

SULPHUR PRINT TEST

49. 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 manufacturer.

FREEDOM FROM DEFECTS

50. The finished material shall be sound, free from harmful segregation of impurities and from cracks, surface flaws and laminations. It shall also have a workmanlike finish and shall not have been hammer dressed, patched or repaired by welding. This shall not prevent minor corrections by agreement between purchaser and manufacturer, nor shall it prevent the removal of slight scale or shell by such means as chisel, file, buff or

* When the material is required for flame-cutting and/or welding, special precautions will be required when the carbon content exceeds 0.26 per cent.

sand or shot blast, provided that the material is not thereby reduced below the specified thickness.

ROLLING MARGIN

51. No plate, section or bar 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 tolerance shall be as set out in Table 5.

TESTING AND INSPECTION

52. 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, such material shall be rejected notwithstanding any previous certificate of satisfactory examination or testing.

MECHANICAL TESTS

53. Plates, sections and bars shall satisfy the following mechanical tests :—

a. Selection of test pieces. All test pieces shall be selected by the inspector (or by the steel manufacturer's representative where testing and inspection are not carried out by the purchaser). They shall be tested in his presence and he shall satisfy himself that the conditions of this British Standard are fulfilled.

The test pieces shall not be annealed or otherwise heat treated, unless the material from which they are taken is similarly treated, in which case the test pieces shall be similarly and simultaneously treated with the material before testing.

b. Tensile test pieces. The ultimate tensile stress and elongation shall be determined on British Standard test pieces which, in the case of plates, shall be taken crosswise from the rolled material. Any straightening of the test pieces which may be required shall be done cold.

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

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

If tested at 1 in. diameter or under, standard test piece B (see Appendix A) shall be used. The sectional area of a machined test piece shall be not less than $\frac{1}{4}$ sq. in. If the test piece is over 1 in. in diameter, standard test piece B1 (see Appendix A) may be used.

c. Tensile test. The ultimate tensile stress and elongation of the various classes of materials shall be between the limits shown in Table 4.

NOTE. Should a tensile test piece break outside the middle half of its gauge length (see Fig. 1), the test may, at the manufacturer's option, be discarded and another test made on a test piece cut from the same plate, section or bar.

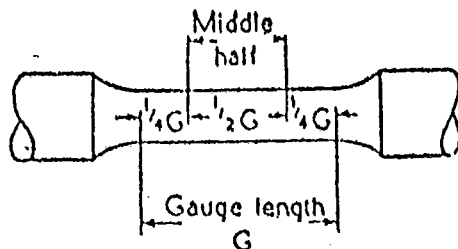


Fig. 1. Diagram explaining the term 'middle half' of the gauge length

d. Bend test pieces. Test pieces shall be taken lengthwise or crosswise from plates and lengthwise from sections and bars, and shall, where practicable be not less than $1\frac{1}{4}$ in. wide. For small sections and bars the whole section may be used.

The rough edge or arris caused by cutting may be removed by filing, grinding or machining, but the test pieces shall receive no other preparation.

e. Bend test. The test piece when cold shall be capable of being doubled over until the internal radius is equal to that shown in Table 5 and the limbs are parallel.

f. Dump test. Short lengths, equal to twice their diameter, taken from the selected rivet bars shall, when cold, be capable of being compressed to half their length without fracture.

NUMBER OF TENSILE, BEND AND DUMP TESTS

54. *a. Plates.* For shell plates, butt straps and gusset plates, one tensile test and one bend test shall be taken from each end of each plate as rolled. For other plates, such as end plates, crown plates, furnace and flanging plates, one tensile and one bend test shall be taken from one end of each plate as rolled.

b. Sections and bars. One tensile test shall be made for each 15, or part of 15 bars rolled of each section or diameter from the same cast, but not less than two tensile tests shall be made unless the total number of bars rolled from the same cast is 8, or less than 8, and the bars are the same section or diameter, when one test will suffice. For round bars $1\frac{1}{4}$ in. in diameter and under, the numbers 50 and 20 shall be substituted for 15 and 8, respectively, for determining the number of tests required.

For sections, one bend test shall be made from each section as rolled.

For bars for screwed stays and bar stays, one bend test shall be made for each tensile test.

For bars for rivets, one dump test shall be made for each tensile test. Bend tests are not required.

TESTS ON MANUFACTURED RIVETS

55. Rivets selected by the inspector from the bulk in such proportion as may be specified and approved, shall satisfy the following tests :—

a. Rivet shanks shall be bent cold and hammered until the two parts of the shank touch in the manner shown in Fig. 2 without fracture on the outside of the bend.

b. Rivet heads shall comply with B.S. 425, 'Forms and dimensions of boiler rivets' and shall be flattened, while hot, in the manner shown in Fig. 3, without cracking at the edges. The head shall be flattened until its diameter is $2\frac{1}{2}$ times the diameter of the shank.



Fig. 2

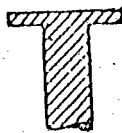


Fig. 3

RE-TESTS

56. Should any test piece fail to fulfil the test requirements, two further tests of the same kind may be made, but should either of these fail, the material represented thereby shall be rejected, or, at the option of the manufacturer, normalized or annealed, and re-submitted for test.

MARKING

57. All plates, sections and bars shall be legibly marked in two places with the manufacturer's name or trade mark and with numbers or other identification marks by which they can be traced to the cast of steel from which they were made. A line of white paint shall encircle the numbers or identification marks. Where a plate is cut into pieces it shall be so stamped that each piece shall bear the numbers or identification marks.

Rivet bars shall be so marked, or bundled and tabbed, as to enable the material to be traced to the cast of steel from which it was made.

CERTIFICATES

58. The manufacturer shall supply signed certificates of test stating the reference number of each plate, section and bar, the results of the mechanical tests, the process by which the steel has been manufactured and the chemical analysis of each cast, as required by this standard.

BOLTS, STUDS AND NUTS

59. *a.* Bolts and studs shall comply with B.S. 1083*, Codes B and P of Table 9.

b. Nuts shall comply with B.S. 1083, Code A of Table 10.

*B.S. 1083, 'Precision hexagon bolts, screws, nuts and plain washers'

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The steel shall not be of the free cutting quality and shall contain not more than 0.06 per cent of sulphur or of phosphorus.

It is recommended that, as far as possible, the steel should be made by the open hearth process or by an electric process, acid or basic.

TABLE 4. MECHANICAL PROPERTIES

TABLE 4. MINIMUM ELONGATION*							
Description	ULTIMATE TENSILE STRESS	MINIMUM ELONGATION* per cent			Test piece B1	BEND TEST	
		Test piece A 8 in. gauge length	Test piece B†	Test piece B1			
Plates for shells, butt straps, gussets and stays	tons/sq. in. 26-36†	23 for 26-30 tons/sq. in. 20 for 28-32 tons/sq. in. 20 for 30-36 tons/sq. in.	21 for 26-30 tons/sq. in. 18 for 28-32 tons/sq. in. 18 for 30-36 tons/sq. in.	—	—	1T for 26-30 tons/sq. in. 1½T for 28-32 tons/sq. in. 1½T for 30-36 tons/sq. in.	—
		23 for 24-30 tons/sq. in. 20 for 28-32 tons/sq. in.	21 for 24-30 tons/sq. in. 18 for 28-32 tons/sq. in.	—	—	1T for 24-30 tons/sq. in. 1½T for 28-32 tons/sq. in.	
Plates for flanging, and for furnaces	24-32†	23 for 24-30 tons/sq. in. 20 for 28-32 tons/sq. in.	21 tons/sq. in.	—	—	1T for 24-30 tons/sq. in.	—
Plates for forge-welding	24-30†	23 for 24-30 tons/sq. in.	21 tons/sq. in.	—	—	1T for 24-30 tons/sq. in.	—
Sections	26-30 or 28-33	23 for 26-30 tons/sq. in. 20 for 28-33 tons/sq. in.	— tons/sq. in.	—	—	1T for 26-30 tons/sq. in. 1½T for 28-33 tons/sq. in.	—
Bars for bar stays	26-36†	—	25 for 26-30 tons/sq. in. 22 for 30-36 tons/sq. in.	30 for 26-30 tons/sq. in. 27 for 30-36 tons/sq. in.	—	1½T	—
Bars for screwed stays	24-28 or 26-30	—	25 tons/sq. in.	30	—	1T	—
Bars for rivets	24-28 or 26-30	—	25 tons/sq. in.	30	—	—	—

* For material under ¾ in. in thickness reduce minimum percentage elongation value by 1.

† A range of not more than 4 tons/sq. in. in each class of material shall apply, such range to be specified for each component part of the boiler, receiver or other pressure vessel.

‡ Machined in the case of plates.

TABLE 5. SCHEDULE OF PERCENTAGE ROLLING WEIGHT
TOLERANCES FOR BOILER PLATES

Ordered thickness	Widths 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.	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
Under $\frac{1}{8}$	10	10	12	—	—	—	—	—	—
$\frac{1}{8}$ to under $\frac{3}{16}$	10	10	10	10	—	—	—	—	—
$\frac{3}{16}$ to under $\frac{1}{4}$	10	10	10	10	—	—	—	—	—
$\frac{1}{4}$ to under $\frac{5}{16}$	5	5	5	7	9	12	12	—	—
$\frac{5}{16}$ to under $\frac{3}{8}$	5	5	5	6	7.5	10	11	12	—
$\frac{3}{8}$ to under $\frac{7}{16}$	5	5	5	6	6	8	9	11	15
$\frac{7}{16}$ to under $\frac{1}{2}$	5	5	5	5	6	7.5	8	9	12
$\frac{1}{2}$ to under $\frac{5}{8}$	5	5	5	5	6	6	7.5	9	10
$\frac{5}{8}$ to under $\frac{3}{4}$	5	5	5	5	5	5	7	8	9
$\frac{3}{4}$ 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 net theoretical weight.

SECTION TWO : REQUIREMENTS FOR RIVETED STEEL BOILERS

A. CONSTRUCTION AND WORKMANSHIP

PREPARATION OF PLATES

60. The edges of all plates and butt straps shall be machined or flame-cut by machine and the caulking edges shall be at an angle of approximately 80 degrees to the surface of the plate.

Plates which are to be flame-cut by machine without heat treatment or subsequent grinding or machining shall not have a higher carbon content than 0.26 per cent.

Where the carbon content exceeds 0.26 per cent, heat treatment, grinding or machining shall be carried out.

All plate edges shall have a smooth finish.



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CYLINDRICAL SHELLS

61. Each cylindrical ring shall be formed from one plate. All plain cylindrical portions shall be bent while cold to cylindrical form to the extreme ends of the plates. The bending shall be done entirely by machine, and not by heating or hammering.

Longitudinal seams may be lap jointed or fitted with double butt straps (see Clause 74). Where the longitudinal seams are lap jointed the plates at the junction of the longitudinal and circumferential seams shall be tapered by machining to provide a fair inner surface to the joint. The seams for successive rings shall not fall in line, but shall be arranged alternately on each side of the boiler, breaking joint not less than 120 degrees apart.

BUTT STRAPS

62. Butt straps shall be machined or machine flame-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 shall be transverse to the direction of rolling of the plate. Straps shall be pressed or bent in rolls to the shell curvature.

The ends of the butt seams of shell rings may be welded for a length not exceeding three times the overlap at the circumferential seam, provided that the butt straps are run as closely as practicable up to the circumferential seam.

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, alternatively, where the ends of butt straps butt against the shell rings or end plates they may be welded to them.

DISHED END PLATES

63. All dished end plates shall preferably be in one piece and made from one rolled plate. They shall be flanged and riveted to the shell (see Clause 75).

Where the end plates are dished, the dishing and flanging operations shall preferably be done by machine and at one heat; creep flanging, however, is permissible provided that the plate is worked at a suitable temperature and heated for an adequate distance beyond that portion of the plate under immediate treatment. Cold flanging shall not be employed. For the purpose of relieving any internal stress, end plates which have been dished, flanged or locally heated shall afterwards be effectively heat treated, unless during last stage of manufacture they have been uniformly heated throughout to ensure adequate stress relief.

Care shall be taken to ensure that the flanges are circular, of good surface, and free from local irregularities.

All flanges shall be circular and a good fit to the connecting parts. Flogging and/or hammering shall not be used in the fitting of these parts. The caulking edges of all flanged plates shall be machined or machine flame-cut (see Clause 60).

BAR STAYS

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

Where the bar stay passes through clearing holes an internal nut and washer shall also be fitted. Where the stay is not perpendicular to the surface of the plate the washers shall be so shaped as to form a true surface for the nuts.

The screw threads of the stays shall be clean, free from checks or imperfections, of full depth and of correct Whitworth form and pitch. Nuts shall be a close fit to the threaded portion of the stays and shall have machined faces where they bear on plates or washers. Non-ferrous metal jointing washers or rings may be used to ensure tight joints.

ANGLE RINGS

65. Angle rings for the attachment of end plates or covers shall be rolled or machined so that they fit closely to the surfaces to be connected ; they shall be machined on the caulking edges.

INSPECTION OPENINGS, MANHOLES, COMPENSATING RINGS, AND DOORS

66. Inspection openings, compensating rings and doors, where fitted, shall be of mild steel. Wherever possible, the shorter axis of the manhole shall be arranged parallel to the longitudinal centre line of the shell.

All compensating plates shall be formed to bed closely to the surfaces to be connected. All caulking edges shall be dressed.

Internal doors shall be formed from steel plate and shall be fitted with two studs, each provided with an integral collar and each screwed through the plate with a nut on the inside of the door, or with the ends of the studs riveted over.

Internal doors for openings not larger than 9 in. $\times$ 7 in. in size need be fitted with only one stud which shall be provided with an integral collar and screwed through the plate with a nut on the inside of the door, or with the end of the stud riveted over. Internal doors for openings not larger than 5 in. $\times$ 3½ in. in size may have the stud forged solid with the door.

The spigot or the recess shall have a clearance not greater than ¼ in. all round.

DOUBLING PLATES AND COMPENSATING RINGS

67. Doubling plates and compensating rings shall be of mild steel, without weld. Before riveting they shall be closely to the plates to which they are to be connected.

OPENINGS FOR FLANGED PIPE CONNECTIONS

68. Where pads, blocks or pipe stools are fitted they shall be designed to suit British Standard flange connections (B.S. 10, 'Tables of pipe flanges for land use'). The joint faces of such pads, blocks or pipe stools shall be machined. The pads or blocks shall be of sufficient thickness to allow the drilling of stud holes without the inner surface of the pad plate being pierced, and the length of the screwed portion of the stud in the pad or block shall be not less than the diameter of the stud. All bolt or stud holes in pads, blocks and pipe stools shall be drilled.

RIVET HOLES

69. 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 and ends bolted in position. After drilling, burrs and sharp edges of the holes shall be removed. 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 reaming.

The diameter of the rivet hole shall be not more than $\frac{1}{16}$ in. larger than the standard diameter of the cold rivet as manufactured (see Clause 70).

RIVETING

70. Rivets shall be closed by hydraulic machinery wherever the design permits. They may be closed by hand or pneumatic hammer in positions where hydraulic riveting is impracticable.

Rivets shall be of sufficient length to fill the 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.

The rivets shall comply with B.S. 425, 'Forms and dimensions of boiler rivets (as manufactured).'

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 reamed fair before riveting is commenced.

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.

FULLERING AND CAULKING

71. All seams shall be fullered inside and outside. Where caulking is found to be necessary it shall be done in such a manner that the plates are neither sprung nor damaged.

B. RULES FOR SCANTLINGS

SCANTLINGS

72. The calculations made to determine the scantlings shall be based on the design pressure which shall be not less than the highest pressure at which any safety or relief valve is to be set to lift.

NOTE. It is desirable that there should be a margin between the actual pressure at which the boiler operates and the lowest pressure at which any of the safety or relief valves is set to lift, to prevent the unnecessary blowing-off of the safety or relief valve(s).

MINIMUM THICKNESS

73. In no case shall the factor of safety of the shell and ends be less than 4. The plate thickness shall be not less than $\frac{3}{4}$ in. for shells up to and including 2 ft. in diameter, $\frac{5}{16}$ in. for shells above 2 ft. in diameter up to and including 3 ft. in diameter, and $\frac{3}{8}$ in. for shells above 3 ft. in diameter.

SHELLS

74. The diameter shall be measured inside the outer ring of plates.

As stated in Clause 61, the longitudinal seams of shells may be lap jointed or fitted with double butt straps, but where the thickness of the shell exceeds $\frac{5}{16}$ in. and/or where the diameter of the shell exceeds 72 in. the longitudinal seams shall be butt-jointed and fitted with double butt straps.

The thickness of cylindrical shells shall be determined by the following formula :—

$$t = \frac{PDC}{SJ} + 2 \quad \dots \dots \dots \text{Equation 1}$$

where

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

P = design pressure in pounds per square inch.

D = maximum internal diameter in inches.

S = minimum ultimate breaking strength of plate, tons per square inch.

J = calculated joint efficiency per cent.

C = 2.75 when the longitudinal seams are made with double butt straps.

C = 2.83 when the longitudinal seams are made with lap joints and are treble riveted.

C = 2.90 when the longitudinal seams are made with lap joints and are double riveted.

C = 3.30 when the longitudinal seams are made with lap joints and are single riveted.