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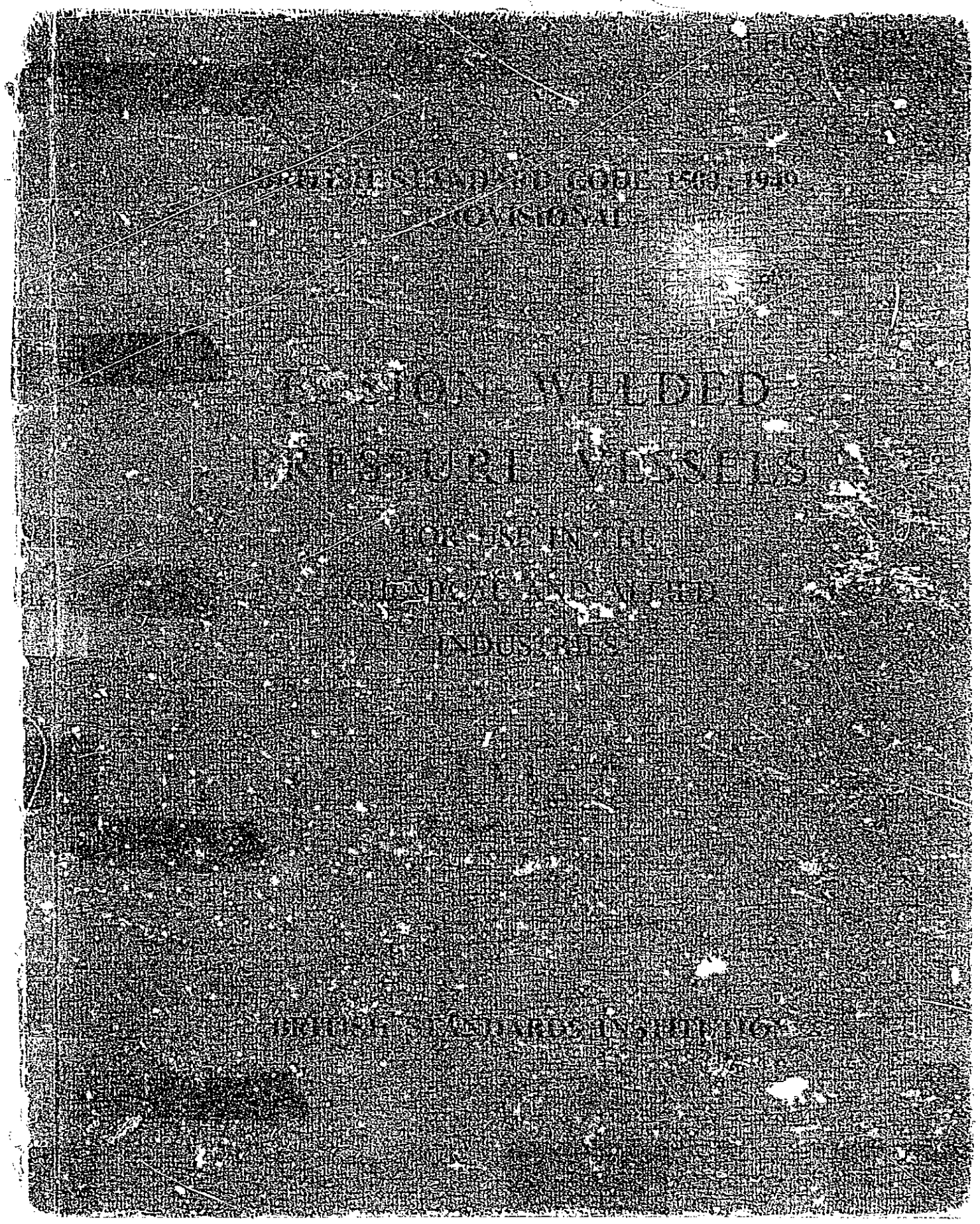

THIS PROVISIONAL BRITISH STANDARD is being issued for comment over a period of 12 months. It will then be reviewed in the light of experience gained and the observations submitted.

Date of issue, 11th November, 1949.

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.

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CO-OPERATING ORGANIZATIONS

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

Association of British Chemical Manufacturers
Association of Consulting Engineers, Incorporated
Board of Trade
British Chemical Plant Manufacturers Association
Coke Oven Managers Association
Electrodepositors' Technical Society
Glass Manufacturers Federation
*Institute of Petroleum
*Institution of Chemical Engineers
Institution of Gas Engineers
*Institution of Mechanical Engineers
Institution of Structural Engineers
Iron and Steel Institute
Society of Chemical Industry

The scientific 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:—

Associated Offices Technical Committee
British Iron and Steel Federation
Lloyds Register of Shipping
Manufacturers of Pressure Vessels
Ministry of Transport
National Physical Laboratory
Users of Pressure Vessels

PROVISIONAL BRITISH STANDARD CODE

FUSION-WELDED PRESSURE VESSELS

FOR USE IN THE CHEMICAL AND ALLIED INDUSTRIES

B.S. 1500 : 1949

Price ~~25/-~~ 30/- post free

BRITISH STANDARDS INSTITUTION

INCORPORATED BY ROYAL CHARTER

24/28 VICTORIA STREET, LONDON, S.W.1

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SCHEME OF CODES

RELATING TO PRESSURE VESSELS

SUMMARY OF CODE REQUIREMENTS

1	2	3	4	5	6	7	8	9	10	11
Vessel duty	Diameter	Plate thickness	Pressure	Temperature	Material inspection	Construction inspection	Mechanical tests	Radiographic tests	Stress relief	Joint* efficiency, 'J'
SEVERE	No limit	No limit	No limit	No limit but fired vessels not to exceed 100 lb/sq. in. working pressure	Full	Full	Full	Full	All vessels	0·95
Clauses	—	—	—	—	20 & 180–193	21 & 180–193	22 & 194–196	23 & 197–207	24 & 172–179	Table 8
MEDIUM	No limit	No limit	No limit	No limit but fired vessels not to exceed 100 lb/sq. in. working pressure	Limited	Limited	Limited	Longitudinal seams only, if exceeding 1½ in. thick or 1000 lb/sq. in. working pressure, or if special materials used	All steel vessels exceeding 0·3 carbon. Vessels with less carbon to Fig. 4	0·89 if stress relieved and radiographed. 0·80 stress relieved only. 0·83 to 0·89 radiographed only. 0·74 to 0·80 not stress relieved or radiographed.
Clauses	—	—	—	—	20 & 180–193	21 & 180–193	22 & 194–196	23 & 197–207	24 & 172–179	Table 9
LIGHT	Limited by ⅝ in. thick and 250 lb/sq. in. hydraulic pressure.	⅝ in. thick	50 lb/sq. in. vapour pressure or 250 lb/sq. in. hydraulic pressure	300°F. (150°C.) unfired	Minimum	Minimum	Minimum	Longitudinal seams only, if special materials used.	All steel vessels exceeding 0·3 carbon. Vessels with less carbon to Fig. 4	0·80 if stress relieved and radiographed. 0·71 stress relieved only. 0·74 to 0·80 radiographed only. 0·65 to 0·71 not stress relieved or radiographed.
Clauses	3	3	3	3	20 & 180–193	21 & 180–193	22 & 194–196	23 & 197–207	24 & 172–179	Table 10

* Double welded butt and welability = 1.0.

PROVISIONAL BRITISH STANDARD CODE FOR FUSION-WELDED PRESSURE VESSELS

FOR USE IN THE CHEMICAL AND ALLIED INDUSTRIES

NOTE. *This first edition is intended to serve as a tentative code for comment over a period of 12 months. It will then be reviewed in the light of the experience gained and observations submitted.*

FOREWORD

The industry which makes the greatest use of pressure vessels (other than steam boilers) is undoubtedly the chemical industry in its many branches—petroleum, soap, paper rubber, plastics, etc. There are also many subsidiary 'chemical units' in general industrial plants, such as impregnators in electric cable manufacture and vacuum stills for dry cleaning in laundries.

The petroleum branch operates on a very large scale and it is appropriate to consider the special activities of this branch when reviewing the requirements for pressure vessels. In the preparation of this Code, therefore, full consideration has been given not only to British practice but also to the experience of the American petroleum industry and acknowledgement is made to the American Petroleum Institute and American Society of Mechanical Engineers (A.P.I.—A.S.M.E.) Code.

In this British Standard Code vessels are graded according to the severity of the duty or danger, and inspection and tests of increasing stringency have been applied as the duty becomes more severe.

Section One: General

A. SCOPE

GENERAL

1. *a.* This British Standard Code covers the design, construction, inspection and repair of fusion-welded pressure vessels for use in the chemical and allied industries. The field is very wide and the following list, which is not exhaustive, gives examples of such vessels in common use in the chemical and allied industries :—

Absorbers	Impregnators
Autoclaves (digestors, etc.)	Mixers
Canning 'retorts'	Montejus (acid eggs, etc.)
Coolers	Pressure storage vessels
Condensers	Reactors
Dephlegmators	Receivers
Disinfectors	Scrubbers for gas
Extractors	Separators
Filters	Sterilizers
Fractionators	Stills
Heat exchangers	Tanks
Heaters	Vulcanizers

All of these may be operated under pressure or vacuum according to process requirements.

b. Attention is called to the fact that British Standards exist for a number of pressure vessels, for example :—

(i) *Gas cylinders.*

B.S. 399. 'High carbon' steel cylinders for 'permanent' gases.

B.S. 400. 'Low carbon' steel cylinders for the storage and transport of 'permanent' gases.

B.S. 401. Steel cylinders for the storage and transport of 'liquefiable' gases.

B.S. 1045. Manganese steel gas cylinders for atmospheric gases.

B.S. 1287. 'High carbon' steel gas cylinders for carbon dioxide, nitrous oxide and ethylene.

B.S. 1288. Manganese steel gas cylinders for carbon dioxide, nitrous oxide and ethylene.

(ii) *Unfired pressure vessels.*

B.S. 428. Forge welded steel air receivers.

B.S. 429. Riveted steel air receivers.

B.S. 430. Solid drawn steel air receivers (not intended for transport).

B.S. 487. Fusion welded steel air receivers.

B.S. 1099. Small fusion welded steel air receivers.

B.S. 1101. Pressure paint containers.

(iii) *Boilers.*

B.S. 537. Lancashire and Cornish boilers.

B.S. 609. Horizontal multitubular boilers.

B.S. 665. Vertical cross tube boilers.

B.S. 761. Vertical multitubular boilers.

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

B.S. 1113. Water-tube boilers.

B.S.*..... Steam receivers and separators.

c. Many of the requirements of the Code are not mandatory, as are those of a specification, which outlines exactly the requirements for a specific article. It is intended to serve as a guide for agreement between the purchaser and manufacturer.

d. Nothing in this Code is intended to contravene any provision of the Factories Act 1937 or of any regulations made thereunder, or any other statutory requirements.

* In course of preparation.

e. The 'Scheme of Codes' (see page 2) shows the ground covered by this Code and also, to complete the subject, other relevant British Standards and Codes.

B. DEFINITIONS

The range of pressures, temperatures, materials and duties, etc., is much wider in the chemical industry than in any other fields, and to avoid confusion users of this Code are recommended to adhere to the following terms :—

DOMED END

2. *Domed end.* An end closure the shape of which is a surface of revolution of a curve, arc or combination of arcs, and this includes all shapes varying from hemispherical to slightly 'dished.' The curves are tangential to the surface of the wall of the shell where the end joins the parallel portion of the vessel shell.

(i) *Semi-ellipsoidal end.* An end having a profile which is truly semi-elliptical.

(ii) *'Dished' end.* An end having a profile formed by two radii.

JOINT EFFICIENCY (OF A JOINT OR LIGAMENT)

3. The ratio of the strength of the joint or ligament to the strength of the plates which it unites, expressed as a decimal fraction.

LININGS AND COATINGS FOR VESSELS

4. *a. Vessels with metal linings.*

(i) Vessels in which the lining is completely loose or secured to the walls of the vessel only from point to point.

(ii) Vessels in which the lining is bonded or rigidly attached to the walls of the vessel. Nickel or stainless 'clad' and 'homogeneous' lead-lined vessels belong to this class.

b. Vessels with non-metallic linings.

(i) Vessels in which linings of stoneware tiles and similar corrosion-resisting materials are set in special cements.

(ii) Vessels in which linings of soft or hard rubber, synthetic compounds, etc., are attached to the walls of the vessel with or without adhesive cements, etc.

c. Vessels with metal coatings. Vessels, the walls of which are provided with thin metallic coatings of zinc, tin, copper, nickel, cadmium, etc., applied by hot processes such as galvanizing, tinning or metal-spraying, electric deposition, etc.

d. Vessels with non-metallic coatings. Vessels, the walls of which are provided with thin non-metallic coatings of special enamels, varnishes, etc., of high corrosion resistance against acids, alkalis, oils, etc. Such coatings are brushed or sprayed on, and fused or baked in position. Vitreous enamels belong to this class.

PEENING

5. A method of hammering weld metal to relieve internal stresses. This is carried out by special shaped hammers or by tools which give hammer-like blows.

PLANISHING

6. A method of increasing the strength of some soft metals and alloys by hammering or beating in the cold condition.

PRESSURE

7. *a. Design pressure.* The maximum differential pressure permitted by the rules of this Code for the weakest element of the vessel. (Particular attention is drawn to vessel walls subject to pressure on one side and accidental vacuum on the other). (See Clause 36.)

b. Disc rupture pressure. The pressure at which safety devices of the rupture disc, or low weight flap type, etc., operate.

c. Hydraulic test pressure. The pressure at which the vessel is tested for porosity, etc. It may be applied by water, or by any other liquid such as paraffin.

d. Maximum permissible working pressure. The maximum pressure at which the vessel or part of the vessel may be operated. It is usually the blow-off pressure of the safety valve or other pressure-relieving device. (See Clause 36.)

e. Normal operating pressure. The pressure at which the vessel is normally to be operated.

NOTE. It is recommended that there should be an adequate margin between the normal operating pressure and the maximum permissible working pressure, in order to prevent unnecessary blowing-off of the safety valves.

f. Safety valve blow-off pressure. The highest pressure at which a safety valve (or valves) is set to prevent the vessel from being worked at a pressure greater than the maximum permissible working pressure.

g. Pneumatic test pressure. The pressure applied to a vessel to facilitate the tracing of leakage. Air or any other gas such as ammonia, etc., may be used for this purpose. (See Clause 212.)

h. Proof hydraulic test. The pressure applied to test the vessel when the strength cannot be satisfactorily calculated. (See Clause 210.)

i. Proof pneumatic test. The pressure applied to test a low pressure or thin walled vessel when the strength cannot be satisfactorily calculated. (See Clause 212.)

j. Vacuum loss (short time) test. The drop in vacuum over a period of one hour under agreed conditions of temperature and of sealing off the vessel.

k. Vacuum loss (long time) test. The total drop in vacuum over a 12 hour period, under agreed conditions of temperature and of sealing off the vessel.

RADIOGRAPHY

8. The process of obtaining, upon sensitive film, a record of the homogeneity of an object by passing radiations of suitable wave length through it.

STRESSES

9. *Safe working stress.* The unit stress from all known sources permitted for the material of construction under the working temperature.

STRESS RELIEF

10. *a. Relief of internal stresses by heat treatment.*

(i) *Stress relieving.* The heating of a vessel to a suitable temperature at which stresses caused by fabrication and welding are practically annulled. (See Clauses 172 to 174.)

(ii) *Normalizing* (as required by Clause 24c). Heat treating the vessel in such a manner as to change the structure of the metal, e.g., in the case of steel, by raising it to a temperature above the upper critical point and allowing it to cool in still air.

b. Relief of internal stresses by mechanical work. Correcting for the thermal contraction of the weld metal by peening. (See Clauses 5 and 175.)

TEMPERATURES

11. *a. Safe working temperature.* The maximum temperature to which the material of construction may be submitted when in service. (See Clause 35.)

b. Normal operating temperature. The temperature at which the vessel is normally operated.

NOTE. This shall not exceed the safe working temperature.

TOXIC AND LETHAL SUBSTANCES

12. For the purpose of interpreting the references in this Code, toxic and lethal substances shall be regarded as meaning poisonous substances of such a nature that a small amount of the substance (mixed or unmixed with air) is dangerous to life on short exposure. For example, for the purposes of this Code, hydrogen sulphide, carbon monoxide (pure or in mixtures), chlorine, oxides of nitrogen, hydrocyanic acid, carbonyl chloride, cyanogen, ammonia and xylyl bromide are typical of these substances.

Hydrogen, natural gas, 'towns' or petroleum gases are not regarded as toxic or lethal substances.

TYPES OF VESSEL

13. *a. Non-pressure vessels.* Vessels in which the internal pressure is due solely to the static head of the fluid within the vessel, plus any slight pressure or vacuum caused by vapour venting or lightly loaded breathing devices. Figs. 1 and 2 indicate the limits for non-pressure vessels based upon the pressure or vacuum in the vapour space. Attention is drawn to the fact that the scantlings of many vessels falling within the scope of this definition, are determined by questions of stability and the necessity for adequate structural rigidity.

b. Pressure vessels. Vessels in which the fluid in the vessel is subjected to an internal or external pressure falling outside the minimum limits shown in Figs. 1 and 2.

c. Fired vessels. Vessels in which heat is applied direct to the shell or tubes by hot gases of combustion.

STAYS

14. Members giving local support to parts subject to pressure, to which they are attached. (See Clauses 118 to 124.)

a. Staybars. Stays connecting widely spaced surfaces. They are attached to the plates they support by threading the ends of the staybar and fitting nuts, or nuts and washers, on each side of each plate. They may be screwed into the plates and fitted with single nuts or made unscrewed and welded to the plates. (See Figs. 40 m—r.)

b. Stayblocks. Stays connecting closely spaced surfaces. They may be fillet welded to one plate and plug welded to the second, or formed by a spacer block between the two plates and rivets passing through all three members. (See Figs. 40 b—d.)

c. Staybolts. Stays, having a length between the stayed surfaces not exceeding 20 diameters, connecting closely spaced surfaces. They may be threaded for the whole of their length and screwed into the plates they support, or screwed through one plate and into a block welded to the other or welded to the plates. (See Figs. 40 e—l.)

d. Staytubes. Special tubes in a tube nest threaded at each end and screwed into the plates they support, and with or without nuts, or welded into the tube plates. (See Figs. 40 s—u.)

WELDING PROCESSES (FUSION)

15. A group of processes in which metals are welded together by bringing them to the molten state at the surfaces to be joined, with or without the addition of filler metal, without the application of mechanical pressure or blows. This group includes :

a. Arc welding. A fusion-welding process in which the heat is obtained from an electric arc formed between the base metal and an electrode or between two electrodes, with or without the use of shielding gases.

b. Gas welding. A fusion-welding process in which the heat is obtained from a gas flame.

WELDING TERMS

NOTE. B.S. 499 gives in detail nomenclature, definitions and symbols in connection with welding and flame cutting.

16. *a. Double-welded butt joint.* A joint formed by the fusion of two abutting edges with weld metal added from both sides of the joint.

b. Single-welded butt joint with backing strip. A joint formed by the fusion of two abutting edges with weld metal added from one side only, full penetration throughout the joint being obtained by the use of a suitable backing strip or bar.

c. Single-welded butt join: without backing strip. A joint formed by the fusion of two abutting edges with weld metal added from one side only.

d. Fillet weld. A weld of approximately triangular cross-section lying external to the parts joined.

e. Full-fillet weld. A fillet weld brought up to the full thickness of a plate or branch flange that has been joined to a parallel plate, having a throat thickness not less than 0·7 times the thickness of the edge of the plate being welded.

f. Single full-fillet lap joint. A joint in which the overlap edges of two plates are full-fillet welded along one edge only.

g. Double full-fillet lap joint. A joint in which the overlap edges of two plates to be joined are full-fillet welded at the edges of each plate.

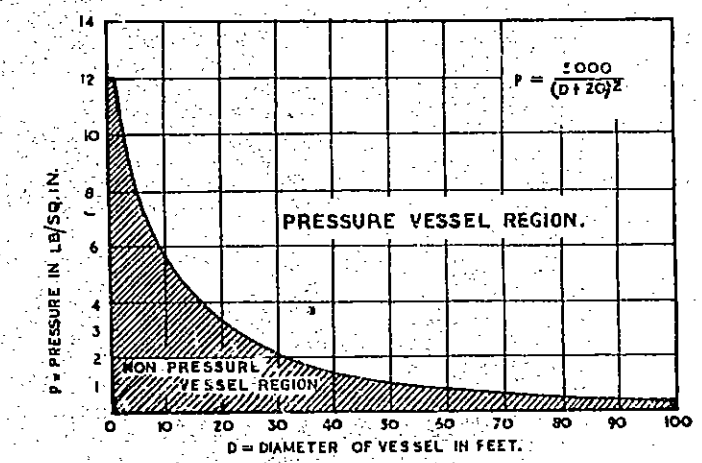

Fig. 1. Limits for pressure vessels covered by the requirements of the Code

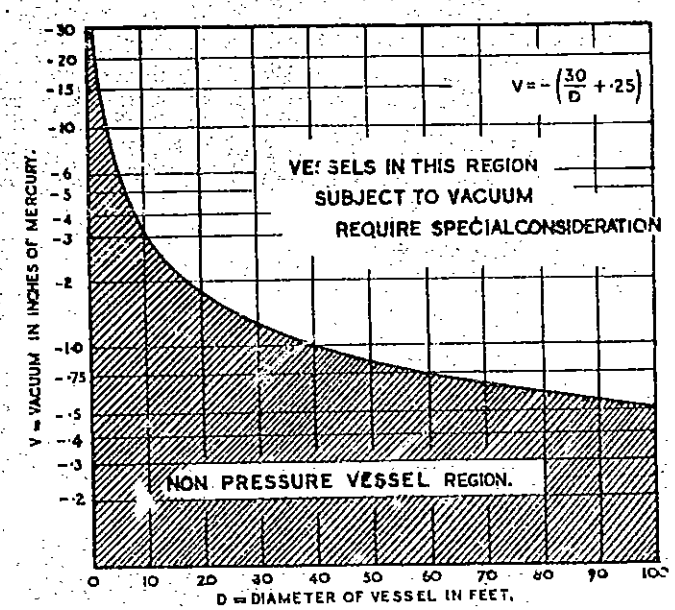

Fig. 2. Limits for vacuum vessels covered by the requirements of the Code

h. Corner weld. A joint in which the parts joined form approximately a right angle with one another and an edge or end of one part is situated at or near a surface of the other part but does not intersect it.

i. Seal weld. A weld applied in place of, or in addition to, mechanical caulking for the purpose of obtaining tightness of the seam. It is not considered as adding to the strength of the joint.

j. Plug weld. A weld made in a circular or elongated hole formed in one of the parts of a lapped joint to attach the lower part.

k. Backing strip. Material of any kind placed adjacent to the root of the welding groove to aid in obtaining full penetration of the weld and which may or may not be removed after the weld is completed.

l. Weld imperfections. B.S. 499, Part Two, gives terminology of weld imperfections.

C. USE OF CODE

GENERAL

17. In this British Standard Code a common set of rules for design formulae for scantlings, for manufacture and for workmanship is included to cover all requirements for chemical pressure vessels. The amount and nature of the inspection to be carried out is covered by varying the inspection visits and tests to ensure that the finished vessel conforms to the designed requirements.

The formulae given in Section Three of this Code apply to vessels constructed throughout under the conditions prescribed in Sections Four and Five of the Code, and working under normal conditions and adequate supervision.

Where conditions are adverse, or where of necessity maintenance supervision will be inadequate, it is recommended that the scantlings found by calculation from the formulae should be increased.

It is recognized that the design of pressure vessels, particularly in the chemical industry, is the subject of continuous development, and it is intended to review the Code annually in order to incorporate such modifications as are found desirable as a result of progress.

CLASSIFICATION

18. The following classification of pressure vessels is adopted as the basis of this Code, but any particular pressure vessel may be classified in any one of the higher categories where deemed advisable or desirable by the inspecting authority or when agreed between the purchaser or his representative and the manufacturer.

a. Severe duty *vessels* are vessels that are to contain toxic or lethal substances or materials at a temperature above their self-ignition point or fired vessels for pressures exceeding 100 lb/sq. in. They are generally equivalent to what are known as 'Class I vessels.'

b. Medium duty *vessels* are vessels that do not fall within the scope of paragraphs (*a*) and (*c*) and can be rated generally as 'Class II vessels.'

c. Light duty *vessels* are vessels, for relatively light duties, having plate thicknesses not in excess of ⅝ in. built for working pressures not exceeding 50 lb/sq. in. vapour pressure, or 250 lb/sq. in. hydrostatic pressure, at temperatures not exceeding 300°F. (150°C.) and unfired. They can be generally rated as 'Class III vessels.'

d. Vessels for service at sub-atmospheric temperature. All vessels constructed of any of the materials noted in Table I as liable to embrittlement at temperatures below + 32°F. (0°C.) shall be subject to impact tests for the materials, and these shall be carried out at the lowest temperature at which the vessel will be operated. (See Clause 195 and Appendix A.)

INSPECTION AND TESTS : GENERAL

19. The degree of inspection and testing required for vessels is varied according to the classification of the duty as set out in Clause 18. These variable requirements are as follows :—

a. Tests and inspection of material.

b. Degree of inspection during construction.

c. Amount of mechanical testing relating to welded seams.

d. Radiographic examination of welded seams.

e. Stress relief.

See also 'Summary,' page 3, and Section Five.

MATERIAL INSPECTION

20. For details of the mechanical tests and inspection required see the appropriate British Standard and Clause 28.

a. Full inspection of material. Mechanical tests on each plate witnessed by the purchaser's representative and inspection of material at the mills.

b. Limited inspection of material. Mechanical tests on each plate certified by the producer of the material. Inspection of material at the mills *not* required.

c. Minimum inspection of material. Mechanical tests on each batch of material certified by the producer. Inspection of material at the mills *not* required.

CONSTRUCTION INSPECTION

21. This does not cover visits for material inspection, mechanical tests or radiographic examination. These are additional depending upon the requirements for each vessel. See also Clauses 180 to 193.

a. Full inspection during manufacture. The requirements are :—

(i) Approval of drawings.
(ii) Inspection when the shell plates are bent to the circular form, the ends pressed to shape, welding grooves formed, and the parts are assembled ready for welding.
(iii) Inspection when welding of the main seams is actually in progress.
(iv) Inspection when welding at the outside surface has been completed, and the inside surface has been prepared for welding. This examination will be required before the outside surface is 'dressed.'
(v) Inspection when the seams are 'dressed.'
(vi) Inspection when the openings are being prepared for branches, etc., and are being welded in.
(vii) Witnessing by inspector of hydraulic test.
(viii) Inspection of finished vessel.

b. Limited inspection during manufacture. The requirements are :—

(i) Approval of drawings.
(ii) Inspection when the shell plates are bent to the circular form, the ends pressed to shape, welding grooves formed and the parts are assembled ready for welding.
(iii) Witnessing by inspector of hydraulic test.
(iv) Inspection of finished vessel.

c. Minimum inspection. The requirements are :—

(i) Approval of drawings.
(ii) Witnessing by inspector of hydraulic test.
(iii) Inspection of finished vessel.

MECHANICAL TESTS OF WELDED SEAMS

22. For details see Clauses 194 to 196.

a. Full mechanical tests.

(i) Tensile test for joint.
(ii) Impact test for outer surface of shell.
(iii) Impact test for inner surface of shell.
(iv) Tensile test on 'all weld metal' specimen.
(v) Bend test, outer surface of weld in tension.
(vi) Bend test, inner surface of weld in tension.
(vii) Micro test.
(viii) Macro test.

b. Limited mechanical tests.

(i) Tensile test on 'all weld metal' specimen, except in the case of plates less than ½ in. in thickness or lap joints, when a tensile test on a joint test specimen may be substituted.
(ii) Bend test, outer surface of weld in tension.
(iii) Bend test, inner surface of weld in tension.
(iv) Nick break test.

c. Minimum mechanical tests.

(i) Bend test, outer surface of weld in tension.
(ii) Nick break test.

d. New developments. Light or medium duty vessels of materials or methods of construction not covered by the manufacturer's normal experience shall, at the discretion of the inspecting authority, be subject to the full mechanical tests required for severe duty vessels.

The following changes shall be regarded as constituting new developments :—

(i) Change of plate material to be welded.
(ii) Welding seam in plate of a greater or lesser thickness than previously carried out in similar material.
(iii) Change in type of plate preparation involving reduction in the amount of such preparation, i.e., change from double 'U' to single 'U' groove, or 'U' to 'V' type groove, etc.
(iv) Change in type of welded seams, i.e., double butt to single butt with backing strip, etc.
(v) Change in the amount of metal deposited per pass due, for instance, to unusual size of electrode or rate of feed.
(vi) Change of manufacturer of electrode, type or analysis of electrode or filler rod.

e. Research tests on welds are full investigation tests on new methods or new materials to determine their suitability for fusion welding.

RADIOGRAPHIC EXAMINATION

23. *a. Full radiographic tests.* All longitudinal and circumferential seams. (See also Clauses 197 to 207.)

b. Limited radiographic tests. Longitudinal seams only, in all the following cases :—

(i) When the plate thickness exceeds 1½ in.
(ii) When the vessel is to be used for vapours at a pressure in excess of 1000 lb/sq. in. or liquids the vapour pressure of which at the operating temperature is in excess of 1000 lb/sq. in.
(iii) When the material is one of the following and the working pressure exceeds 150 lb/sq. in. :—

All low and medium alloy steels having air hardening characteristics or a 'carbon equivalent' value greater than 0·48—0·06t. (See Clause 168.)

Austenitic stainless steels.

STRESS RELIEF

24. For details see Clauses 172 to 179.

a. All severe duty vessels, and those vessels having proportions within the hatched area of Fig. 4, shall be stress relieved, with the exception of vessels referred to in Clause 176.

b. All vessels constructed of the following materials, in all thicknesses shall be stress relieved by heat treatment after welding (see also notes to Tables 1a—f).

Type 200 low alloy steels.*

c. All vessels welded by gas flame should be normalized.

d. Vessels for service at sub-atmospheric temperatures shall be stress relieved by heat treatment, as required by Fig. 4. When the vessel is constructed of a material liable to embrittlement at the minimum operating temperature (see Table I) any portion of the vessel incorporating connections or access openings larger than 10 in. bore, or complicated support details, shall be stress relieved as a sub-assembly if the vessel is not subsequently stress relieved.

e. Under certain conditions it is possible for corrosion to be accelerated by conditions of high stress in the vessel wall and preferential corrosion may occur in the highly stressed zone adjacent to a weld joint not stress relieved. Caustic embrittlement in mild steel is an example of this phenomenon. It is recommended that all vessels subject to severe corrosion conditions, or for service with media likely to cause stress corrosion, should be stress relieved.

RECOMMENDED INSPECTION AND TESTS ACCORDING TO DUTY OF VESSEL

25. *a. Severe duty vessels.*

(i) Full inspection of materials.
(ii) Full inspection during manufacture.
(iii) Full mechanical tests.
(iv) Full radiographic tests.

b. Medium duty vessels.

(i) Limited inspection of materials.
(ii) Limited inspection during manufacture.
(iii) Limited mechanical tests.
(iv) Radiographic tests on longitudinal seams only, as required by Clause 23*b*.

* See B.S. 1501/1506, Steels for pressure vessels.

c. Light duty vessels.
(i) Minimum inspection of materials.
(ii) Minimum inspection during manufacture.
(iii) Minimum mechanical tests.
(iv) Radiographic tests on longitudinal seams only, as required by Clause 23*b*.

The 'Summary' given on page 3 covers the above requirements and also tabulates the various clauses dealing in detail with these requirements.

MINIMUM REQUIREMENTS

26. Clause 25 outlines the minimum requirements for any vessel, but the purchaser and/or the inspecting authority may, if they consider it desirable, specify inspection and testing requirements more stringent than those called for in Clause 25.

MINIMUM WEIGHT

27. The increased joint efficiency factors set out for vessels that are radiographed and/or stress relieved may be used in the design formulae when it is desired to reduce scantlings to the minimum, provided that either or both of these operations are carried out even though not normally required by this Code. (i.e., if it is desired to use the factor for a radiographed joint, then the main welded seams shall be radiographed).

Section Two : Materials and Working Stresses

A. MATERIALS

GENERAL

28. *a.* All materials used in the manufacture of pressure parts of pressure vessels constructed to this Code shall be in accordance with the appropriate material specifications referred to in this section.

b. Materials for which test certificates are not available may be used for supporting lugs and skirts, baffles and other similar non-pressure parts of a vessel constructed in accordance with this Code, provided that such material is otherwise suitable for the purpose.

MATERIALS FOR SERVICE AT SUB-ATMOSPHERIC TEMPERATURES

29. All materials intended for service at temperatures below 32°F. (0°C.) shall, when so noted in Table I, show a minimum impact test value of 20 foot pounds Izod at the lowest operating temperature of the vessel. Impact tests may be dispensed with on material having a ruling section greater than 2 in. (i.e., plates over approx. 1⅝ in. thick) or solely for internal parts such as baffles, heat exchanger tubes, etc., by agreement between purchaser, inspecting authority and manufacturer. Attention is drawn to the 'footnote' in the appropriate sections of Table I, which requires this information regarding impact tests to be given to the steelmaker at the time of the enquiry and/or order.

CONDITION OF MATERIAL

30. All non-ferrous materials shall preferably be supplied in the dead soft condition because of the annealing effect of the welding operation on the plate adjacent to the welded joints. By agreement between purchaser, inspecting authority and manufacturer, hardened materials may be used provided that the parts softened by the welding process are re-hardened to their original condition and are not liable to return to the soft state in subsequent service.

VESSELS CONSTRUCTED OF STANDARD PIPES AND TUBES

31. Vessels may be made of standard pipes and tubes, provided the working stresses given in Tables 1 and 2 are not exceeded, and the special joint efficiencies given in Clause 52 are used where applicable.

OTHER MATERIALS

32. The materials covered by this Code are considered to be specially representative of the requirements of the chemical engineering and allied industries, but nothing in this Code shall be construed to preclude the use of other suitable materials. In such cases the permissible working stresses shall be determined by agreement between purchaser, inspecting authority and manufacturer. The appropriate sections of the Code should be adhered to as far as practicable.

B. WORKING STRESSES

GENERAL

33. The working stresses in Tables 1 and 2 are maximum values to be used in conjunction with the formulae given in this Code and do not make any allowance for corrosion or the efficiency of welded joints or ligaments between openings. (See also Clause 37). If it is desired to keep a vessel in service after the corrosion allowance (see Clauses 40 to 42) has wasted away, the maximum allowable working pressure shall be reduced to ensure that the allowable working stress is not exceeded. (See also Clauses 228 to 246.)

a. Tensile stress. Basic allowable working stresses for suitable materials for the construction of fusion welded pressure vessels built in accordance with this Code, are given in Tables 1 and 2. (See Clause 32.)

b. Shear and bearing (or compressive) stresses. The maximum allowable shear or bearing stress shall not exceed the values given in Tables 1 and 2 multiplied by a factor taken from Table 7 below.

Table 7. Factors for shear and bearing stresses

	Factor	
	Shear	Bearing
Carbon and low alloy steels of less than 35 tons/sq. in. tensile	0·8	1·7
Carbon and low alloy steels 35 tons/sq. in. tensile and over	0·7	2·0
Austenitic stainless steels	0·7	1·4
Aluminium	0·75	1·35
Copper	0·7	1·25
Copper silicon	0·8	1·6
Yellow brass	0·75	1·6
Nickel	0·67	1·43
Nickel chromium iron	0·69	1·45
Nickel copper	0·8	1·4
Cast gunmetal	1·1	2·0

c. Planished vessels. The maximum allowable working stress for parts of vessels which are subjected to a planishing or cold working operation after welding shall be the subject of agreement between the purchaser, inspector and manufacturer. The inspector shall satisfy himself that the planishing or cold working operation has been properly carried out and the strength of the material increased to the desired degree, and that the conditions of service are such that softening of the material will not occur in service. Such vessels should be constructed to permit the planished portion to be removed and re-planished after repairs have been carried out by welding.

TABLE 1a. DESIGN STRESSES (TENSILE) FOR FERROUS PLATES, BARS AND SECTIONS

Material	*Reference B.S. number	Minimum ultimate tensile strength (tons/sq. in.)	Notes	Weld discount factor	Permissible design stresses at the design temperature of the metal (lb/sq. in.)														
					300°F. 149°C.	500°F. 260°C.	550°F. 288°C.	600°F. 315°C.	650°F. 342°C.	700°F. 371°C.	750°F. 399°C.	800°F. 427°C.	850°F. 454°C.	900°F. 482°C.	925°F. 495°C.	950°F. 510°C.	975°F. 523°C.	1 000°F. 538°C.	1 050°F. 566°C.	1 100°F. 593°C.	1 150°F. 620°C.	1 200°F. 649°C.
Carbon steel	1501–101	28	(1)	Nil	15 700	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	1501–151																				
	Grade A	24	(2) (3)	Nil	13 400	13 400	13 400	13 400	13 400	13 200	—	—	—	—	—	—	—	—	—	—	—
	Grade B	26	(2) (3)	Nil	14 500	14 500	14 500	14 500	14 500	14 200	—	—	—	—	—	—	—	—	—	—	—
	Grade C	28	(2) (3)	Nil	15 700	15 700	15 700	15 700	15 700	15 200	—	—	—	—	—	—	—	—	—	—	—
	1501–154																				
	Grade A	24	(3)	Nil	13 400	13 400	13 400	13 400	13 400	13 200	12 000	10 500	8 500	6 300	4 800	3 350	—	—	—	—	—
	Grade B	26	(3)	Nil	14 500	14 500	14 500	14 500	14 500	14 200	12 700	10 900	8 700	6 300	4 800	3 350	—	—	—	—	—
	Grade C	28	(3)	Nil	15 700	15 700	15 700	15 700	15 700	15 200	13 400	11 300	8 900	6 300	4 800	3 350	—	—	—	—	—
	1501–157																				
	Grade A	24	(2) (4)	Nil	13 400	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Grade B	26	(2) (4)	Nil	14 500	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Grade C	28	(2) (4)	Nil	15 700	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carbon manganese steel	1501–221	32	(5)	Nil	18 000	18 000	18 000	18 000	18 000	17 700	15 700	12 500	9 400	6 400	4 900	3 350	—	—	—	—	—
Carbon molybdenum steel	1501–240																				
	Grade A	27	(5)	Nil	15 100	15 100	15 100	15 100	15 100	15 100	15 100	14 600	13 800	13 000	12 200	9 000	5 200	3 800	—	—	—
	Grade B	33	(5)	0·05	18 500	18 500	18 500	18 500	18 500	18 100	17 500	16 800	16 200	14 500	12 600	8 700	4 700	3 000	—	—	—
13 per cent Chromium steel	1501–613	28	(4) (6)	0·10	15 700	15 700	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18/8 Chromium nickel steel, unstabilized	1501–801																				
	Grade A	35	(7)	See Note 7	19 600	19 600	19 600	19 500	19 100	18 700	—	—	—	—	—	—	—	—	—	—	—
	Grade B	35	(7)	See Note 7	19 600	19 600	19 600	19 500	19 100	18 700	—	—	—	—	—	—	—	—	—	—	—
18/8 Chromium nickel steel, stabilized	1501–821																				
	Grade A	35	(8)	Nil	19 600	19 600	19 600	19 500	19 100	18 700	18 300	17 900	17 500	16 700	16 300	15 700	15 000	14 000	11 600	8 800	5 000	2 250
	Grade B	35	(8)	Nil	19 600	19 600	19 600	19 500	19 100	18 700	18 300	17 900	17 500	16 700	16 300	15 700	15 000	14 000	11 600	8 800	5 000	2 250
18/10/3 Chromium nickel molybdenum steel, unstabiiized	1501–844	35	(7)	See Note 7	19 600	19 600	19 600	19 500	19 100	18 700	—	—	—	—	—	—	—	—	—	—	—
18/10/3 Chromium nickel molybdenum steel, stabilized	1501–845																				
	Grade A	35	(9)	Nil	19 600	19 600	19 600	19 500	19 100	18 700	—	—	—	—	—	—	—	—	—	—	—
	Grade B	35	(8)	Nil	19 600	19 600	19 600	19 500	19 100	18 700	18 300	17 900	17 500	16 700	16 300	15 700	15 000	14 000	11 600	8 800	5 000	2 250

The stress values are based on the Fahrenheit scale, centigrade equivalents are approximate.

Intermediate values may be obtained by linear interpolation.

NOTE 1. This material is suitable for the construction of Light Duty vessels only and is not recommended for service at temperatures below 50°F. (10°C.) except for applications where embrittlement would not be considered to create a hazard.

NOTE 2. Where a plain carbon steel is required for service at temperatures in excess of 700°F. (370°C.) it shall be ordered to specification B.S. 1501–154.

NOTE 3. Where a plain carbon steel is required for service at temperatures below 32°F. (0°C.) it shall be ordered to specification B.S. 1501–157.

NOTE 4. This material shall be subjected to Izod impact tests at the lowest operating temperature to which the vessel will be subjected in service. The steelmaker shall be advised of this requirement at the time of the enquiry and/or order (see Clause 29).

NOTE 5. As usually supplied this material may be brittle at sub-atmospheric temperatures. Whenever this material is to be used for service at temperatures below 32°F. (0°C.) Izod impact tests shall be carried out at the lowest temperature to which the vessel will be subjected in service. The steelmaker shall be advised of this requirement at the time of the enquiry and/or order (see Clause 29).

NOTE 6. There is insufficient data available to enable the committee to formulate reliable design stresses for these materials in the higher range of temperature. It is not, however, suggested that this material is unsuitable for service at elevated temperatures but it should be noted that it has a creep strength at temperatures in excess of 950°F. (510°C.) of the same order only as carbon steel.

NOTE 7. This material is essentially a corrosion resisting material and is extensively used for this purpose. It also possesses good resistance to scaling at elevated temperatures but is not recommended for service at temperatures in excess of 700°F. (370°C.). It is recommended that this material be welded in thin gauges only and the designer should consult with the steelmaker regarding its suitability for the proposed application.

NOTE 8. It is not considered that there is sufficient long term data available upon the properties of these materials at elevated temperatures to justify the inclusion of final values for design stresses. For the present, therefore, these figures and stresses have been based largely upon the values given in Table U-2 and paragraph U-200 of the A.S.M.E. Boiler Code Section VIII, Unfired Pressure Vessels, and are included for the guidance of users of this British Standard Code.

NOTE 9. This material is not recommended for service at temperatures in excess of 700°F. (370°C.).

* See B.S. 1501 Carbon and alloy steel plates, sections and bars for use in the chemical, petroleum and allied industries.

TABLE 1b. DESIGN STRESSES (TENSILE) FOR FERROUS FORGINGS

Material	*Reference B.S. number	Minimum ultimate tensile strength (tons/sq. in.)	Notes	Weld discount factor	Permissible design stresses at the design temperature of the metal (lb/sq. in.)														
					300°F. 149°C.	500°F. 260°C.	550°F. 288°C.	600°F. 315°C.	650°F. 342°C.	700°F. 371°C.	750°F. 399°C.	800°F. 427°C.	850°F. 454°C.	900°F. 482°C.	925°F. 495°C.	950°F. 510°C.	975°F. 523°C.	1 000°F. 538°C.	1 050°F. 566°C.	1 100°F. 593°C.	1 150°F. 620°C.	1 200°F. 649°C.
Carbon steel	1503-151																				
	Grade A	24	(1)	Nil	13 400	13 400	13 400	13 400	13 400	13 200	12 000	10 500	8 500	6 300	4 800	3 350	—	—	—	—	—	—
	Grade B	28	(1)	Nil	15 700	15 700	15 700	15 700	15 700	15 200	13 400	11 300	8 900	6 300	4 800	3 350	—	—	—	—	—	—
	Grade C	32	(1)	0·05	18 000	18 000	18 000	18 000	18 000	17 200	14 800	12 100	9 300	6 300	4 800	3 350	—	—	—	—	—	—
Carbon manganese steel	1503-221	32	(1)	Nil	18 000	18 000	18 000	18 000	18 000	17 700	15 700	12 500	9 400	6 400	4 900	3 350	—	—	—	—	—	—
Carbon molybdenum steel	1503-240																				
	Grade A	26	(1)	Nil	14 600	14 600	14 600	14 600	14 600	14 600	14 600	14 200	13 400	12 600	11 800	9 000	5 200	3 800	—	—	—	—
	Grade B	32	(1)	0·05	18 000	18 000	18 000	18 000	18 000	17 800	17 000	16 500	15 800	14 500	12 600	8 700	4 700	3 000	—	—	—	—
13 per cent Chromium steel	1503-613	38	(1) (2) (3)	0·20	21 300	21 300	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1¼ per cent Chromium molybdenum steel	1503-621	40	(1) (3)	0·10	22 400	22 400	22 400	22 400	22 400	22 400	22 400	21 000	18 000	12 750	8 500	5 500	3 600	2 200	—	—	—	—
3 per cent Chromium molybdenum steel	1503-623	38	(1) (3)	0·20	21 300	21 300	21 300	21 300	21 300	21 300	21 300	19 500	15 100	9 700	7 100	4 800	—	—	—	—	—	—
5 per cent Chromium molybdenum steel	1503-625	40	(1) (2) (3)	0·20	22 400	22 400	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18/8 Chromium nickel steel, unstabilized	1503-801																				
	Grade A	33	(4)	See Note 4	18 500	18 500	18 500	18 500	18 500	18 500	—	—	—	—	—	—	—	—	—	—	—	—
	Grade B	33	(4)	See Note 4	18 500	18 500	18 500	18 500	18 500	18 500	—	—	—	—	—	—	—	—	—	—	—	—
18/8 Chromium nickel steel, stabilized	1503-821																				
	Grade A	33	(5)	Nil	18 500	18 500	18 500	18 500	18 500	18 500	18 300	17 900	17 500	16 700	16 300	15 700	15 000	14 000	11 600	8 800	5 000	2 250
	Grade B	33	(5)	Nil	18 500	18 500	18 500	18 500	18 500	18 500	18 300	17 900	17 500	16 700	16 300	15 700	15 000	14 000	11 600	8 800	5 000	2 250
18/8/3 Chromium nickel molybdenum steel, unstabilized	1503-844	33	(4)	See Note 4	18 500	18 500	18 500	18 500	18 500	18 500	—	—	—	—	—	—	—	—	—	—	—	—
18/10/3 Chromium nickel molybdenum steel, stabilized	1503-845																				
	Grade A	33	(6)	Nil	18 500	18 500	18 500	18 500	18 500	18 500	—	—	—	—	—	—	—	—	—	—	—	—
	Grade B	33	(5)	Nil	18 500	18 500	18 500	18 500	18 500	18 500	18 300	17 900	17 500	16 700	16 300	15 700	15 000	14 000	11 600	8 800	5 000	2 250

The stress values are based on the Fahrenheit scale, centigrade equivalents are approximate.

Intermediate values may be obtained by linear interpolation.

NOTE 1. As usually supplied this material may be brittle at sub-atmospheric temperatures. Whenever this material is to be used for service at temperatures below 32°F. (0°C.) Izod impact tests shall be carried out at the lowest operating temperature to which the vessel will be subjected in service. The steelmaker shall be advised of this requirement at the time of the enquiry and/or order (see Clause 29).

NOTE 2. There is insufficient data available to enable reliable design stresses to be formulated for these materials in the higher range of temperature. It is not, however, suggested that these materials are unsuitable for service at elevated temperatures but it should be noted that they are, in general, inferior in creep strength to lower chromium molybdenum steels.

NOTE 3. The 'weld discount factors' given for these materials presuppose that an appropriate welding technique is adopted. The weld metal (as deposited) shall have a chemical composition similar to the parent metal, suitable preheating shall be used and the parts after welding shall be given a suitable heat treatment to produce the specified mechanical properties.

NOTE 4. This material is essentially a corrosion resisting material and is extensively used for this purpose. It also possesses good resistance to scaling at elevated temperatures but is not recommended for service at temperatures in excess of 700°F. (370°C.). It is recommended that this material be welded in thin sections only and the designer should consult with the steelmaker regarding its suitability for the proposed application.

NOTE 5. It is not considered that there is sufficient long term data available upon the properties of these materials at elevated temperatures to justify the inclusion of final values for design stresses. For the present, therefore, these figures and stresses have been based largely upon the values given in Table U-2 and paragraph U-200 of the A.S.M.E. Boiler Code Section VIII, Unfired Pressure Vessels, and are included for the guidance of the users of this British Standard Code.

NOTE 6. This material is not recommended for service at temperatures in excess of 700°F. (370°C.).

* See B.S. 1503 Carbon and alloy steel forgings for use in the chemical, petroleum and allied industries.