

Specification for

Tubular heat exchangers for general purposes

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Aluminium Development Association	Institute of Welding
Aluminium Industry Council	Institution of Chemical Engineers
British Non-ferrous Metals Research Association	Lloyds' Register of Shipping
Copper Development Association	National Forgemasters' Association
Council of British Manufacturers of Petroleum Equipment	Individual manufacturers

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Foreword

BS 24-5, *Copper*.

BS 378, *Solid drawn copper and copper alloy tubes for condensers, evaporators, heaters and coolers*.

BS 885, *Brass tubes for general purposes*.

BS 1133, *Packaging code*.

BS 1172-4, *Raw copper*.

BS 1306-2, *Seamless copper tubes for steam services*.

BS 1400, *Copper alloy ingots and castings*.

BS 1464, *Solid drawn copper alloy tubes for heat exchange equipment in the petroleum industry*.

BS 1470, *Wrought aluminium and aluminium alloys. Sheet and strip*.

BS 1471, *Wrought aluminium and aluminium alloys. Drawn tube*.

BS 1474, *Wrought aluminium and aluminium alloys. Extruded round tube and hollow sections*.

BS 1476, *Wrought aluminium and aluminium alloys. Bars, rods and sections*.

BS 1500, *Fusion-welded pressure vessels for use in the chemical, petroleum and allied industries — Part 1: Carbon and low-alloy steels*.

BS 1501-6, *Steels for use in the chemical, petroleum and allied industries*.

BS 1508, *Steel pipe and tube for pressure vessels*.

BS 1541, *Rolled brass and naval brass condenser tube plates*.

BS 1600-7, *Wrought steel pipe for the petroleum industry*.

BS 1627, *Cold drawn low carbon steel tubes for the petroleum industry*.

BS 1628, *Cold drawn alloy steel tubes for the petroleum industry*.

BS 1750, *Bolting for the petroleum industry*.

BS 1867, *Solid drawn aluminium bronze tubes for general purposes (7 per cent aluminium)*.

BS 1948, *Copper-silicon alloy rods, sections and forgings (for general engineering purposes)*.

BS 2017, *Copper tubes for general purposes*.

BS 2041, *Tubular heat exchangers for use in the petroleum industry*.

BS 3059-2, *Cold drawn seamless carbon steel tubes (20 tons minimum tensile strength)*.

BS 3059-10, *Cold drawn seamless 1 per cent chromium, $\frac{1}{2}$ per cent molybdenum steel boiler and superheater tubes*.

BS 3059-3, *Electrically welded carbon steel tubes (20 tons minimum tensile strength)*.

BS 3059-4, *Cold drawn electrically welded carbon steel tubes (20 tons minimum tensile strength)*.

BS 3059-13, *Electrically welded carbon steel tubes (27 tons minimum tensile strength)*.

BS 3072, *Nickel and nickel alloys: sheet*.

BS 3074, *Nickel and nickel alloys: tube*.

This British Standard has been prepared under the authority of the Mechanical Engineering Industry Standards Committee.

Heat exchangers are a specialized form of pressure vessel, and BS 1500, *“Fusion-welded pressure vessels”*, should be used in conjunction with this standard, unless otherwise specified. Since publication of this standard, BS 1515, *“Fusion-welded pressure vessels (advanced design and construction) for use in the chemical, petroleum and allied industries”* has been published. There is nothing in BS 3274 which precludes the use of BS 1515.

Acknowledgement is made to the Tubular Heat Exchanger Manufacturers' Association of America and also to the American Society of Mechanical Engineers for use of certain data.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 50 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Introduction

Many branches of industry are users of shell-and-tube heat exchangers for duties such as heating, cooling, evaporating and chemical reaction. The purpose of this standard is to specify the essential requirements and give guidance for the mechanical design and construction of such heat exchangers. This standard does not deal with the thermal design, but information on thermal requirements must, of course, pass between purchaser and manufacturer when an exchanger is to be designed for a specific duty.

The standard of the Tubular Heat Exchanger Manufacturers' Association (T.E.M.A.)¹⁾ is widely used, but like BS 2041, it was originally based on the requirements of the petroleum industry. The present standard deals more fully with the use of non-ferrous metals for construction and provides data on these materials. The range is extended to lower pressures, and lighter types of construction suitable for use when the more costly metals are involved. The range of ring flanges is extended, since these are at present the most commonly-used type in this country.

Pressure classes are as in T.E.M.A., with the addition of Class 20. The design pressure is related to a basic metal temperature. A reduction in the strength of the metal usually occurs with increase in temperature and stress tables have been provided for the more commonly used metals to enable the designer to design for the particular working temperature. This method has been preferred to supplying de-rating tables.

There are no comprehensive British tables of design stresses for non-ferrous metals and Committee CHE/19/-/7 which is considering this subject, has not yet published its findings. Also Committees CHE/19/-/3 and MEE/-/11 have not yet published stress tables for stainless steels. For all these materials the Committee has drawn largely upon the A.S.M.E. Boiler and Pressure Vessel Code (1959), Sec. VIII. The stress values given in this Code are for materials to American specifications, but the Committee has inserted the British Standards which are regarded as approximately equivalent from the point of view of design stresses. BS 1501–BS 1506 gives the British and American equivalents for stainless steels.

Where the evidence has indicated that design stresses should be selected which are other than those given in the A.S.M.E. Code, the stress tables are so marked, and a reference is given. In all cases the design stress has been derived from the fundamental data in accordance with the A.S.M.E. criteria, as follows:

The design stress is the lowest of the following, the tests being carried out at the temperature under consideration:

- 1) One-fourth of the minimum specified tensile strength;
- or 2) Two-thirds of the minimum specified yield strength;
- or 3) The stress producing a secondary creep of 0.1 per cent in 10 000 hours;
- or 4) Four-fifths of the stress producing rupture in 100 000 hours.

In this connection, the Committee has noted the work of Committee MEE/-/11, and their criteria for determining design stresses for steels of which yield points are not specified.

BS 1500 is employed as the basis of mechanical design for these heat exchangers, including the flanges. BS 1500 gives a method for designing flanges but does not give tables of standard flanges. Such tables for carbon steel ring flanges are incorporated in the present standard, and the standard flange thickness is in accordance with BS 1500. The T.E.M.A. thickness is also given, since this standard has been in use for so long, but these flanges would only be used if specified by the purchaser and recommended by the maker. For the other flange dimensions, where BS 1500 permits variation, T.E.M.A. dimensions have been used unless there is good reason for a change, in which case the change is noted. There is thus a good measure of interchangeability. Tables for welding-neck flanges (from T.E.M.A. tables) are also included, as although they are at present used in a minority of cases, their use is increasing.

It is appreciated that a wide range of heat exchangers is already in existence, and therefore many more sizes of tubes and shells have been listed than are desirable in a standard. Industry as a whole, should encourage the use of those sizes which are asterisked as being preferred, and eventually it should be possible to cut out the non-preferred sizes thus achieving a greater measure of standardization.

¹⁾ All references to the T.E.M.A. standard are to the third edition (1952).

Section 1. General

1 Scope

This British Standard applies to the mechanical design, construction, inspection and testing of cylindrical shell and plain tube heat exchangers for general applications.

a) *Types*. Typical examples of heat exchangers referred to in the standard are shown in Figure 1 to Figure 8.

Type 1. Fixed tube-plate (non-removable tube bundle), with or without expansion bellows (see Figure 1).

Type 2. U-tube (removable tube bundle) (see Figure 2 and Figure 3).

Type 3. Floating head (removable tube bundle):

- i) Internal with clamp ring (see Figure 4).
- ii) Internal without clamp ring (see Figure 5 and Figure 6).
- iii) External packed (see Figure 7).
- iv) Internal packed (see Figure 8).

b) *Size*. Requirements are specified for the design of heat exchangers from 6 in to 42 in nominal shell diameter and 6 ft to 16 ft tube lengths, with tube diameters from $\frac{1}{2}$ in to $1\frac{1}{2}$ in.

NOTE Attention is drawn to the data sheet (Appendix A) which shows a convenient form for interchange of information between purchaser and manufacturer, and to Appendix C which gives conversion factors from British to metric figures.

2 Nomenclature

a) The following nomenclature shall be used, the reference numbers corresponding to those on the typical designs illustrated in Figure 1 to Figure 8.

- | | |
|----------|---|
| Part No. | 1. Shell. |
| | 2. Shell cover. |
| | 3. Floating head cover. |
| | 4. Floating tube plate. |
| | 5. Clamp ring. |
| | 6. Fixed tube plate. |
| | 7. Channel ("end-box" or "header"). |
| | 8. Channel cover. |
| | 9. Branch. |
| | 10. Tie rod and spacer. |
| | 11. Cross baffle or tube support plate. |
| | 12. Impingement baffle. |
| | 13. Longitudinal baffle. |

- 14. Supporting bracket.
- 15. Floating head support.
- 16. Weir.
- 17. Split ring.
- 18. Tube (straight or "U").
- 19. Tube bundle.
- 20. Pass partition.
- 21. Floating head gland.
- 22. Floating head gland ring.
- 23. Vent connection.
- 24. Drain connection.
- 25. Test connection.
- 26. Expansion bellows.
- 27. Lifting ring.

b) The term "Tube bundle" (Item 19) includes Items 6, 10, 11, 12, 13 and 18 in Type 2 exchangers, with the addition of Item 4 in Type 3 exchangers.

3 Definitions

For the purposes of this standard the following definitions apply:

3.1 design pressure²⁾

the maximum pressure the heat exchanger is permitted to withstand in service

3.2 design temperature²⁾

the maximum temperature the heat exchanger is permitted to withstand in service

3.3 design stress

the maximum stress from all sources permitted for the materials of construction at the design temperature

²⁾ The design pressure and temperature shall be specified separately for the shell and tube sides. It is necessary to take into account all conditions of service, including start-up, shut-down and cleaning.

4 Pressure classification

Classified heat exchangers shall be designated separately on the shell and tube sides by the following pressure classifications. For pressures outside these classifications, or where the duty is such as to necessitate the use of costly materials, the heat exchangers may be designed to the specified duty requirements as agreed between purchaser and manufacturer. The pressures for each class are design pressures at a basic metal temperature of 600 °F (315 °C) for carbon and low-alloy steels and 250 °F (120 °C) for non-ferrous metals and stainless steels.

Class	lb/in ² (gauge)
20	20
75	75
150	150
300	300
450	450
600	600

When a standard heat exchanger is to be used at a temperature higher or lower than that given above for the particular material, the design pressure shall be determined from the stress figures in BS 1500 and Table 11 to Table 14 in this standard.

When the pressures on the two sides of the exchanger are different there shall be adequate safety precautions on the lower pressure side. Where there is a possibility of a vacuum being created, the exchanger shall be individually designed to withstand this vacuum, and shall be considered outside the pressure classification.

Section 2. Materials and stresses

5 Carbon and low alloy steels and cast iron

For carbon and low-alloy steels, materials and design stresses shall be as given in BS 1500, *"Fusion-welded pressure vessels for use in the chemical, petroleum and allied industries"*, Part 1, *"Carbon and low-alloy steels"*. For cast iron the design stress shall be 2 000 lb/in² up to a temperature of 400 °F (205 °C) and a pressure of 150 lb/in².

6 Non-ferrous metals and stainless steels

For commonly-used non-ferrous metals and stainless steels, the materials and design stresses are as follows:

Copper and copper alloys: Table 11.

Aluminium and aluminium alloys: Table 12.

Nickel and nickel alloys: Table 13.

Stainless steel: see A.S.M.E. Boiler and Pressure Vessel Code, Section VIII, with particular reference to the Winter 1965 addendum and any subsequent revisions.

NOTE *Derivation of stress tables.* The A.S.M.E. Code for unfired pressure vessels (1959), Section VIII, has been used for stresses given in Table 11 and Table 13 where British Standards for various metals are regarded as equivalent to A.S.T.M. Standards for this purpose. Where other values have been preferred, reference is made in the footnotes to the tables.

7 Other materials

Other materials having mechanical and corrosion-resisting properties appropriate to the specified service conditions may be substituted by agreement between purchaser and manufacturer.

8 Stress values for non-ferrous metals not in the annealed condition

a) When welding is done on a material having increased tensile strength produced by hot or cold working, the stress value for the material in the annealed or softened condition shall be used for the joint design.

b) When welding is done on material having increased tensile strength produced by heat treatment or when the metal has been heated for fabrication purposes, the stress value for the material in the annealed or softened condition shall be used.

9 Materials to comply with British Standards

If possible, all materials shall comply with the appropriate British Standard. If no appropriate British Standard exists for a particular material, the use of this material shall be the subject of agreement between the manufacturer, inspecting authority and purchaser.

10 Test certificates for materials

All materials used in the manufacture of pressure parts of heat exchangers constructed to this standard shall have available test certificates of chemical analysis and physical properties [see Clause 31 d) ii)]. Materials for which test certificates are not available may be used for supporting lugs, baffles, baffle spacers and other similar non-pressure parts.

11 Materials for use at low temperatures

Any carbon and low-alloy steel which is liable to embrittlement in service at temperatures below 32 °F (0 °C) shall be subject to the limitations specified in BS 1500. For the non-ferrous metals given in Table 11, Table 12 and Table 13 and for the austenitic stainless steels in Table 14, no additional requirements are necessary when they are to be used at temperatures down to – 325 °F (– 200 °C).

12 Gaskets

Compressed asbestos fibre, natural or synthetic rubber, metal-jacketed or solid metal gaskets shall be used for joints on heat exchangers unless suitable gasket materials having special mechanical and corrosion-resisting properties appropriate to the specified service conditions are substituted by agreement between manufacturer and purchaser. Gaskets shall be made in one piece.

13 Gland packing

Gland packing to Type 3 iii) external packed floating head exchangers, gland packing to floating head branches on single pass Type 3 i) exchangers, and packing used to seal longitudinal baffles on any exchanger, shall be carefully selected to suit the specified service conditions and agreed between purchaser and manufacturer.

Section 3. Construction

14 Design

Heat exchangers in carbon and low-alloy steels shall be designed in accordance with BS 1500 unless otherwise specified (e.g. Clauses 15 and 27). For non-ferrous metals and stainless steels, scantlings shall be determined by the principles laid down in BS 1500, using the stresses given in Table 11 to Table 14, unless otherwise agreed between the purchaser and manufacturer.

15 Fabrication

Heat exchangers in carbon and low-alloy steels shall be fabricated in accordance with BS 1500. It is intended that the fabrication of heat exchangers in non-ferrous metals and stainless steels should be in accordance with BS 1500, BS 1500-2, BS 1500-3 and BS 1500-4 (in course of preparation). Pending the publication of BS 1500, BS 1500-2, BS 1500-3 and BS 1500-4, the method of fabrication shall be the subject of agreement between purchaser and manufacturer.

a) The method of determining the weld joint efficiencies specified in BS 1500 applies to carbon and low alloy steels only. Pending further information it is recommended that the weld joint efficiencies should be the subject of agreement between purchaser and manufacturer, where other materials are used.

b) A weld joint efficiency of 70 per cent has been used with satisfactory results for welding non-ferrous metals. For the acceptance of higher joint efficiencies than this, these shall be based upon the performance of test plates.

16 Corrosion allowance

a) *Carbon steel pressure parts.* All carbon steel pressure parts, except tubes, shall have a minimum corrosion allowance of $\frac{1}{16}$ inch. If the conditions of service make a greater allowance advisable, such allowance shall be specified. For carbon steel tubes, a corrosion allowance is included in the minimum thicknesses shown in Table 2. Support plates shall have a corrosion allowance.

b) *Stainless steel, cast iron and non-ferrous pressure parts.* All stainless steel and non-ferrous pressure parts shall have no corrosion allowance unless the conditions of service make such allowance advisable, and it is specified by the purchaser. For cast iron an allowance of $\frac{1}{8}$ in shall be made on the calculated thickness.

c) *Tube plates and covers.* Where tube plates or flat external covers are grooved, the depth of the pass-partition grooves may be considered as available for corrosion allowance [see Clause 25 a) iii)].

d) *Non-pressure parts.* Non-pressure parts such as tie-rods, spacers, baffles, floating head clamping devices, floating head glands and gland rings, and internal bolting shall have no corrosion allowances unless otherwise agreed between purchaser and manufacturer.

e) *Electrolytic corrosion.* Due consideration shall be given to the selection of materials and to other anticorrosion measures when a heat exchanger is required to handle an electrolyte which would cause galvanic corrosion. The preventive measures taken shall be agreed between purchaser and manufacturer.

17 Type limitations

a) *Packed floating head exchangers.* Packed floating head exchangers, Type 3 iii) and 3 iv) shall not be used when the gland will be subject to a pressure in excess of 150 lb/in² nor for toxic nor highly inflammable fluids.

b) *Expansion devices.* An expansion device shall be fitted on exchangers of Type 1 when the combined stress due to pressure and thermal expansion exceeds the design stress of the material.

c) *Tube cleaning.*

i) U-tubes shall not be used except where the purchaser specifically indicates that his cleaning procedure will permit them.

ii) When external mechanical cleaning of tubes is necessary, a removable tube bundle shall be used and the tubes assembled on square pitch with a minimum design ligament of $\frac{1}{4}$ in [see also Clause 20 d)].

d) *Testing.* In selecting appropriate types of heat exchangers it is recommended that special attention should be paid to the requirements of hydraulic testing, particularly the testing of tubes and fixings. In particular, it is desirable that the tube-ends should be visible when the higher of the two test pressures is being applied (see Table 10).

18 Tolerances

a) *External dimensions.* Standard tolerances for the external dimensions of heat exchangers and for branch and support locations shall be as shown in Figure 9.

b) *Tube-plate, covers, flanges.* Standard tolerances for the dimensions of tube-plates, covers and flanges shall be as shown in Figure 10.

NOTE For other tolerances see Clauses 19 b), 20 c) and 22 c).

19 Shells and shell covers

a) *Shell diameters.* The following nominal internal diameters of heat exchanger shells, shell covers and channels shall be standard:

6³⁾, 8³⁾, 10³⁾, 12³⁾, 13, 15³⁾, 17³⁾, 19, 21³⁾, 23, 25³⁾, 27, 29³⁾, 31, 33³⁾, 35, 37³⁾, 39 and 42³⁾ inches.

³⁾ Preferred sizes.

b) *Diametral tolerances.*

i) At any section the minimum internal diameter shall be not less than the nominal internal diameter and the maximum internal diameter shall not exceed the value given in the following table:

Nominal internal diameter	Maximum plus tolerance
in	in
Up to 25	$\frac{1}{8}$
27 to 33	$\frac{3}{16}$
35 to 42	$\frac{1}{4}$

ii) Deviations from the nominal diameter of the shell shall be checked after the completion of all welding and stress-relieving.

iii) If the diameter of any branch in the shell exceeds 25 per cent of that of the shell, the tolerance on the shell internal diameter shall be agreed between purchaser and manufacturer.

c) *Method of manufacture.* Shells, shell covers, and channels may be rolled from plate, may be made from seamless or fusion-welded pipe, or cast. For carbon steel pipe shells BS 1604 gives satisfactory tolerances.

d) *Shell thickness.*

i) For Type 1 exchangers, no minimum thickness is specified.

ii) For Types 2 and 3 exchangers, where removable tube bundles are used, Table 1 gives the minimum thickness to provide the necessary stiffness and shape.

20 Tubes

a) *Tube length.* Standard overall lengths of straight tubes shall be:

6, 8, 12 and 16 ft

b) *Tube diameter and thickness.* Standard tube diameters and minimum nominal thicknesses for carbon steel and other metals shall be as given in Table 2.

c) *Tube standards.* Tubes shall comply with one of the following British Standards, unless otherwise agreed between purchaser and manufacturer:

BS 1508, *Steel pipe and tube for pressure vessels.*

NOTE For cold-drawn tubes only.

BS 1627, *Cold drawn low carbon steel tubes for the petroleum industry.*

BS 1628, *Cold drawn alloy steel tubes for the petroleum industry.*

BS 3059-2, *Cold drawn seamless carbon steel tubes (20 tons minimum tensile strength).*

BS 3059-10, *Cold drawn seamless 1 per cent chromium, $1/2$ per cent molybdenum steel boiler and superheater tubes.*

BS 3059-3, *Electrically welded carbon steel tubes (20 tons minimum tensile strength).*

BS 3059-4, *Cold drawn electrically welded carbon steel tubes (20 tons minimum tensile strength).*

BS 3059-13, *Electrically welded carbon steel boiler and superheater tubes (27 tons/in minimum tensile strength).*

BS 378, *Solid drawn copper and copper alloy tubes for condensers, evaporators, heaters and coolers.*

BS 1464, *Solid drawn copper alloy tubes for heat exchange equipment in the petroleum industry.*

BS 1471, *Wrought aluminium and aluminium alloys, drawn tube.*

BS 3074, *Nickel and nickel alloys: tube.*

NOTE Where necessary, tubes should be ordered to special tolerances, so that the maximum diametral clearances specified in Clause 21 c) ii) are not exceeded.

d) *Tube arrangements.* Tubes shall be laid out either on an equilateral triangular pitch or on a square pitch [see Clause 17 c) ii)].

e) *Tube pitch.* Tubes shall have a minimum design pitch of 1.25 times their nominal outside diameter [but see Clause 17 c) ii)].

The tube pitch shall be subject to the following tolerances:

For design pitches of $1\frac{1}{4}$ in and less: $\pm 1/32$ in.

For design pitches over $1\frac{1}{4}$ in: $\pm 1/16$ in.

Special consideration shall be given to the pitch of tubes and to tube-plate preparation when tubes are welded-in to the tube-plate.

f) *Tube-plate ligaments.* The tolerances on tube-plate design ligament widths shall be as follows:

For design ligaments under $1/4$ in wide: $\pm 1/32$ in.

For design ligaments $1/4$ in wide and over: $\pm 1/16$ in.

g) *Tube fixing.*

i) Where tubes are expanded into tube plates they shall be expanded to a depth equal to not more than 90 per cent of the tube plate thickness. Expansion shall not extend beyond the inner face of the tube plate [see Clause 21 f)].

ii) Where tubes are expanded the ends shall be in a condition to enable this work to be performed satisfactorily. Tubes in the fully work-hardened condition are not suitable for expanding unless the ends have been previously softened. For brass tubes it is recommended that the tubes should be supplied in the heat-treated condition so as to comply with the requirements of BS 378 or BS 1464, [see Clause 21 c) ii)].

iii) Where the tubes are welded into the tube plates, they shall first be lightly expanded. Welding without prior expanding may be carried out by agreement between purchaser and manufacturer. Since the heat-resisting properties of certain special alloys are impaired by cold working, these tubes should be welded without prior expansion. For these conditions, the method and details of welding shall be agreed between purchaser and manufacturer.

iv) The ends of the expanded tubes may be bell-mouthed if required by the purchaser.

v) Where tubes are fixed by expansion only, the ends shall not project beyond the face of the tube-plate by more than $3/16$ in.

vi) Where tubes are expanded into tube-plates it is recommended that some automatic device should be employed to restrict and control the torque applied and consequently the degree of thinning of the tube wall.

Table 1 — Minimum shell thickness

All dimensions in inches

1	2	3	4	5	6	7	8
Nominal internal dia.	Cast iron	Carbon steel (incl. corrosion allowance)	Copper and copper alloys	Aluminium and aluminium alloys	Aust. stainless steel	Nickel	Monel, inconel
6 ^a	3/8	3/16	1/8	3/16	1/8	1/8	1/8
8 ^a	3/8	1/4	1/8	3/16	1/8	1/8	1/8
10 ^a	3/8	1/4	1/8	3/16	1/8	1/8	1/8
12 ^a	1/2	1/4	1/8	3/16	1/8	1/8	1/8
13	1/2	1/4	3/16	3/16	1/8	3/16	1/8
15 ^a	1/2	1/4	3/16	1/4	1/8	3/16	1/8
17 ^a	1/2	1/4	3/16	1/4	1/8	3/16	1/8
19	1/2	5/16	1/4	1/4	1/8	1/4	1/8
21 ^a	5/8	5/16	1/4	5/16	1/8	1/4	1/8
23	5/8	5/16	1/4	5/16	1/8	1/4	1/8
25 ^a	5/8	3/8	5/16	3/8	3/16	5/16	3/16
27	5/8	3/8	5/16	3/8	3/16	5/16	3/16
29 ^a	5/8	3/8	5/16	3/8	3/16	5/16	3/16
31	5/8	3/8	3/8	3/8	1/4	3/8	1/4
33 ^a	5/8	3/8	3/8	7/16	1/4	3/8	1/4
35	5/8	3/8	3/8	7/16	1/4	3/8	1/4
37 ^a	3/4	3/8	7/16	7/16	1/4	7/16	1/4
39	3/4	3/8	7/16	1/2	1/4	7/16	1/4
42 ^a	7/8	7/16	7/16	1/2	1/4	7/16	1/4

^a Preferred sizes.

Table 2 — Standard tube diameters and minimum nominal thicknesses

Minimum nominal thicknesses

Nominal outside diameter	Carbon and low alloy steels ^b	Copper and copper alloys	Aluminium and aluminium alloys	Austenitic stainless steel, nickel, monel, inconel
in	in	in	in	in
1/2	0.064 (16 S.W.G.)	0.036 (20 S.W.G.)	0.048 (18 S.W.G.)	0.036 (20 S.W.G.)
5/8	0.064 (16 S.W.G.)	0.048 (18 S.W.G.)	0.064 (16 S.W.G.)	0.048 (18 S.W.G.)
3/4 ^a	0.064 (16 S.W.G.)	0.048 (18 S.W.G.)	0.064 (16 S.W.G.)	0.048 (18 S.W.G.)
1 ^a	0.080 (14 S.W.G.)	0.064 (16 S.W.G.)	0.080 (14 S.W.G.)	0.064 (16 S.W.G.)
1 1/4	0.104 (12 S.W.G.)	0.080 (14 S.W.G.)	0.104 (12 S.W.G.)	0.080 (14 S.W.G.)
1 1/2	0.128 (10 S.W.G.)	0.104 (12 S.W.G.)	0.128 (10 S.W.G.)	0.080 (14 S.W.G.)

NOTE Special consideration may be given to wall thicknesses of tubes in special materials.

^a Preferred nominal outside diameter.^b Thicknesses for carbon steel tubes include a corrosion allowance.

21 Tube plates

a) *Minimum tube plate thickness.* The thickness of tube-plates, where tubes are expanded, shall be not less than those in Table 3.

Table 3 — Minimum tube-plate thickness

Tube outside diameter	Minimum thickness
in	in
$\frac{1}{2}$	$\frac{1}{2}$
$\frac{5}{8}$	$\frac{1}{2}$
$\frac{3}{4}$ ^a	$\frac{9}{16}$
1 ^a	$\frac{3}{4}$
$1\frac{1}{4}$	$\frac{7}{8}$
$1\frac{1}{2}$	1
^a Preferred sizes.	

b) *Calculation of tube-plate thickness.* The thickness of tube-plates shall be calculated in accordance with BS 1500, "Fusion-welded pressure vessels".

c) *Tube holes in tube-plates.*

i) Tube holes in tube-plates shall be machined to the following dimensions in Table 4.

Table 4 — Tube hole tolerances

Specified tube outside diameter	Diameter of tube hole (standard fit)
in	in in
$\frac{1}{2}$	0.508 ± 0.002
$\frac{5}{8}$	0.633 ± 0.002
$\frac{3}{4}$	0.760 ± 0.002
1	1.010 ± 0.002
$1\frac{1}{4}$	1.265 ± 0.002
$1\frac{1}{2}$	1.518 ± 0.003

ii) Where special precautions must be taken to avoid unnecessary working of tube ends during expansion, which might lead to stress corrosion, e.g. for stainless steel, the tube shall be fitted to the hole with the maximum clearance given in Table 5 [see Clause 20 e)].

d) The inside edges of tube holes shall be slightly chamfered after drilling and reaming to remove burrs and prevent cutting of the tubes.

Table 5 — Special tube and hole clearance

Specified tube outside diameter	Maximum diametral clearance
in	in
$\frac{3}{4}$	0.008
1	0.010
$1\frac{1}{4}$	0.011
$1\frac{1}{2}$	0.014

e) Where specified, tube holes shall have two anchor grooves, approximately $\frac{1}{8}$ in wide and $\frac{1}{64}$ in deep. These shall be obligatory for pressures of 300 lb/in² and over and for temperatures of 350 °F and over. Where anchor grooves are used the minimum tube-plate thickness specified in Table 3 may be increased accordingly.

By agreement between purchaser and manufacturer, an exception may be made in the case of materials of the type referred to in Clause 21 c) ii). In such cases seal-welding may be used as an alternative.

f) Where tube holes in thick tube-plates are clearance counterbored, the available seat width for tube expanding shall be not less than the outside diameter of the tubes [see Clause 20 g) i)]. The minimum ligament after counterboring shall be in accordance with Clause 20 f).

g) Tube-plates shall be machined on all gasket seating surfaces. It is preferable that, where possible, this should be done after any welding.

h) Tube-plates used in conjunction with cast iron shell flanges or cast iron internal floating head flanges shall extend to the outside diameter of such flanges, and full face gaskets shall be used on both sides [see Clause 24 a) ii)].

j) Where holes are drilled in tube-plates for the tie-rods and spacer supports, they shall be blind.

k) Means, e.g. jack screws, shall be provided for breaking the joints between tube-plates and shell flanges in exchangers of Types 2 and 3.

Special attention shall be paid to the material for the jack screws and similar devices to avoid seizure.

l) For design pressures of 300 lb/in² and above and also for tongued and grooved channel joints, pass-partition grooves are required and shall be $\frac{3}{16}$ in deep.

m) For bonnet-type channels combined with non-welded tube plates (see Figure 2) it is recommended that sufficient collar-bolts be used to prevent the joint between the fixed tube-plate and the shell being broken when the channel is removed.

22 Baffles and support plates

a) *General.* Removable tube bundles shall be checked for truth by fitting in the shell at two positions 180° apart.

b) *Types and baffles.* Transverse baffles shall be standard and, in horizontal heat exchangers, they shall be arranged so that the flow is from side to side unless otherwise specified. Where it is necessary for the flow to be up and down provision shall be made for drainage. Longitudinal baffles may be used provided special attention is given to the sealing between baffle and shell (see Clause 13).

c) *Baffle dimensions.* The diameters of baffles and tube support plates, for both plate and pipe shells, shall be in accordance with Table 6, where D = the nominal internal diameter of the shell for plate shells, and where D = the measured internal diameter of the shell for pipe shells, in inches. Smaller clearances may be required for special purposes, and shall be the subject of agreement between purchaser and manufacturer.

Table 6 — Baffle dimensions

Nominal diameter of internal shell	Diameter of baffles and tube support plates	
	Diameter	Tolerance
in	in	in
Pipe shells	$D - 1/16$	$\pm 1/32$
6–25	$D - 1/8$	+ 0
Plate shells		$- 1/32$
27–42	$D - 3/16$	+ 0
		$- 1/16$

d) *Tube holes in baffles.*

- i) Tube holes in transverse baffles and in support plates shall be drilled not more than $1/32$ in larger than the nominal outside diameter of the tubes.
- ii) All burrs shall be removed from the tube holes.

e) *Spacing.*

- i) *Baffles.* Transverse baffles shall not be pitched closer than 2 in or one-fifth of the shell internal diameter, whichever is the greater.
- ii) *Support plates.* Tube support plates shall be so spaced that the unsupported tube length shall be not greater than the following:
 - 36 in for $1/2$ in outside diameter tubes.
 - 42 in for $5/8$ in outside diameter tubes.
 - 52 in for $3/8$ in outside diameter tubes.
 - 60 tube diameters for 1 in outside diameter tubes or larger.
- iii) *Baffles used as support plates.* When baffles are used as support plates they shall be pitched so that the length of unsupported tube does not exceed the figures given in ii) above.

f) *Thickness.* The thickness of transverse baffles and tube support plates shall not be less than the values given in Table 7 unless by special agreement between purchaser and manufacturer for heat exchangers fabricated from materials other than carbon steel.

Special consideration shall be given to the strength and spacing of transverse baffles and support plates where there is a pulsating flow on the shell side.

Table 7 — Baffle and support plate thickness

Nominal shell internal diameter	Unsupported tube length of			
	24 in and under	Over 24 to 36 in incl.	Over 36 to 48 in incl.	Over 48 to 60 in incl.
	Minimum plate thickness			
in	in	in	in	in
6–15	$1/8$	$3/16$	$1/4$	$3/8$
15–27	$3/16$	$1/4$	$3/8$	$3/8$
29–37	$1/4$	$5/16$	$3/8$	$1/2$
39–42	$1/4$	$3/8$	$1/2$	$5/8$

g) *Tie rods and spacers.*

- i) Tie rods and spacers or other equivalent devices shall be provided to retain all transverse baffles and tube support plates accurately in position and shall be of a material similar to that of the baffles.
- ii) The number and diameter of tie rods shall be not less than specified in Table 8.

Table 8 — Tie rods

Nominal internal diameter of shell	Minimum tie rod diameter	Minimum number of tie rods
in	in	in
15 and under	$3/8$	4
17–27	$3/8$	6
29–33	$1/2$	6
35–42	$1/2$	8

h) *Impingement baffles.*

- i) Impingement baffles to protect the tube bundle shall be provided as required by service conditions.
- ii) The flow area between the impingement baffle and adjacent parts of the heat exchanger shell shall be not less than the area of the associated inlet branch.

j) *Longitudinal sealing strips.* Longitudinal sealing strips shall be incorporated where necessary to minimize by-passing around the bundle.

k) *Slide rails.* Slide rails shall be included in the design to support and locate the tube bundle in the re-boiler type of heat exchanger.

23 Floating heads

a) *Internal floating heads.*

- i) Internal floating heads shall be designed to permit withdrawal of the tube bundle from the fixed tube-plate end of the exchanger. The design of the floating head cover backing device (if any) shall be determined by agreement between purchaser and manufacturer.

ii) Special attention shall be given to the support of the internal floating head independently of the shell cover.

iii) Provision shall be made for easy access to the internal floating head cover bolting without removing the tube bundle. This does not apply to the re-boiler type of heat exchanger (Figure 6).

iv) If provision is required for refitting shortened tubes, the purchaser shall specify this in his enquiry.

b) *Packed floating heads.*

i) Packed floating heads shall be designed to permit withdrawal of the tube bundle from the fixed tube-plate end of the exchanger. The design of the floating head cover backing device (if any) shall be determined by agreement between purchaser and manufacturer.

ii) The design of the gland and gland ring and the selection of packing material used shall be determined by agreement between purchaser and manufacturer.

24 Gaskets

a) *Size.*

i) The minimum width of peripheral and pass partition gaskets, whether confined or otherwise, shall be $\frac{3}{8}$ in.

ii) Gaskets, used where either or both flanges are of cast iron, shall extend to the full face of the flanges.

b) *Continuity.*

i) Compressed asbestos or other composition gaskets, shall be of one-piece construction throughout.

ii) Metal-jacketed or solid metal gaskets shall have no break in continuity of the metal in contact with the flange surfaces to be sealed, and, where practicable, any joint or gap shall be on the external periphery (see Clause 12 for gasket materials).

25 Channels and channel covers

a) *Types.* Channels may be of either fabricated or cast construction and may be of the one-piece "bonnet" type or of the "bobbin" type with a separable bolted cover. For a typical "bonnet" type channel, see Figure 2 and for a typical "bobbin" type channel, see Figure 4.

b) *Diameter.* The diameter of channels shall be as specified in Clause 19 a).

c) *Thickness.* The minimum thickness of channels shall be as specified in Clause 19 d).

d) i) The minimum thickness of pass partitions shall be not less than $\frac{3}{8}$ in.

ii) Pass partition plates thicker than $\frac{3}{8}$ in may be tapered down to the width of the gasket (see Clause 24).

e) *Channel covers.*

i) The thickness of dished ends of bonnet type channels shall not be less than the thickness of the channel.

ii) Although the thickness of flat channel covers is calculated in accordance with BS 1500, as specified in Clause 14, special consideration shall be given to the need for adequate stiffness in the cover to ensure adequate sealing of pass partition plates.

iii) Where pass partition grooves are required, they shall be $\frac{3}{16}$ in deep [see Clause 16 c)].

26 Branches and connexions

a) All branches and connexions shall comply with the requirements of BS 1500.

b) Branches on shells, shell covers and channels shall either be integral or welded thereto. Branches attached by welding may be made from tube of adequate wall thickness, may be forgings or may be rolled from plate of the required thickness with welded seams.

c) Radially arranged branches shall be provided unless otherwise agreed between purchaser and manufacturer.

d) All flanges on branches shall conform to the appropriate British Standard for pipe flanges to suit the temperature and pressure required, unless otherwise specified.

e) One drain and one vent connexion shall be provided on the shell side and a similar set provided on the tube side of each section, except where several sections are arranged in a vertical stack and complete drainage is provided by this means. Adequate pressure and temperature connexions shall be provided on both the shell and tube sides. Other connexions such as test or sampling points, safety valves, etc. shall be provided as required by the purchaser or by statutory regulations.

f) The use of screwed connexions shall be limited to a maximum of 1 inch nominal bore of pipe. Tapped bosses shall be forged and shall have a wall thickness not less than $\frac{1}{4}$ inch.

g) It is recommended that connexions for instruments should have a nominal bore of 1 inch.

27 Shell flanges

a) All main flanges for shells, shell covers and channels shall be of the ring type, loose backing ring type or welding-neck type, and may be cut from plate, formed from bar, forged or cast, but welding-neck type flanges shall preferably not be machined from plate.

b) Dimensions of flanges shall be in accordance with Table 15A, Table 15B, Table 15C, Table 15D, Table 15E, Table 15F, Table 15G, Table 15H, Table 15J, Table 15K and Table 15L.

NOTE In a few cases in Table 15A, Table 15B and Table 15C, BS 1500 has not been strictly followed, inasmuch as the chordal distance between bolts exceeds 5d, but this is not regarded as significant.

c) It is recommended that Class 75 flanges be used for Class 20 heat exchangers (see Clause 4).

d) Any flanged joint in which either or both flanges are of cast iron shall be flat faced for gaskets which shall extend over the full face of the flange [see Clause 24 a) ii)].

iv) Test pressure, shell.....lb/in² (gauge)
tubes.....lb/in² (gauge)

v) The letters SR if stress-relieved.

vi) The letters XR if completely radiographed.

vii) The number of this British Standard, i.e. BS 3274^a.

viii) Any additional information as mutually agreed between purchaser and manufacturer.

^a The mark, BS 3274, on the product is an indication by the manufacturer that the goods purport to comply with the requirements of the British Standard.

c) The shell cover, floating head cover and channel shall be clearly marked on the edges of the flanges with the serial number of the heat exchanger.

The position of collar-bolts shall be indicated by stamping the letter "C" on the edges of the flanges adjacent to each collar-bolt.



28 Bolting

Internal flange bolting shall have UNC threads and shall be in accordance with BS 1750, "*Bolting for the petroleum industry*", unless otherwise specified by the purchaser. The material shall be Grade B7 for the bolts or studs and Grade 2H for the nuts.

d) For exchangers with removable tube bundles the stationary tube plate shall be marked on its edge so as to indicate its correct orientation in the shell.

Section 4. Inspection, marking, testing and preparation for despatch

29 Inspection

The purchaser shall have the right to inspect at any reasonable time the fabrication at any stage and to reject any parts which do not comply with this standard.

30 Marking

a) The manufacturer shall provide a nameplate in a suitable corrosion-resistant material, securely attached to the heat exchanger in an accessible position.

Where the exchanger is to be lagged, the nameplate shall be mounted so that it will not be obscured by the lagging.

b) The nameplate shall indicate:

- i) Manufacturer's name.
- ii) Manufacturer's serial number.
- iii) Design pressure, shell.....lb/in² (gauge)
at.....°F
tubes.....lb/in² (gauge)
at.....°F

31 Hydraulic testing

a) *General.*

i) Each part of a completed heat exchanger shall be hydraulically tested at room temperature at the manufacturer's works to the appropriate pressure specified in Table 9 in the manner specified in BS 1500:

Table 9 — Test pressures

Class	Test pressure lb/in ²
20	40
75	150
150	225
300	450
450	675
600	900

Fresh water shall be the standard fluid for hydraulic testing. Other liquids may be used as agreed between purchaser and inspecting authority.

ii) Exchangers shall be tested using the service gaskets to permit the exchanger leaving the manufacturer's in the "as tested" condition. Special gaskets may be used for testing purposes as agreed between purchaser and manufacturer providing they are of the same general type as the service gaskets.

b) *Hydraulic test.*

i) Table 10 specifies the minimum testing requirements for the basic types of exchangers illustrated in Figure 1 to Figure 8. It gives tests for each type of exchanger which are to be carried out in the order shown, the first test for each type being the primary test which includes checking soundness of tube to tube plate fixing.

NOTE Where it is necessary to use test rings this is indicated in the table by the symbol "O". The main components of a heat exchanger which are not required during a particular test are indicated by the symbol "X". All other parts are assembled

ii) For other types of exchangers not fully covered by Figure 1 to Figure 8, testing shall be carried out in a similar manner to Table 10 as agreed with the purchaser.

iii) For complete inspection of all joints (bolted, welded, etc.) it is sometimes necessary, depending on design, to test components of the heat exchanger before final assembly. To facilitate this, suitable gland rings and clamp rings may be necessary.

iv) The manufacturer, if he so wishes, may incorporate additional test rings to those referred for inspection and testing as agreed between purchaser and manufacturer. This includes the use of special test shells where numbers of identical units are involved.

c) *Conditions of test.* (The numbers refer to Table 10, Column 2.)

1. The procedure given is only for the case where the tube-side test pressure is equal to or in excess of shell-side test pressure.

2. The procedure given is only for the case where the shell-side test pressure is equal to or in excess of tube-side.

3. There is no limitation on which side of the exchanger has the higher pressure.

4. This is an alternative test procedure for Figure 4 and Figure 5 where tube-side test pressure is equal to or in excess of shell-side test pressure.

d) *Test certificates.*

i) *Hydraulic test certificate.* The manufacturer shall supply to the purchaser a certificate stating that the exchanger complies in all respects with this British Standard, and that it has passed the hydraulic test specified in this clause.

ii) *Material test certificate.* In cases where the purchaser requires a more detailed certificate, including materials of construction, he shall specify this. A typical form of such a certificate is given in Appendix B (see Clause 10).

32 Preparation for despatch

After hydraulic testing all parts of the exchanger shall be dried out completely. All external ferrous parts, other than stainless steels, shall be painted or treated with temporary corrosion preventive.

Attention is drawn to BS 1133, "*Packaging code*", Section 6.