Indian Standard
SPECIFICATION FOR SHELL AND TUBE TYPE HEAT EXCHANGERS

Chemical Engineering Sectional Committee, EDC 57

Chairman	*Representing*
DR A. NAGARAJA RAO	Planning Commission
Members	
SHRI J. D. ADHIA	Hindustan Organic Chemicals Ltd, Bombay
DR ASGHAR HUSAIN	Regional Research Laboratory (CSIR), Hyderabad
SHRI K. SESHACHARYULU (*Alternate*)	
SHRI J. M. AYAN DUTT	Indian Institute of Chemical Engineers, Calcutta
DR D. C. TAPADAR (*Alternate*)	
SHRI H. N. BANERJEA	Associated Cement Companies Ltd, Bombay
DR V. C. THAKAR (*Alternate*)	
SHRI N. N. BANERJEE	Gansons Private Ltd, Bombay
DR R. KRISHNASWAMY (*Alternate*)	
SHRI S. D. BHASIN	Imperial Chemical Industries (India) Private Ltd, Calcutta
SHRI P. K. BHATTACHARYA (*Alternate*)	
SHRI P. K. CHAKRAVARTY	Directorate General of Supplies & Disposals (Ministry of Supply, Technical Development & Materials Planning)
SHRI K. S. CHARI	Central Design & Engineering Unit (CSIR), New Delhi
SHRI G. CODD	Lloyd's Register of Shipping, Bombay
SHRI A. KILPATRICK (*Alternate*)	
SHRI FRANCIS RAYMOND CRUZ	Chemida (India), Bombay
SHRI T. K. RAO (*Alternate*)	
SHRI S. C. DASGUPTA	Directorate General of Ordnance Factories (Ministry of Defence), Calcutta
SHRI C. S. GOURISHANKARAN (*Alternate*)	
SHRI H. P DESAI	Esso Standard Refining Co of India Ltd, Bombay
SHRI V. H. PANDYA (*Alternate*)	
SHRI R. S. KACHWAHA	The Fertilizer Corporation of India Ltd, New Delhi
SHRI H. H. JETHANANDANI (*Alternate*)	
PROF N. R. KAMATH	Indian Institute of Technology, Bombay
SHRI K. A. NAIK (*Alternate*)	
SHRI J. P. KAPUR	Indian Chemical Manufacturers Association, Calcutta
DR R. K. GUPTA (*Alternate*)	

(*Continued on page* 2)

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

(*Continued from page* 1)

Members	*Representing*
DR O. P. KHARBANDA	Larsen & Toubro Ltd, Bombay
SHRI D. L. PRADHAN (*Alternate*)	
DR M. G. KRISHNA	Indian Institute of Petroleum (CSIR), Dehra Dun
DR J. S. AHLUWALIA (*Alternate*)	
PROF N. R. KULOOR	Indian Institute of Science, Bangalore
DR D. S. VISWANATH (*Alternate*)	
SHRI B. B. MATHUR	The Delhi Cloth & General Mills Co Ltd, Delhi
SHRI K. C. MOHAN	Hindustan Steel Ltd, Ranchi
SHRI J. P. MUKHERJEE	Walchandnagar Industries Ltd, Walchandnagar, District Poona
DR R. S. DUBEY (*Alternate*)	
DR M. U. PAI	National Chemical Laboratory (CSIR), Poona
SHRI R. V. KULKARNI (*Alternate*)	
SHRI R. PRABHAKAR	Tata Chemicals Ltd, Mithapur
SHRI A. P. NARAYANAN (*Alternate*)	
DR M. N. RAO	Indian Institute of Technology, Kharagpur
SHRI V. M. RAO	The K. C. P. Ltd, Madras
SHRI K. SATYANARAYANA (*Alternate*)	
SHRI T. L. SANKARAN	Indian Refineries Ltd, New Delhi
SHRI M. T. SHAH	Indo-Berolina Industries Private Ltd, Bombay
SHRI P. V. S. NAMBOOTHIRIPAD (*Alternate*)	
SHRI P. C. SILAICHIA	Burmah-Shell Refineries Ltd, Bombay
SHRI J. B. MALIK (*Alternate*)	
SHRI S. P. SINGH	Directorate General of Technical Development, Department of Technical Development (Ministry of Supply, Technical Development & Materials Planning)
SHRI P. K. SESHAN (*Alternate*)	
SHRI N. THANDAVAN	The A. P. V. Engineering Co Private Ltd, Calcutta
SHRI J. G. BROWN (*Alternate*)	
SHRI S. D. TIRUMULA RAO	Oil Technological Research Institute, Anantpur (A. P.)
SHRI B. A. R. SOMAYAJULU (*Alternate*)	
SHRI M. V. PATANKAR, Director (Mech Engg)	Director General, ISI (*Ex-officio Member*)

Secretary

SHRI M. G. KRISHNA RAO
Deputy Director (Mech Engg), ISI

Heat Generation and Heat Transfer Equipment Subcommittee, EDC 57 : 3

Convener	
DR O. P. KHARBANDA	Larsen and Toubro Ltd, Bombay
Members	
SHRI J. M. AYAN DUTT	Indian Institute of Chemical Engineers, Calcutta
DR D. C. TAPADAR (*Alternate*)	
SHRI K. S. BIST	Teksons Private Ltd, Bombay

(*Continued on page* 66)

CONTENTS

Indian Standard

SPECIFICATION FOR SHELL AND TUBE TYPE HEAT EXCHANGERS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 27 September 1967, after the draft finalized by the Chemical Engineering Sectional Committee had been approved by the Mechanical Engineering Division Council.

0.2 Shell and tube type heat exchangers are widely used in many branches of industry for duties such as heating, cooling, evaporating chemical reaction. This specification lays down the essential requirements and gives guidance for the design and construction of such heat exchangers.

0.3 The design requirements given in this specification are based on those given in IS : 2825-1969*.

0.4 A typical heat exchanger data sheet has been given in Appendix A.

0.5 The following data have been tabulated in Appendix B for various materials at different temperatures:

a) Thermal conductivity of metals,
b) Mean coefficient of thermal expansion, and
c) Modulus of elasticity.

0.6 In the preparation of this standard considerable assistance has been derived from the following:

B.S. 2041 : 1953 Tubular heat exchangers for use in the petroleum industry. British Standards Institution.

B.S. 3274 : 1960 Tubular heat exchangers for general purposes. British Standards Institution.

TEMA Standards Section 5 and 6 : 1959. Tubular Exchanger Manufacturers' Association, USA.

0.7 This edition 1.3 incorporates Amendment No. 3 (July 1983). Side bar indicates modification of the text as the result of incorporation of the amendment. Amendment Nos. 1 & 2 had been incorporated earlier.

0.8 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated,

*Code for unfired pressure vessels.

expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

SECTION 1 GENERAL

1. SCOPE

1.1 This specification covers the design, construction, inspection and testing of cylindrical shell and plain tube heat exchangers for application in the petroleum and general chemical industry. Both the requirements of the industries where the operating conditions are not severe or where costlier materials of construction are used as well as the more severe requirements of the petroleum and chemical processing industries are covered.

2. TYPES AND NOMENCLATURE

2.1 TYPES — Shell and tube type heat exchangers may be broadly classified into three types:

a) Fixed tube plate — non-removable tube bundle — (*see* Fig. 1).
b) U-tube — removable tube bundle — (*see* Fig. 2 and 3).
c) Floating head — removable tube bundle — (*see* Fig. 4 to 7).

These with subdivisions, give the following seven designs:

1) Fixed tube plate (*see* Fig. 1),
2) U-tube (*see* Fig. 2),
3) U-tube reboiler or kettle (*see* Fig. 3),
4) Internal floating head (pull through type) (*see* Fig. 4),
5) Internal floating head (non-pull through type) (*see* Fig. 5),
6) Internal floating head (reboiler or kettle) (*see* Fig. 6), and
7) Floating head external packed (*see* Fig. 7).

In a shell and tube type heat exchanger, one end will have a stationary tube sheet called the stationary head and at the other end, the tube plate may be stationary or floating (rear end). Typical designs of stationary and floating heads are given in Fig. 8.

*Rules for rounding off numerical values (*revised*).

2.2 Nomenclature — For the purpose of this specification the different parts of a heat exchanger shall be designated in accordance with the following table. They are numbered for identification in Fig. 1 to 7:

1. Shell
2. Shell cover
3. Shell flange (channel end)
4. Shell flange (cover end)
5. Shell nozzle or branch
6. Floating tube sheet
7. Floating head cover
8. Floating head flange
9. Floating head gland
10. Floating head backing ring
11. Stationary tube sheet
12. Channel or stationary head
13. Channel cover
14. Channel nozzle or branch
15. Tube (straight)
16. Tubes (U-type)
17. Tie rods and spacers
18. Transverse (or cross) baffles or support plates
19. Longitudinal baffles
20. Impingement baffles
21. Floating head support
22. Pass partition
23. Vent connection
24. Drain connection
25. Instrument connection
26. Expansion bellows
27. Support saddles
28. Lifting lugs
29. Weir
30. Liquid level connection

3. TERMINOLOGY

3.0 For the purpose of this standard, the following definitions shall apply.

3.1 Design Pressure — The pressure used in the design calculations for the purpose of determining the minimum thickness of the various component parts. It is obtained by adding a minimum of 5 percent (or any other figure as may be agreed between the purchaser and the manufacturer) to the maximum working pressure. It shall be specified separately for the shell and the tube sides.

3.2 Design Stress — The maximum stress from all sources permitted for the materials of construction at the design temperature.

3.3 Design Temperature — The temperature used in the design of the exchanger for determining the minimum thickness of the component parts of the exchanger. It is taken as 10°C higher than the maximum temperature that any part of the exchanger is likely to attain in course of operation. It shall be specified separately for the shell and the tube sides.

3.4 Inspecting Authority — Duly authorized representative of the purchaser or any other competent authority recognised by the statutory regulations to inspect the heat exchanger and determine its acceptability or otherwise on the basis of this specification.

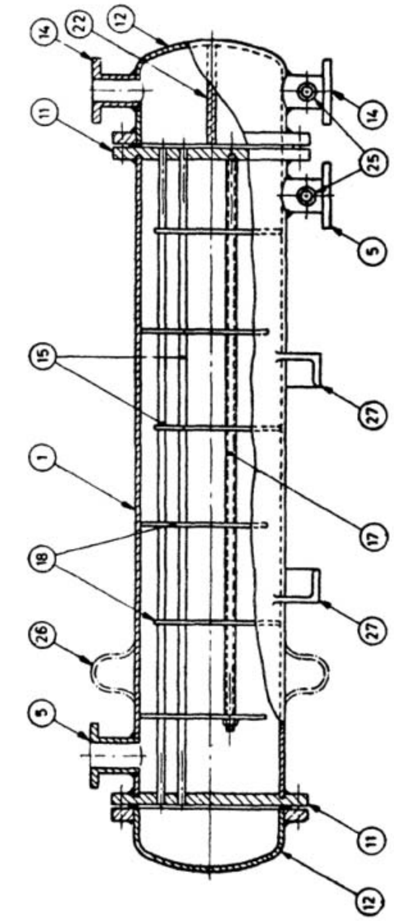


FIG. 1 FIXED TUBE PLATE TYPE HEAT EXCHANGER

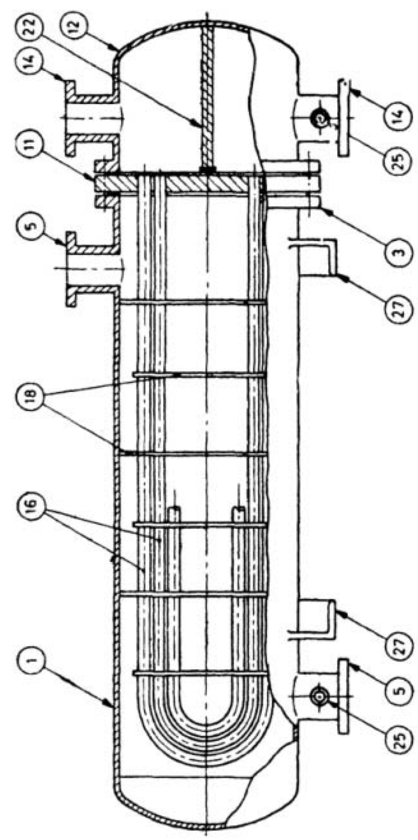


FIG. 2 U-TUBE TYPE HEAT EXCHANGER

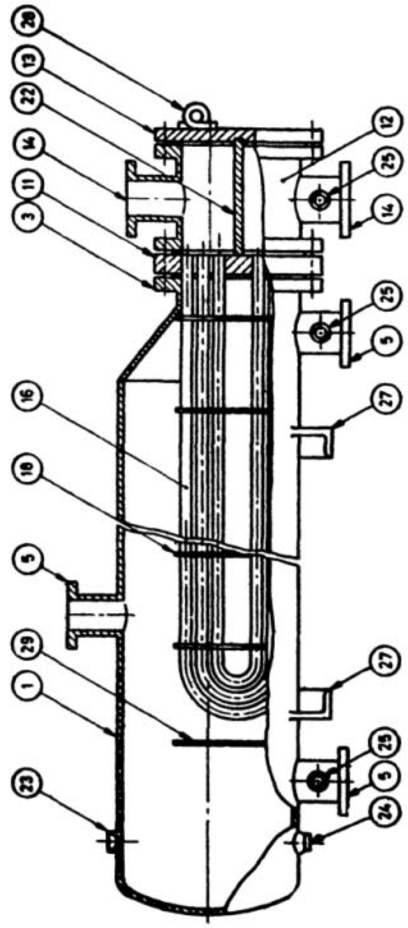


FIG. 3 U-TUBE REBOILER OR KETTLE TYPE HEAT EXCHANGER

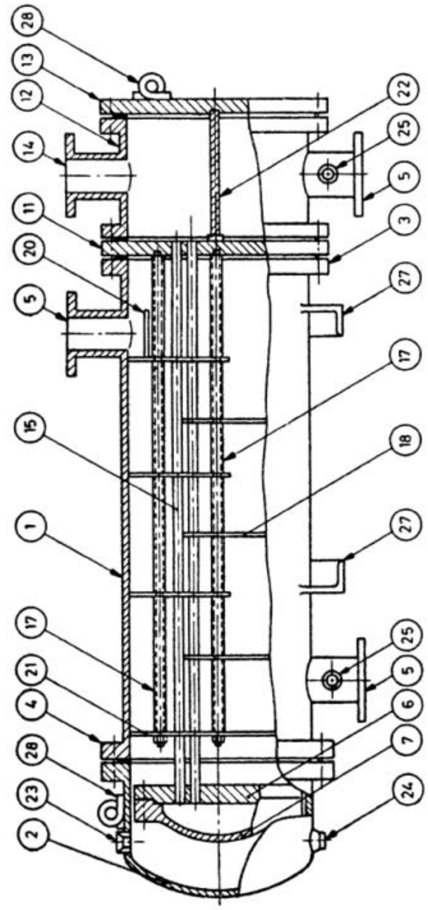


FIG. 4 INTERNAL FLOATING HEAD (PULL-THROUGH TYPE) HEAT EXCHANGER

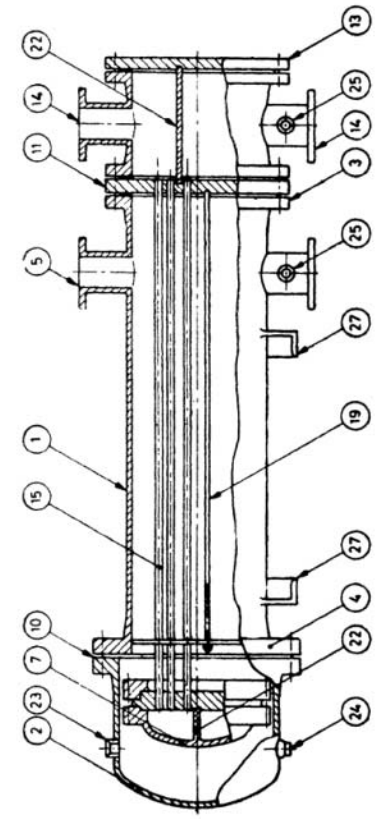


FIG. 5 INTERNAL FLOATING HEAD (NON-PULL THROUGH TYPE) HEAT EXCHANGER

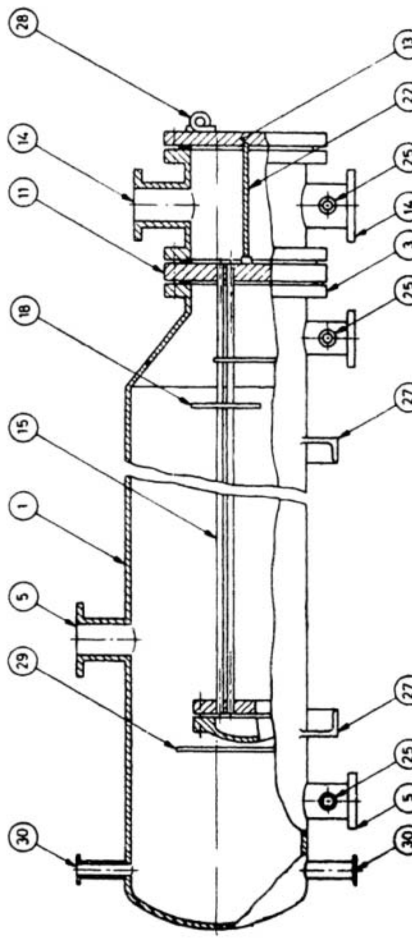


FIG. 6 INTERNAL FLOATING HEAD (REBOILER OR KETTLE TYPE) HEAT EXCHANGER

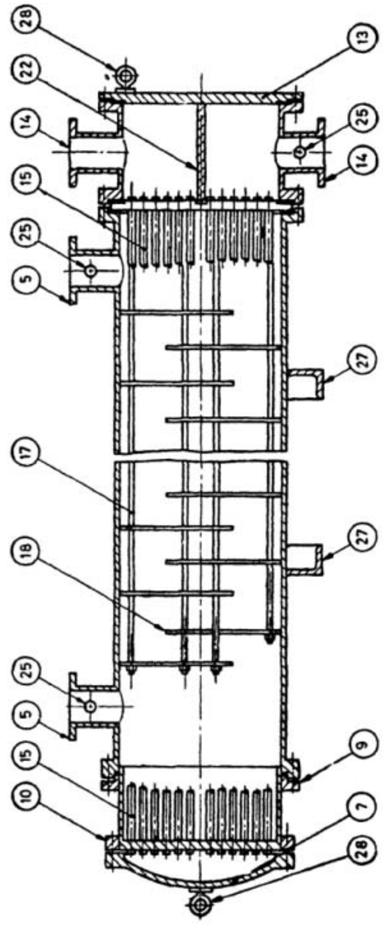


FIG. 7 FLOATING HEAD EXTERNAL PACKED TYPE HEAT EXCHANGER

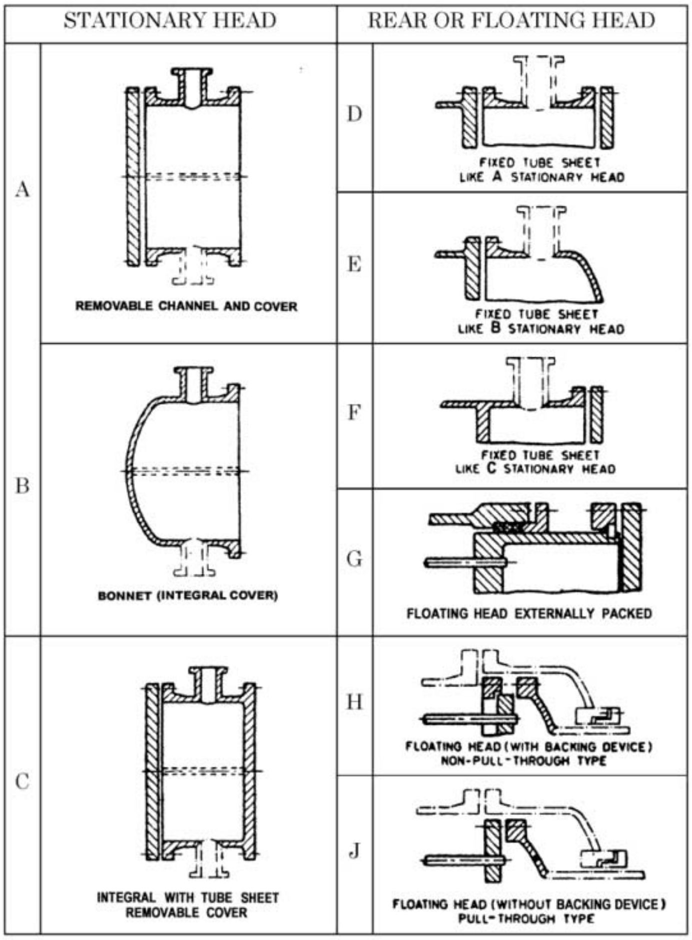


FIG. 8 TYPICAL DESIGNS OF STATIONARY AND FLOATING HEADS

3.5 Nominal Diameter — The nominal diameter shall be the outer diameter of the shell in millimetres, rounded off to the nearest integer. For kettle reboilers the nominal diameter shall be the port diameter followed by the shell diameter, each rounded off to the nearest integer.

3.6 Nominal Length — The nominal length shall be the tube length in metres. Tube length for straight tubes shall be taken as the actual length. For U-tubes the length shall be taken as the straight length from end of tube to bend tangent.

4. CLASSIFICATION AND PERMITTED PRESSURES

4.1 Pressure Classification — Heat exchangers shall be designated separately on the shell and tube sides by the following pressure classification:

2.5 kgf/cm^2 (gauge)
6.3 ,,
10 ,,
16 ,,
25 ,,
40 ,,

The classification pressure being the design pressure at a basic metal temperature which is 250°C, 120°C and 65°C respectively for carbon steel, stainless steel and non-ferrous metals.

4.2 Permitted Pressure — The permitted pressure shall be such that the stress in the various parts of the exchanger in no case exceeds the maximum permissible stress for the material of which the part is made, at the temperature concerned.

SECTION 2 MATERIALS AND DESIGN STRESS VALUES

5. MATERIALS OF CONSTRUCTION

5.1 Specification to Which Material Should Comply — All materials shall comply with the appropriate specification as given in Appendix C. If no standard exists for a particular material, the use of this material shall be the subject of agreement between the purchaser, the fabricator and the inspecting authority.

5.2 Materials for Use at Low Temperatures

5.2.1 *Carbon and Low Alloy Steel* — Any carbon or low alloy steel which is liable to embrittlement in service at temperatures below 0°C shall be subject to the limitations specified in Appendix D of IS : 2825-1969*.

*Code for unfired pressure vessels.

5.2.2 *Non-ferrous Alloys and Stainless Steels* — For the non-ferrous metals and for the austenitic stainless steels, Tables 20 to 22 may be used for temperatures down to – 200°C, *see* Appendix C.

5.3 Fluid Temperature Limitations for Pressure Parts — The maximum permissible operating fluid temperatures to be observed for pressure parts are given in Table 1.

TABLE 1 FLUID TEMPERATURE LIMITATIONS FOR PRESSURE PARTS

MATERIAL	MAXIMUM PERMISSIBLE TEMPERATURE, °C
Carbon steel	540
C-Mo steel	590
Cr-Mo steel	650
Low alloy steel (less than 6 percent chromium)	590
Alloy steel (less than 17 percent chromium)	590
Austenitic Cr-Ni steel	650
Cast iron	200
Brass	200

5.4 Limitations Regarding Use of Cast Iron — Cast iron shall not be used in any heat exchanger part which has a primary service pressure rating in excess of 10 kgf/cm^2 or temperature in excess of 200°C or where failure would create a fire hazard.

6. DESIGN STRESS

6.1 The design stress values for ferrous and non-ferrous material at the design temperature shall be determined by dividing the appropriate properties of the material by factors given in Table 2 and taking the lowest value.

6.1.1 The design stress values for carbon and low alloy steels, high alloy steels, copper and copper alloys, aluminium and aluminium alloys and casting alloys based on the above criteria are given in Appendix C.

SECTION 3 DESIGN AND CONSTRUCTION

7. GENERAL DESIGN

7.1 All heat exchangers shall be designed and fabricated in accordance with IS : 2825-1969* and shall in addition take into account the requirements specified in this section.

*Code for unfired pressure vessels.

TABLE 2 DESIGN STRESS FACTORS FOR VARIOUS MATERIALS
(*Clause* 6.1)

	CARBON AND CARBON MANGANESE STEELS	LOW ALLOY STEELS	NON-FERROUS MATERIAL OTHER THAN BOLTING MATERIAL	NON-FERROUS BOLTING MATERIAL	HIGH ALLOY STEELS
Certified or specified minimum yield (or 0.2 percent proof) stress* at design temperature	1.5	1.5	1.5	4	—
Specified minimum tensile stress at room temperature	2.4	2.4	4	5	—
Average stress to produce rupture in 100 000 hours at design temperature	1.5	1.5	1	1	1.5
Average stress to produce a total creep strain of one percent in 100 000 hours at design temperature	1	1	1	1	1
Certified or specified minimum yield (or 1.0 percent proof) stress at room temperature	—	—	—	—	1.5
Certified 1.0 percent proof stress at design temperature	—	—	—	—	1.25

NOTE — In the case of castings, the above factors shall be divided by a quality factor of 0.75. However a quality factor of 0.90 shall be used when the following requirements have been met with:

a) Each casting has been radiographically examined at all critical locations and found free from harmful defects, or the castings have been fully machined to such an extent that all critical sections are exposed for the full thickness as in the case of tube plates with holes spaced not further apart than the thickness of the casting

b) All castings have been examined at all critical locations using magnetic particle, or penetrant fluid procedure, or by grinding or machining and etching.

c) Castings found to be defective have been rejected or repaired to the satisfaction of the inspecting authority. If repairs by welding are carried out, the castings should be subsequently stress-relieved or heat-treated as agreed between steel maker and inspecting authority. Repaired areas of castings should be re-examined in accordance with (a) above and should be shown to be free from harmful defects.

In all other cases the factor of 0.75 shall be used instead of 0.90.

*The minimum specified yield stress (at room temperature) may be taken to apply for all temperatures up to 50°C

8. CORROSION AND CORROSION ALLOWANCE*

8.1 Corrosion Allowance

8.1.0 Unless otherwise required, the corrosion allowance for the various parts of the heat exchanger shall be as follows:

a) *Carbon steel and cast iron pressure parts* — 1.5 mm on all parts except tubes, in the case of those chemical industries where severe conditions are not expected, and 3 mm in case of petroleum industry or in those chemical industries where severe conditions are expected.

b) *Stainless steel and non-ferrous pressure parts* — none or as may be specified by the purchaser.

Floating head backing devices, internal bolting, non-pressure parts, such as tie rods, spacers, baffles and support plates need not have any allowance for corrosion.

8.1.1 *Internal Covers* — Internal covers shall have a corrosion allowance on each side.

8.1.2 *Tube Plates* — Tube plates shall have the corrosion allowance on each side with the provision that on the grooved side of a grooved tube plate, the depth of the pass partition groove may be considered as available for corrosion allowance.

8.1.3 *External Covers* — Wherever external covers are grooved, the depth of the groove may be considered as available for corrosion allowance.

8.1.4 *End Flanges* — Corrosion allowance shall be applied only to the inside diameter of flanges.

8.2 Electrolytic Corrosion — Due consideration shall be given to the selection of materials and to other anti-corrosion measures when a heat exchanger is required to handle an electrolyte which would cause galvanic corrosion.

9. SHELLS

9.1 Method of Manufacture — Shells may be rolled from plate, may be made from seamless or fusion welded pipe to accepted standard, or cast.

9.2 Design

9.2.1 *Length* — The length of the shell, between flanges, shall be such as to provide easy access to the floating head cover bolting without withdrawing the tube bundle.

See also* **3.2 of IS : 2825-1969 Code for unfired pressure vessels.

9.2.2 *Expansion Devices* — An expansion device shall be fitted on exchangers of the fixed tube plate type when the combined stress due to pressure and thermal expansion exceeds the design stress of the material.

9.3 Dimensions and Tolerances

9.3.1 *Overall Dimensions and Tolerances* — The standard tolerances for the external dimensions of heat exchangers and for branch and support locations shall be as shown in figure in Appendix D.

9.3.2 *Diameter* — The nominal diameter of the heat exchanger shall be the outer diameter in millimetres and shall be one of those specified in IS : 2844-1964* in case of shells fabricated from sheet. In the case of pipe shells it shall be preferably one of the following:

159, 219, 267, 324, 368, 419, 457, 508, 558.8, 609.6, 660.4, 711.2, 762, 812.8, 863.6, 914.4 and 1 016

[These values are taken from ISO/R 336-1963 Plain end steel tubes, welded or seamless (general table of dimensions and masses per unit length)].

9.3.2.1 *Tolerances*

a) *Pipe shells* — The tolerances on diameter shall be in accordance with the relevant pipe specifications.

b) *Plate shells* — The diameter of the shell at any point shall not deviate from the nominal diameter by more than the values given in Table 3, but in no case shall the circumference be less than the calculated circumference or be more than 10 mm in excess of the calculated circumference.

c) The tolerance shall be determined after fabrication, that is, after welding on the flanges, nozzles and supports, and after stress relieving where this operation is carried out.

d) Where the diameter of any branch in the shell exceeds 25 percent of that of the shell, the tolerance on diameter shall be the subject of agreement between the manufacturer and the purchaser.

9.3.3 *Thickness*

9.3.3.1 The minimum thicknesses of shells for those chemical industries where severe conditions are not expected, shall be in accordance with Table 4 which gives the minimum thickness necessary to provide stiffness and shape.

*Recommendations on nominal diameters for process equipment.

TABLE 3 TOLERANCES ON DIAMETER OF PLATE SHELLS

(*Clause* 9.3.2.1)

All dimensions in millimetres.

NOMINAL DIAMETER	PERMISSIBLE DEVIATION	
	Grade 1	Grade 2
200 up to and including 400	± 3	–
Over 400 ,, 600	± 3	+ 6 – 3
,, 600 ,, 800	± 4	+ 7 – 4
,, 800 ,, 1 000	± 5	+ 8 – 5
,, 1 000	± 6	+ 8 – 6

NOTE — Two grades of tolerance are provided in this table, Grade 1 and Grade 2.

Grade 1 covers heat exchangers where reliable tube bundle interchangeability is essential and implies that greater care should be taken to ensure that no distortion occurs when fittings are welded on.

Grade 2 covers heat exchangers where interchangeability of tube bundles is not an essential requirement.

TABLE 4 MINIMUM SHELL THICKNESS WHERE SEVERE CONDITIONS ARE NOT EXPECTED

(*Clause* 9.3.3.1)

NOMINAL DIAMETER mm	MINIMUM THICKNESS IN mm						
	Cast Iron	Carbon Steel (Including Corrosion Allowance)	Copper and Copper Alloys	Aluminium and Aluminium Alloys	Austenitic Stainless Steel	Nickel	Monel Inconel
150	10	5	3.2	5	3.2	3.2	3.2
200	10	6.3	3.2	5	3.2	3.2	3.2
250	10	6.3	3.2	5	3.2	3.2	3.2
300	13	6.3	3.2	5	3.2	3.2	3.2
350	13	6.3	5	5	3.2	5	3.2
400	13	6.3	5	6.3	3.2	5	3.2
500	13	8	6.3	8	3.2	6.3	3.2
600	16	8	6.3	8	5	6.3	5
700	16	10	8.0	10	5	8	5
800	16	10	10	11.2	6.3	8	6.3
900	19	10	10	11.2	6.3	10	6.3
1 000	19	10	11.2	12.5	6.3	11.2	6.3
1 100	22	11.2	11.2	14	6.3	11.2	6.3

NOTE — The thickness values are exclusive of the corrosion allowance.

9.3.3.2 The minimum thickness of shells for the petroleum industry or in chemical industry where severe conditions are expected, shall be according to Table 5.

TABLE 5 MINIMUM SHELL THICKNESS FOR PETROLEUM INDUSTRY AND CHEMICAL INDUSTRY WHERE SEVERE CONDITIONS ARE EXPECTED

NOMINAL DIAMETER mm				MINIMUM THICKNESS, mm		
				Carbon Steel		Alloy
				Pipe	Plate	
	Up to and including 300			6.3	—	3.2
Over	300	,,	700	10	10	5
,,	700	,,	1 000	—	11.2	6.3
,,	1 000	,,	1 500	—	14	8

NOTE — Two thickness values are exclusive of the corrosion allowance.

9.4 Pressure Temperature Rating — The primary pressures given in **4.1** are for the basic temperatures given in the same clause. When the exchanger is to be used at a temperature higher than the basic, then it shall be de-rated to a lower pressure. The pressure rating at any temperature other than the basic is obtained by multiplying the basic rating with the ratio of allowable stress value at the desired temperature to that at the basic temperature.

10. TUBES

10.1 Length — Unless otherwise specified, tubes shall have the following overall straight lengths:

0.5, 1, 2.5, 3,4, 5, 6 metres.

10.2 Diameter and Thickness — The tube diameters and thicknesses shall be in accordance with Table 6.

10.3 U-Tubes

10.3.1 Due to difficulty of cleaning U-tubes internally they shall not be used except when the purchaser specifically requires it.

10.3.2 The centreline radius of the U-bend, r, should not be less than one and a half times the outer diameter of the tube, d.

10.3.3 *Non-uniform Thickness Bends* — When U-bends are formed in such a way as to thin the tube wall at the outer radius of the bend, the minimum tube wall thickness 't_o' *before bending* shall be calculated from:

$$t_o = \left(1 + \frac{d}{4r}\right) \times t_i$$

where t_i is the minimum tube wall thickness calculated by code rules for a straight tube subjected to same pressure and metal temperature.

10.3.4 *Uniform Thickness Bends* — When bends with nominally uniform wall thickness are used, the minimum wall thickness in the curved portion *after forming* shall be:

$$t = \frac{\left(1 - \dfrac{d}{4r}\right)}{\left(1 - \dfrac{d}{2r}\right)} \times t_i$$

where t_i is the minimum tube wall thickness calculated by code rules for a straight tube subjected to same pressure and metal temperature.

TABLE 6 TUBE DIAMETER AND THICKNESSES

(*Clause* 10.2)

All dimensions in millimetres.

OUTSIDE DIAMETER		MINIMUM THICKNESS					
		Carbon Steel, Aluminium and Aluminium Alloys		Copper and Copper Alloys		Other Alloys	
Carbon steel	Material other than carbon steel	Petroleum and chemical industries where conditions are very severe	Chemical industries where conditions are not very severe	Conditions as in (3)	Conditions as in (4)	Conditions as in (3)	Conditions as in (4)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
6	6	—	—	—	0.6	—	0.6
					0.8		0.8
10.2	10	—	—	—	0.8		0.8
					1.0		1.0
					1.2		1.2
12	12	1.6	—	—	1.0	—	1.0
					1.2		1.2
16	16	1.6	—	—	1.2	—	—
					1.6		
		1.6	1.60	1.2	1.2	1.2	1.2
19	18, 20			1.6	1.5	1.5	1.5
		2.0	2.0	2.0	2.0	2.0	2.0
		2.0	2.0	1.6	1.5	1.2	1.2
25.4	25	2.6		2.0	2.0	1.6	1.6
		3.2	2.6	2.5	2.5	2.0	2.0
						2.5	2.5
		2.0	2.0	2.0	2.0	1.6	1.5
31.8	32	2.6	2.6	2.5	2.5	2.0	2.0
		3.2	3.2	3.0	3.0	2.5	2.5
						3.0	3.0
38	40	3.2	3.2	—	3.0	—	—

10.3.5 *Heat Treatment* — Cold work in forming U-bends may induce embrittlement or susceptibility to stress corrosion in certain materials or environments. Stress relief or heat treatment to alleviate such conditions may be performed by agreement between the manufacturer and the purchaser.

10.4 Tube Arrangements — Tubes shall be laid out either on an equilateral triangular pitch or on a square pitch.

10.5 Tube Pitch — Tubes shall be spaced with a minimum centre-to-centre distance of 1.25 times the outside diameter of the tube. When tubes are on a square pitch, a minimum cleaning lane of 6.5 mm shall be provided.

10.5.1 The tube pitch shall be subject to the following tolerances:

For design pitches of 32 mm and less	± 1 mm
For design pitches of over 32 mm	± 1.5 mm

10.6 Tube Fixing

10.6.1 Where tubes are expanded into tube sheets they shall be expanded to a depth equal to not more than 90 percent of the plate thickness. Expansion shall be uniform throughout the expanded portion of the tube without sharp transition to the unexpanded portion.

10.6.2 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 conditions 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 IS : 2371-1963*.

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

10.6.4 Where tubes are fixed by expansion only, the ends shall not project beyond the face of the tube plate by more than 5 mm.

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

10.6.6 Where the tubes are welded into the tube sheets, they may first be lightly expanded. Welding without prior expanding may be carried out by agreement between the purchaser and the manufacturer. Since the heat-resisting properties of certain special alloys are impaired by cold working, these tubes should be welded without prior expansion. For

*Specification for solid drawn copper-alloy tubes for condensors evaporators, heaters and coolers using saline and hard water. (Since withdrawn).

these conditions, the method and details of welding shall be agreed to between the purchaser and the manufacturer.

11. TUBE SHEET

11.1 Effective Thickness of Tube Sheets

11.1.1 The effective tube sheet thickness shall be the thickness measured at the bottom of the pass partition groove minus shell side corrosion allowance and corrosion allowance on the tube side in excess of the groove depth.

This thickness does not include the thickness of the applied facing material but includes the thickness of the cladding material in integrally clad plates and cladding deposited by welding.

11.1.2 *Special Cases* — Special consideration should be given to tube sheets with abnormal conditions of support or loading, for example, fixed tube sheets in exchangers with expansion joints which require considerable axial loads to produce required movements such as the flued and flanged types, tube sheets with extensions used as flanges, tube sheets with portions not adequately stayed by tubes, etc.

11.1.3 *Tube Sheet Thickness Calculation* — The effective thickness of the tube sheets shall be calculated by the method given in Appendix E. However, in no case shall the thickness be less than that given in Table 7.

TABLE 7 MINIMUM TUBE SHEET THICKNESSES

Tube Outer Diameter mm	Thickness mm
6	6
10	10
12	12
16	13
18, 19, 20	15
25, 25.4	19
31.8, 32	22.4
38, 40	25.4

11.2 Tube Holes in Tube Sheets

11.2.1 *Diameters and Tolerances* — Tube holes in tube sheets shall be finished to the sizes and tolerances shown in Table 8. Two types of fits are specified, standard and special close fit. Close fit is generally used for austenitic steel tubes when used for corrosion resistance as the closer fit between the tube and the hole tends to minimise work hardening and attendant loss of corrosion resistance. Close fit shall be provided only when specified by the purchaser.

TABLE 8 TUBE HOLE DIAMETERS AND TOLERANCES

(*Clause* 11.2.1)

All dimensions in millimetres.

TUBE OUTER DIAMETER *d*	CORRESPONDING TUBE HOLE DIAMETER		PERMISSIBLE DEVIATION ON THE TUBE HOLE DIAMETER			
	For Standard Fit	For Special Close Fit	For Standard Fit	For Special Close Fit	For 96% of Tube Holes	For Remaining Tube Holes
(1)	(2)	(3)	(4)	(5)	(6)	(7)
6, 10, 10.2	d + 0.2	d + 0.15	− 0.1	− 0.05	+ 0.05	+ 0.15
12, 16	d + 0.2	d + 0.15	− 0.1	− 0.05	+ 0.05	+ 0.20
18, 19, 20	d + 0.2	d + 0.15	− 0.1	− 0.05	+ 0.05	+ 0.25
25, 25.4	d + 0.3	d + 0.2	− 0.1	− 0.05	+ 0.05	+ 0.25
31.8, 32	d + 0.4	d + 0.3	− 0.1	− 0.05	+ 0.05	+ 0.25
38, 40	d + 0.5	d + 0.4	− 0.2	− 0.08	+ 0.08	+ 0.25

11.2.2 *Tube Hole Pitch and Ligament Width* — The tube hole pitch and ligament for various tube sheet thicknesses shall be in accordance with Table 9.

11.2.3 *Tube Hole Finish* — The inside edges of tube holes shall be slightly chamfered after drilling and reaming to remove burrs and prevent cutting of the tubes.

11.2.4 *Tube Hole Grooving* — All tube sheet holes for expanded joints for heat exchanger used in petroleum industry and for heat exchangers used in chemical industry for pressures exceeding 20 kgf/cm^2 and temperatures in excess of 175°C, shall be provided with two anchor grooves, approximately 3.2 mm wide and 0.4 mm deep.

By agreement between the purchaser and the manufacturer, exception to the provision of these grooves may be made for materials where unnecessary working of the tube ends during expansion could be avoided.

11.2.5 *Tubesheet Pass Partition Grooves* — In petroleum industry and in case of chemical industries where severe conditions are expected, all tube sheets shall be provided with approximately 5 mm deep grooves for pass partitions.

TABLE 9 TUBE HOLE PITCH AND LIGAMENT WIDTH

(*Clause* 11.2.2)

All dimensions in millimetres.

Tube Dia	Tube Pitch	*Minimum Permissible Ligament Width for Tubesheet Thickness								Minimum Permissible Ligament Width
		25	38	50	63	75	100	125	150	
6	8	0.7	0.7	0.7	0.7	—	—	—	—	0.7
	10	2.2	2.0	1.9	1.7	1.6	—	—	—	1.6
10, 10.2	13	2.3	2.2	2.1	2.0	1.9	1.7	1.6	—	1.6
	14	3.1	3.0	2.9	2.8	2.6	2.4	2.2	2.0	2.0
16	20	2.9	2.8	2.8	2.7	2.6	2.5	2.4	2.3	2.0
	21	3.7	3.7	3.6	3.5	3.5	3.4	3.2	3.1	2.3
	22	5.3	5.2	5.2	5.1	5.1	4.9	4.8	4.6	3.1
18, 19, 20	24	3.7	3.7	3.6	3.5	3.5	3.4	3.3	3.1	2.3
	25	5.3	5.2	5.2	5.1	5.1	5.0	4.9	4.7	3.1
	27	6.9	6.8	6.7	6.7	6.6	6.5	6.4	6.3	3.9
	28	8.5	8.4	8.4	8.3	8.2	8.1	8.0	7.9	4.7
25, 25.4	32	5.3	5.3	5.2	5.2	5.1	5.0	5.0	4.9	3.1
	33	6.9	6.8	6.8	6.8	6.7	6.6	6.5	6.4	3.9
	35	8.5	8.4	8.4	8.4	8.3	8.2	8.2	8.1	4.7
31.8, 32	40	6.8	6.8	6.7	6.7	6.7	6.6	6.5	6.5	3.9
38, 40	49	8.3	8.3	8.3	8.2	8.2	8.1	8.1	8.0	4.6

*Ninety six percent of ligaments should be equal to or more than the values given under these columns.

In case of chemical industries where severe conditions are not expected the pass partition shall only be provided if the design pressure exceeds 20 kgf/cm^2 and when the channel joints are of the tongue and groove type.

In clad or applied facings, there shall be a minimum of 3 mm of facing material beneath the bottom of the groove.

11.2.6 *Tubesheet Machining* — Tubesheets shall be machined on all gasket seating surface. It is preferable that, where possible, this should be done after any welding.

11.2.7 *Pulling Eyes* — In exchangers with removable tube bundles (*see* Fig. 2 to 7) having nominal diameter exceeding 300 mm and/or a tube length exceeding 2.5 m, the stationary tube sheet shall be provided with two tapped holes in its face for pulling eyes. These holes shall be protected in service by plugs. Provision for pulling means may have to be modified or waived for special constructions, such as clad tube sheets, by agreement between the fabricator and the purchaser.

11.2.8 *Holes for Tie-Rods and Spacer Supports* — The holes for tie-rods and spacer supports shall be drilled blind.

11.2.9 Tubesheets used in conjunction with cast iron shell or floating head flanges shall be drilled for bolt holes and shall extend to outside diameter of flanges.

For bonnet type channels combined with non-welded tubesheets (*see* Fig. 2) sufficient number of collar bolts should be used to prevent the joint between the fixed tubesheet and the shell being broken when the channel is removed.

When vertical heat exchangers are to be installed with the fixed tube-sheet at the bottom end of the shell, sufficient number of collar bolts or set screws shall be provided to hold the tube bundle when the channel is removed.

11.2.10 *Tolerances* — The standard tolerance for the tubesheet dimensions shall be as shown in figure in Appendix F.

12. SHELL COVERS

12.1 Nominal Diameter — The nominal (outer) diameter of the heat exchanger shell cover shall be one of those specified in **9.3.2**.

12.2 Thickness — Shell covers shall have a thickness at least equal to the thickness of the shell when the same material of construction is used both for the shell and cover.

13. BAFFLES AND SUPPORT PLATES

13.1 Type of Baffle

13.1.1 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.

13.1.2 Longitudinal baffles may be used provided special attention is given to the sealing between baffle and shell (*see* **13.2.4**).

13.2 Baffle and Support Plate Clearances

13.2.1 The diameters of transverse baffles and tube support plates for exchangers specified to Grade 1 tolerances shall be as shown in Table 10.

TABLE 10 DIAMETER OF BAFFLES AND TUBE SUPPORT PLATES FOR GRADE 1 TOLERANCES

All dimensions in millimetres.

NOMINAL SHELL SIZE			DIAMETER OF BAFFLE OR SUPPORT PLATE	PERMISSIBLE DEVIATION
200 up to and including 600			$D_1 - 3$	+0 −1
Over 600	,,	800	$D_1 - 4$	+0
,, 800	,,	1 000	$D_1 - 5$	+0
,, 1 000	,,	1 200	$D_1 - 5.5$	−1.5
,, 1 200			$D_1 - 6$	−1.5

D_1 = inside diameter of the shell.

13.2.2 The clearance of transverse baffles specified to Grade 2 tolerance shall be such that the difference between the internal diameter of the shell and the outside diameter of the baffle shall not exceed the values given in Table 11. However, where such clearance has no significant effect on shell side heat transfer coefficient or mean temperature difference, these maximum clearances may be increased to twice the tabulated values.

13.2.3 It is recommended that the tolerance should be obtained by clamping together all baffles or support plates, or both, required for one heat exchanger and machining to size in one operation. Removable tube bundles should be checked for truth by fitting in the shell at two positions 180° apart.

13.2.4 In the case of longitudinal baffles, special consideration should be given to the clearance between the baffle and the shell. The clearance shall be the subject of agreement between the purchaser and the fabricator. If required, special arrangements shall be made to prevent by-passing.

TABLE 11 CLEARANCE OF TRANSVERSE BAFFLES TO GRADE 2 TOLERANCE

(*Clause* 13.2.2)

All dimensions in millimetres.

NOMINAL SHELL SIZE				CLEARANCE	
				For Gases and Vapours	For Liquids
	200 up to and including		400	4	2
Over	400	,,	500	6	3
,,	500	,,	600	7	4
,,	600	,,	1 000	9	5
,,	1 000	,,	1 200	11	6

13.3 Spacing of Baffles and Support Plates

13.3.1 *Minimum Spacing* — Transverse baffles shall not be pitched closer than one-fifth of the shell diameter or 50 mm, whichever is greater.

13.3.2 *Maximum Spacing* — Tube support plates shall be so spaced that the unsupported tube length does not exceed the values given in Table 12 for tube material used.

13.3.3 *U-Tube Rear Support* — The support plates or baffles adjacent to the bends in U-tube exchangers shall be so located that for any individual bend, the sum of the bend diameter plus the straight lengths measured along both legs from support to bend tangent does not exceed the maximum unsupported span determined from Table 12.

13.3.4 *Special Cases* — Where the purchaser specifies pulsating conditions, unsupported spans shall be as short as pressure drop restrictions permit. If the span under these circumstances approaches the maximum permitted by Table 12 above, consideration should be given to alternative flow arrangements which would permit shorter spans under the same pressure drop restrictions.

13.3.5 *Spacing Tolerance* — The following tolerance shall apply to spacing of baffles:

Stationary tubesheet to first baffle	± 6 mm
First baffle to last baffle	± 12 mm

TABLE 12 MAXIMUM UNSUPPORTED STRAIGHT TUBE LENGTHS

(*Clauses* 13.3.2, 13.3.3, *and* 13.3.4)

TUBE DIAMETERS	MAXIMUM UNSUPPORTED LENGTH IN METRES FOR DIFFERENT TUBE MATERIALS AND TEMPERATURE LIMITS	
	Carbon and High Alloy Steel (400°C), Low Alloy Steel (450°C), Nickel-Copper (315°C), Nickel (450°C), and Nickel-Chromium-Iron (540°C)	Aluminium and Aluminium Alloys, and Copper and Copper Alloys
mm		
6	0.6	0.5
10, 10.2	0.8	0.7
12	1.1	0.9
16	1.3	1.1
18, 19, 20	1.5	1.3
25, 25.4	1.8	1.6
31 8, 32	2.2	1.9
38, 40	2.5	2.2

13.4 Thickness of Baffles and Support Plates

13.4.1 *Transverse Baffles and Support Plates* — The thickness of transverse baffles and support plates for both vertical and horizontal exchangers shall be agreed to between the purchaser and the fabricator. However, the thickness of the baffles in no case shall be less than that specified in Table 13.

13.4.2 *Longitudinal Baffles*

13.4.2.1 Longitudinal steel baffles shall have a minimum total metal thickness of 6 mm.

13.4.2.2 Longitudinal alloy baffles shall have a minimum total metal thickness of 3 mm.

13.4.3 *Special Precautions* — Special consideration should be given to baffles and support plates subjected to pulsations, to baffles and support plates engaging finned tubes, and to longitudinal baffles subjected to large differential pressures due to high shell side fluid pressure drop.

13.5 Impingement Baffles — In the petroleum industry or in chemical industry where severe conditions are expected, for services involving non-corrosive, non-abrasive, single phase fluids having entrance line values of ρV^2 less than 125, protection against impingement may not be required. In this, V is the linear velocity of the fluid in metres per second, and ρV^2 is its density in grams/cubic centimetre. In all other cases, means shall be provided to protect the tube bundle at entrance against impinging fluids.

TABLE 13 MINIMUM TRANSVERSE BAFFLE AND SUPPORT PLATE THICKNESS

(*Clause* 13.4.1)

All dimensions in millimetres.

Nominal Shell Diameter	Distance Between Adjacent Segmental Plates					
	150	Over 150 up to 300	Over 300 up to 450	Over 450 up to 600	Over 600 up to 750	Over 750
150 up to and including 400	1.5	3	4	6	10	10
Over 400 ,, 700	3	4	6	10	10	12
,, 700 ,, 1 000	4	6	8	10	12	16
,, 1 000	6	6	10	12	16	16

13.6 Tie-Rods and Spacers — Tie-rods and spacers shall be provided to retain all cross baffles and tube support plates accurately in position, and shall be of a material similar to that of the baffles.

13.7 Number and Size of Rods — Number of tie-rods and diameters for various sizes of heat exchangers shall be in accordance with Table 14. Other combinations of tie-rod number and diameter with equivalent metal area are permissible; however, the minimum number of rods shall be four, and the minimum diameter shall be 10 mm.

14. FLOATING HEADS

14.1 Minimum Inside Depth of Floating Head — For single pass floating heads, the depth at the centre of the tube sheets shall be at least one-third the tubesheet diameter. For multipass floating heads, the inside depth shall be such that the minimum cross-over area for flow between successive tube passes is at least equal to 1.3 times the flow area through the tubes for one pass.

14.2 Stress Relieving — Fabricated steel floating covers shall be stress relieved in accordance with the requirements of IS : 2825-1969* after completion of all welding.

*Code for unfired pressure vessels.

TABLE 14 NUMBER AND DIAMETER OF TIE-RODS

(*Clause* 13.7)

	Nominal Shell Diameter			Tie-Rod Diameter	Minimum Number of Tie-Rods
	mm			mm	mm
	150 up to and including		400	10	4
Over	400	,,	700	10	6
,,	700	,,	900	13	6
,,	900	,,	1 200	13	8
,,	1 200			13	10

14.3 Floating Head Backing Device — If backing devices are used, they are usually of carbon steel and no corrosion allowance is made for them.

14.4 Internal Floating Heads

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

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

14.4.3 Provision shall be made for easy access to the internal floating head cover bolting without removing the tube bundle.

14.4.4 *Packed Floating Heads*

14.4.4.1 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 the purchaser and the manufacturer.

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

15. CHANNELS AND CHANNEL COVERS

15.1 Types — Channels may be of either fabricated or cast construction and may be of the one-piece 'bonnet' type or of the 'straight' type with a separable bolted cover.

15.2 Diameter and Thickness of Channels — The outside diameter of the channel shall be the same as that of the shell. The thickness of the channel shall be greater of the following two values:

a) Shell thickness, and

b) Thickness calculated on the basis of pressure.

15.3 Minimum Inside Channel Depth

15.3.1 For the petroleum industry and for chemical industry where severe conditions are expected, the inside depth for multipass channels shall be such that the minimum cross-over area for flow between successive tube passes is at least equal to 1.3 times the flow area through the tubes of one pass.

15.3.2 For chemical industry where severe conditions are not expected, the inside depth for multipass channels shall be such that the minimum cross-over area for flow between successive tube passes is at least equal to the flow area through the tubes of one pass.

15.4 Fabricated channels and bonnets shall be stress relieved in accordance with the requirements of IS : 2825-1969* after welding.

15.5 Pass Partition Plates

15.5.1 The minimum thickness, including corrosion allowance of channel pass partitions, shall be in accordance with Table 15.

TABLE 15 THICKNESS OF PASS PARTITIONS

NOMINAL CHANNEL SIZE	MINIMUM PARTITION THICKNESS	
	Carbon Steel	Alloy
mm	mm	mm
Less than 600	10	10
600 and larger	13	10

Partition plates may be tapered down to gasket width at the contact surface.

15.5.2 *Tolerances* — Tolerances for partition thickness shall be as given in Appendix F.

15.5.3 *Special Precaution* — Special consideration shall be given to thickness requirements for internal partitions subjected to pulsating

*Code for unfired pressure vessels.

fluid flow or to large differential pressures due to specified operating conditions or specified maintenance procedures.

15.6 Channel Covers

15.6.1 *Effective Channel Cover Thickness* — The effective thickness is calculated from the formula:

$$t = \frac{d}{10} \quad \frac{\sqrt{CP}}{f}$$

where

t = thickness of the channel cover in mm;

d = diameter of the cover in mm;

C = a factor which is 0.25 when the cover is bolted with full faced gaskets and 0.3 when bolted with narrow faced or ring type gaskets;

P = design pressure in kgf/cm^2; and

f = allowable stress value in kgf/mm^2, at design temperature.

15.6.2 *Channel Cover Pass Partition Grooves* — All channel covers shall be provided with approximately 5 mm deep grooves for pass partitions. In clad of applied facings, there shall be at least 3 mm of facing material beneath the bottom of the groove.

16. NOZZLES AND BRANCH PIPES

16.1 General

16.1.1 Nozzles and branch pipes should be strong enough to withstand the accidental loadings which may occur during transit and erection of the vessel; they shall also be strong enough to withstand reasonable loads from connecting pipes.

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

16.1.3 Radially arranged branches shall be provided unless otherwise agreed to between the purchaser and the fabricator.

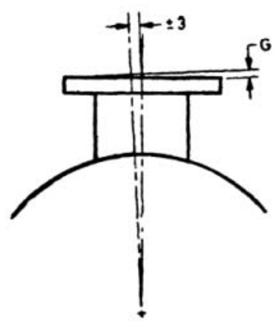
16.1.4 Shell nozzles shall be flush with the inside contour of the shell. Channel nozzles may protrude inside the channel provided vent and drain connections are flush with the inside contour of the channel.

16.1.5 *Alignment Tolerance* — The alignment tolerance for standard nozzles shall be as shown in Table 16.

16.2 Thickness — The wall thickness of nozzles and other connections shall be not less than that defined for the applicable loadings, namely, pressure temperature, bending and static loads, but in no case shall the wall thickness in the case of ferrous piping, excluding the corrosion allowance, be less than 0.04 d_o + 2.5 mm, where d_o is the outside diameter of the connection.

NOTE — Where the nozzles or connections are threaded, the thickness shall be measured at the root of the thread.

TABLE 16 ALIGNMENT TOLERANCE FOR STANDARD NOZZLES
(*Clause* 16.1.5)



	NOZZLE DIAMETER mm		G, *Max* mm
	50 up to and including	100	1.5
Over	100 ,,	150	2.5
,,	150		5

16.2.1 Screwed connections may be provided by means of a welded-in coupling, or integral boss of equivalent diameter. The use of screwed connections shall be limited to a maximum nominal size P1 (*see* IS : 554-1964*).

16.3 Drain, Vent and Instrument Connections — All high and low points on the shell and tube sides of an exchanger not otherwise vented or drained by nozzles shall be provided with P 3/4 nominal size connections for vent and drain. Larger connections may be provided by agreement between the manufacturer and the fabricator. Adequate pressure and temperature connections shall be provided on both the shell and tube sides. Other connections such as test or sampling points

*Dimensions for pipe threads for gas list tubes and pressure tight screwed fittings (*revised*).

and safety valves shall be provided as required by the purchaser or by statutory regulations. It is recommended that the connections for instrument should have a nominal size of P1.

17. GASKETS AND GLAND PACKINGS

17.1 Materials

17.1.1 Metal jacketted or solid metal gaskets shall be used for all joints in contact with oil or oil vapour and for all pressures of 16kgf/cms^2 and over. They shall also be used for internal floating head joints.

17.1.2 For pressures under 16 kgf/cm^2 and when there is no contact with oil or oil vapour, the compressed asbestos fibre, natural or synthetic rubber or other suitable gasket and packing materials having the appropriate mechanical and corrosion resisting properties may be used.

17.2 Continuity of Gaskets — Metal jacketted or solid metal gaskets shall show no break in continuity in the matel in contact with the flange surfaces to be sealed. Compressed asbestos composition (or similar material) gaskets shall be of one piece construction.

17.3 Dimensions

17.3.1 The minimum width of peripheral ring gaskets for external joints shall be 10 mm for shell sizes up to 600 mm nominal diameter and 13 mm for all larger shell sizes.

17.3.2 The width of gasket web for pass ribs of channels and floating heads shall not be less than 10 mm.

17.3.3 Gaskets for use with cast iron flanges shall extend to the outside diameter of the flanges.

18. FLANGES

18.1 Shell, Cover and Channel Flanges

18.1.1 *Types* — 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.

Ring flanges thicker than 100 mm are not recommended, Above this thickness welding-neck flanges are preferred.

18.1.2 *Facing* — Steel flanges shall be provided with a raised face, male-and-female or tongue-and-groove facing, or as specified or agreed.

Cast iron flanges and steel flanges mating with cast iron flanges shall be flat faced for gaskets which shall extend to the outside diameter of the flange.

Ring flanges up to and including Class 16 may have plain faced joints. Ring flanges of Classes 25 and 40 and all welding-neck flanges shall have confined gaskets.

18.1.3 *Dimensions and Tolerances* — The dimensions of flanges, gaskets, flange faces, etc, shall be in accordance with IS : 4864-1968 to IS : 4870-1968*.

Tolerances on the non-standard size flange dimensions shall be in accordance with those shown in figures in Appendix F.

18.2 Nozzle and Branch Flanges

18.2.1 All flanges on branches and nozzles shall conform to Indian Standard Specification for pipe flanges (*under preparation*) to suit the temperature and pressure required, unless otherwise specified.

19. SUPPORTS

19.1 All heat exchangers shall be provided with supports which are designed to avoid undue stress or deflection in supports or shell.

19.2 Horizontal Units — Horizontal units shall be provided with at least two supporting saddles with holes for anchor bolts. The holes in at least one of the supports shall be elongated to provide for expansion of the shell.

19.3 Vertical Units — Vertical units shall be provided with at least two supports of sufficient size to carry the unit in a supporting structure of sufficient width to clear shell flanges.

19.4 Tolerance — Standard tolerances for support location shall be in accordance with those shown in figure in Appendix D.

20. INSPECTION

20.1 The purchaser shall be offered all reasonable facilities to inspect at any reasonable time the fabrication at any stage and to reject any parts which do not comply with this specification (*see also* IS : 2825-1969†).

21. TESTING

21.0 The testing procedure outlined below covers only the mechanical design and construction of the heat exchanger, and does not include the process performance.

*Specification for shell flanges for vessels and equipment.

†Code for unfired pressure vessels.

Each complete heat exchanger shall be hydraulically tested at the manufacturer's works to the appropriate pressure.

Pneumatic testing of heat exchangers shall be normally not carried out, except in circumstances where even the smallest trace of the testing liquid cannot be tolerated.

21.1 Test Facilities — The manufacturer shall supply free of charge the labour and appliances for testing of complete heat exchangers as may be carried out on his premises in accordance with this standard. In the absence of facilities at his own works for making the prescribed tests the manufacturer shall bear the cost of carrying out the tests elsewhere.

21.1.1 *Gaskets on Test Equipment* — Heat exchangers shall be tested using the service gaskets so that the exchanger may leave the fabricator's shop in the 'as tested' condition. If this is not possible then special gaskets may be used by agreement provided they are of the same general type as the service gaskets.

21.2 Hydraulic Test

21.2.1 Fresh water or any non-hazardous, non-corrosive liquid may be used by agreement between the purchaser and the fabricator for hydraulic testing.

The test pressure shall be such that at every point in the vessel, it is at least equal to 1.3 times the design pressure multiplied by the ratio of safe stress value for the material of construction at the test temperature to the safe stress value at the design temperature.

The test pressure shall be maintained for a period of not less than one hour.

21.2.2 *Precautions* — Before applying pressure the equipment shall be inspected to see that it is tight and that all low pressure lines and other non-pressure parts that should not be subjected to the test pressure have been disconnected.

Vents shall be provided at all high points of the vessel in the position in which it is to be tested to purge possible air pockets while the vessel is filling.

21.2.3 *Test Procedure*

a) *Fixed tubesheet type exchangers* — When the shell side and tube side test pressures are not the same, then the test at the lower pressure shall be done first.

   When carrying out the shell side pressure test, the channel cover shall be removed so that leakage from the shell side may be detected.

b) *Floating head type exchangeres — shell side test pressure less than tube side test pressure* — When the required shell side test pressure is less than the required tube side test pressure, the hydraulic test shall be carried out in the following manner:

The tube bundle, with channel and floating-head cover in place, shall be tested to the appropriate test pressure.

After the above test, the tube bundle shall be inserted into the shell and checked for freedom from binding.

The shell side with the tube bundle and channel in position shall then be subjected to the appropriate hydraulic test pressure. During this test the channel cover shall be removed to detect any leakage from the shell side.

c) *Floating head type exchanger — shell side test pressure equal to or greater than tube side test pressure* — When the required shell side test pressure is equal to or greater than required for tube side pressure, the hydraulic test shall be carried out in the following manner:

A suitable test ring and gland shall be provided by the manufacturer (*see* Appendix G).

The shell and tube bundle shall be inspected separately and the tube bundle inserted into the shell and checked for freedom from binding.

With the tube bundle, test ring assembly and channel in position, but with the shell cover, floating head cover and channel cover removed for detecting leakage, the shell side shall be subjected to the appropriate test pressure.

With the test ring assembly and shell cover removed, but with the floating head cover, channel and channel cover in position, the tube bundle shall be subjected to the appropriate test pressure.

With the shell cover in position (heat exchanger fully assembled), the shell side shall again be subjected to the appropriate hydraulic test pressure to determine the tightness of the shell cover joint.

21.3 Pneumatic Testing — Air testing shall be carried out under close supervision of the testing authority. Adequate protection such as blast walls or pits, and means for remote observation and control should be provided.

21.3.1 *Test Pressure* — The pneumatic test pressure shall be at least equal to the design pressure multiplied by the ratio of the safe stress value of the material of construction at the test temperature to that at the design temperature.

21.3.2 *Procedure* — The pressure shall gradually be increased to not more than 50 percent of the test pressure. Thereafter the pressure shall be increased in steps of approximately ten percent of the test pressure till the required test pressure is reached. Then the pressure shall be reduced to a value equal to 80 percent of the test pressure and held there while the vessel is inspected.

22. MARKING

22.1 The manufacturer shall provide a nameplate of a suitable corrosion resistant material, securely attached to the heat exchanger in a position that is accessible and, if the exchanger is to be lagged, where it will not be obscured, stamped with the following information:

a) Manufacturer's name,

b) Manufacturer's serial number and identification,

c) Design pressure: shell ... kgf/cm^2 (gauge) at ... °C,
tube ... kgf/cm^2 (gauge) at ... °C,

d) Test pressure shell ... kgf/cm^2 (gauge) at ... °C,
tube ... kgf/cm^2(gauge) at ... °C,

e) The letters SR if stress relieved,

f) The letters XR if completely radiographed, and

g) The number of this standard.

22.1.1 Heat exchangers may also be marked with the Standard Mark.

NOTE — The use of the Standard Mark is governed by the provisions of the Bureau of Indian Standards Act, 1986 and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

22.2 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.

22.3 For exchangers with removable tube bundles, the stationary tube sheet shall be marked on its edge so as to indicate its correct orientation in the shell.

22.4 Any additional information as mutually agreed upon between the purchaser and the fabricator, shall be given on a separate nameplate.

23. PREPARATION FOR DESPATCH

23.1 Cleaning — The inside of all shells shall be ground or wire brushed if necessary to remove loose scale prior to insertion of bundles. Dirt, weld rod stubs and other foreign materials are to be removed from all units.

23.2 Draining — All liquids used for hydraulic testing or cleaning shall be drained from all units before shipment.

23.3 Painting — All external ferrous parts, other than stainless steels, shall be painted with temporary corrosion-preventive paint.

23.4 Protection of Nozzles — All flange faces of nozzles shall be protected to prevent damage, for example, by covering with wooden blank flanges. All threaded connections shall be plugged.

23.5 Protection of Parts — Separate parts, such as tube bundles and heads, are to be suitably protected to prevent damage during shipment.

24. CERTIFICATES OF COMPLIANCE

24.1 Pressure Test Certificate — The fabricator shall supply to the purchaser a certificate stating that the exchanger complies in all respects with this Indian Standard and that it has passed the pressure test specified by this standard.

24.2 Material Test Certificate — In cases where the purchaser requires a detailed certificate, including materials of construction, it shall be supplied.

APPENDIX A

(*Clause* 0.4)

HEAT EXCHANGER DATA SHEET

1	Customer.......... Job No. .... Ref No.		
2	Address.......... Enquiry No.		
3	Plant location.......... Date..........		
4	Description.......... Item No.		
5	Size.......... Shells per unit.......... Arrangement..........		
6	Type.......... Surface per shell..........m^2 Surface per unit.......... m^2		
7	OPERATING DATA FOR ONE UNIT		
8	Units	Shell Side	Tube Side
9	Description of fluid		
10	Liquid.......... kg/h	In.......... Out..........	In.......... Out..........
11	Vapour.......... kg/h	In.......... Out..........	In.......... Out..........
12	Steam.......... kg/h	In.......... Out..........	In.......... Out..........
13	Non-condensables.......... kg/h	In.......... Out..........	In.......... Out..........
14	Total fluids.......... kg/h	In.......... Out..........	In.......... Out..........
15	Density.......... kg/m^2	In.......... Out..........	In.......... Out..........
16	Absolute viscosity.......... cP	In.......... Out..........	In.......... Out..........
17	Molecular weight		
18	Specific heat (cp).......... kcal/kg degC	....	....
19	Latent heat.......... kcal/kg	....	....
20	Thermal conductivity.......... kcal/mh degC	....	....
21	Temp.......... °C	In.......... Out..........	In.......... Out..........
22	Operating pressure kgf/cm^2 (gauge)	In.......... Out..........	In.......... Out..........
23	Number of passes..........	....	....
24	Velocity.......... m/s		
25	Fouling resistance..........$kcal/m^2.h$ degC-1		
26	Heat exchanged.......... kcal/h M. T. D. (corrected).......... °C		
27	Overall heat transfer coefficient (service).......... $kcal/m^2h$ degC		
28	CONSTRUCTION AND MATERIALS		
29	Pressure class..........		
30	Design pressure and temp....	.... kgf/cm^2 (gauge) .... °C	.... kgf/cm^2 (gauge).......... °C
31	Test pressure and temp..........	.... kgf/cm^2 (gauge) .... °C	.... kgf/cm^2 (gauge).......... °C
32	Tubes Material..........		
33	Tubes No./shell...OD...mm Wall thickness...mm Length...m Pitch...mm Δ □ ◇		
34	Shell Nom. OD..........mm Thickness..........mm		
35	Shell cover Floating head cover..........		
36	Channel Channel Cover..........		
37	Tube plates Stationary Floating..........		
38	Baffles Cross Type.......... Thickness..........mm		
39	Baffles Longitudinal Type.......... Thickness..........mm		
40	Tube Supports Type.......... Thickness..........mm		
41	Gaskets..........		
42	Branches Shell..........In.......... in N/B Out..........in N/B Flanges..........		
43	Channel.......... In.......... in N/B Out..........in N/B Flanges..........		
44	Corrosion allowance Shell side..........Tube side..........		
45	Design code.......... Welding classification..........		
46	Inspection requirements..........		
47	Weights Each exchanger complete-Dry..........Tube bundle..........Unit full of water..........kg		
48	Information supplied by.......... For duty..........For surface area..........		
49	NOTE — Indicate after each part whether stress relieved (SR) and whether radiographed (XR)		
50	Remarks..........		

APPENDIX B

(*Clause* 0.5)

VALUES FOR COEFFICIENT OF THERMAL EXPANSION, THERMAL CONDUCTIVITY AND YOUNG'S MODULUS

B-1. The values of coefficient of thermal expansion are given in Table 17.

TABLE 17 MEAN COEFFICIENT OF THERMAL EXPANSION **α in mm/mm deg** C × 10^6 BETWEEN 20°C AND SPECIFIED TEMPERATURE

MATERIAL	TEMPERATURE °C																
	—125	—75	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750
Carbon & carbon molybdenum steels and low chromium steels up to 3% Cr	10.1	10.4	11.2	11.5	11.9	12.2	12.6	12.9	13.2	13.6	14.0	14.2	14.4	14.6	14.8	15.0	15.1
Intermediate alloy steels 5Cr — Mo to 9Cr — Mo	10.1	10.3	10.6	10.8	11.1	11.3	11.7	12.0	12.2	12.4	12.7	12.8	13.0	13.1	13.3	13.5	13.7
Straight chromium steels 12, 17 25% Cr	9.2	9.5	9.7	9.9	10.2	10.4	10.8	11.0	11.2	11.4	11.6	11.7	11.9	12.1	12.2	12.4	12.4
Austenitic stainless steels	15.8	16.0	16.6	16.7	17.1	17.3	17.5	17.6	17.9	18.1	18.3	18.4	18.5	18.7	18.9	19.1	19.1
25 Cr — 20 Ni steel	—	—	—	14.0	14.2	14.6	14.8	15.0	15.3	15.5	15.7	15.9	16.0	16.2	16.4	16.4	16.6
Grey cast iron	—	—	10.2	10.4	10.8	11.0	11.3	11.6	12.0	12.1	12.4	12.7	12.9	—	—	—	—
Cupro-nickel, 70 Cu — 30 Ni	—	—	—	15.3	15.7	16.0	—	—	—	—	—	—	—	—	—	—	—
Copper	15.5	16.2	17.0	17.3	17.5	17.7	17.8	18.1	18.3	18.5	18.6	18.8	18.9	—	—	—	—
Brass, 66 Cu—34 Zn	16.4	16.7	17.3	17.5	18.0	18.3	18.8	19.2	19.4	19.9	20.4	20.6	21.0	21.4	21.8	—	—
Nickel-copper (Monel)	10.6	11.7	13.1	13.3	13.7	14.0	14.4	14.6	14.8	15.0	15.2	15.4	15.5	15.7	—	—	—
Aluminium	21.2	21.8	23.0	23.4	23.9	24.4	25.0	25.4	—	—	—	—	—	—	—	—	—
Nickel-Cr-iron (Inconel)	10.6	11.0	11.6	11.9	12.2	12.6	13.0	13.4	13.8	14.0	14.4	14.7	15.0	15.3	15.5	15.7	16.0
Nickel	11.2	11.7	12.8	13.0	13.5	13.9	14.0	14.3	14.7	14.8	15.1	15.4	15.5	15.7	15.8	16.0	16.0
Admirality metal	—	—	—	—	—	—	—	20.2	—	—	—	—	—	—	—	—	—

B-2. The values of thermal conductivity are given in Table 18.

TABLE 18 THERMAL CONDUCTIVITY OF METALS IN kcal/m²h (deg C/m)* AT SPECIFIED TEMPERATURE

MATERIAL	TEMPERATURE °C														
	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
Aluminium (annealed)															
grade 1 C	187	185	183	182	180	179	176	176							
grade N 3	165	165	165	165	165	165	165	165							
grade H 20	152	153	155	156	158	158	158	158							
Cast iron	46	46	45	43	42	40	39	39	37						
Carbon steel	45	43	42	40	39	37	36	36	34						
Carbon molybdenum steel (½% Mo)	43	42	40	39	37	37	36	36	34						
Chrome molybdenum steels:															
1 Cr-½ Mo	40	40	39	37	36	36	34	34	31	31					
2¼ Cr-1 Mo	37	36	34	34	33	33	31	31	31	30	30				
5 Cr-½ Mo	31	31	31	30	30	30	30	30	28	28	28				
12 Cr	21	22	22	22	24	24	24	24	24	25	25	25	27		
Austenitic stainless steels															
18 Cr-8 Ni	14	15	15	16	16	18	18	18	19	19	21	21	21	22	22
20 Cr-20 Ni	12	12	13	14	15	16	16	16	18	18	19	21	21	22	22
Admirality metal	104	112	118	125	133										
Naval brass	106	110	115	119	124										
Copper electrolytic	336	336	334	334	332										
Copper & nickel alloys:															
90 Cu-10 Ni	45	46	51	55	63	70	73	73	76	79					
80 Cu-20 Ni	33	34	37	40	58	46	51	51	55	60					
70 Cu-30 Ni	27	28	31	34	37	40	45	45	49	55					
30 Cu-70 Ni	22	22	24	24	25	27	27	27	28	30	30				
Nickel	57	54	49	46	43	42	42	42	43	46	49				
Nickel-chromium-iron	14	14	14	15	15	16	16	16	16	18	18	18	19	19	19

*1 kcal/m² hr (deg C/m) = 0.671 97 BThU/ft²hr (deg F/ft)

B-3. The values of young's modulus for ferrous material, aluminium and aluminium alloys, nickel and nickel alloys, and copper and copper alloys at different temperatures shall be same as given in Tables 3.1, 3.2, 3.3 and 3.4 of IS : 2825-1969* respectively.

*Code for unfired pressure vessels.

APPENDIX C

(*Clauses* 5.2.2 *and* 6.1.1)

ALLOWABLE STRESS VALUES FOR FERROUS AND NON-FERROUS MATERIAL

C-1. STRESS VALUES

C-1.1 The allowable stress values for various material listed **C-2**, at different temperatures, determined by the criteria given in **6.1** and Table 2 are given in Tables 19 to 22.

TABLE 19 ALLOWABLE STRESS VALUES FOR CARBON AND LOW ALLOY STEEL IN TENSION

Material Specification	Grade or Designation	Mechanical Properties			Allowable Stress Values in kgf/mm² at Design Temperature °C												
		Tensile Strength *Min* kgf/mm² R_{20}	Yield Stress *Min* kgf/mm² E_{20}	Percentage Elongation *Min* on Gauge Length $=5.65\sqrt{S_o}$	Up to 250	Up to 300	Up to 350	Up to 375	Up to 400	Up to 425	Up to 450	Up to 475	Up to 500	Up to 525	Up to 550	Up to 575	Up to 600
				plates													
IS : 2002-1962	I	37	0.55 R_{20}	26	9.5	8.7	7.8	7.5	7.2	5.9	4.3	3.6	2.2	—	—	—	—
IS : 2002-1962	2A	42	0.50 R_{20}	25	9.8	9.0	8.1	7.7	7.4	5.9	4.3	3.6	2.2	—	—	—	—
IS : 2002-1962	2B	52	0.50 R_{20}	20	12.1	11.1	10.0	9.5	8.3	5.9	4.3	3.6	2.2	—	—	—	—
IS : 2041-1962	20Mo55	48	28	20	14.3	13.2	12.3	11.9	11.5	11.2	10.8	7.7	5.6	3.7	2.3	1.4	—
IS : 2041-1962	20Mn2	52	30	20	14.0	12.8	11.6	11.0	8.3	5.9	4.3	3.6	2.2	—	—	—	—
IS : 1570-1961	15Cr90Mo55	50	30	20	16.0	15.2	14.4	13.8	13.4	13.0	12.6	11.7	8.6	5.8	3.5	2.1	1.4
IS : 1570-1961	C15Mn75	42	23	25	10.7	9.8	8.9	8.4	8.1	5.9	4.3	3.6	2.2	—	—	—	—
				Forgings													
IS : 2004-1962	Class 2	44	0.50 R_{20}	15	10.2	9.3	8.5	8.0	7.7	5.9	4.3	3.6	2.2	—	—	—	—
IS : 2004-1962	Class 3	50	0.50 R_{20}	21	11.7	10.7	9.6	9.1	8.3	5.9	4.3	3.6	2.2	—	—	—	—
IS : 2004-1962	Class 4	63	0.50 R_{20}	15	14.7	13.4	12.2	11.5	8.3	5.9	4.3	3.6	2.2	—	—	—	—
IS : 1570-1961	20 Mo55	48	28	20	14.3	13.2	12.3	11.9	11.5	11.2	10.8	7.7	5.6	3.7	2.3	1.4	—
IS : 2611-1961	15Cr90Mo55	50	30	20	16.0	15.2	14.4	13.8	13.4	13.0	12.6	11.7	8.6	5.8	3.5	2.1	1.4
IS : 1570-1961	10Cr2Mol	50	32	20	17.9	17.3	16.4	16.1	15.8	15.3	14.9	12.7	9.6	7.0	4.9	3.2	2.3

(*Continued*)

TABLE 19 ALLOWABLE STRESS VALUES FOR CARBON AND LOW ALLOY STEEL IN TENSION — *Contd*

Material Specification	Grade or Designation	Mechanical Properties			Allowable Stress Values in kgf/mm² at Design Temperature °C												
		Tensile Strength *Min* kgf/mm² R_{20}	Yield Stress *Min* kgf/mm² E_{20}	Percentage Elongation *Min* on Gauge Length $=5.65\sqrt{S_o}$	Up to 250	Up to 300	Up to 350	Up to 375	Up to 400	Up to 425	Up to 450	Up to 475	Up to 500	Up to 525	Up to 550	Up to 575	Up to 600
				Tubes and Pipes													
IS : 3609-1966	1Cr-½Mo tube normalized and tempered	44	24	950/R_{20}	12.8	12.1	11.5	11.1	10.7	10.4	10.0	9.7	8.6	5.8	3.5	2.1	1.4
IS : 3609-1966	2¼Cr-1Mo tube normalized and tempered	49	25	950/R_{20}	14.0	13.5	12.8	12.6	12.3	12.0	11.6	11.3	9.6	7.0	4.9	3.2	2.3
IS : 1570-1961	20Mo55	46	25	950/R_{20}	12.8	11.8	11.0	10.6	10.3	10.0	9.6	7.7	5.6	3.7	2.3	1.4	—
IS : 1914-1961	32kgf/mm² *Min* tensile strength	32	0.50R_{20}	950/R_{20}	7.4	6.8	6.2	5.8	5.6	5.0	4.3	3.6	2.2	—	—	—	—
IS : 1914-1961	43kgf/mm² *Min* tensile strength	43	0.50R_{20}	950/R_{20}	10.0	9.2	8.3	7.9	7.6	5.9	4.3	3.6	2.2	—	—	—	—
IS : 2416-1963	32kgf/mm² *Min* tensile strength	32	0.50R_{20}	950/R_{20}	7.4	6.8	6.2	5.8	5.6	5.0	4.3	3.6	2.2	—	—	—	—
IS : 1978-1961	St 18	31.6	17.6	—	8.2	7.5	6.7	6.4	6.2	5.9	4.3	3.6	2.2	—	—	—	—
	St 20	33.7	19.7	—	9.2	8.4	7.6	7.2	6.9	5.9	4.3	3.6	2.2	—	—	—	—
	St 21	33.7	21.1	—	9.8	9.0	8.1	7.7	7.4	5.9	4.3	3.6	2.2	—	—	—	—
	St 25	42.2	24.6	—	11.5	10.5	9.5	9.0	8.3	5.9	4.3	3.6	2.2	—	—	—	—
IS : 1979-1961	St 30	42.2	29.5	—	13.8	12.6	11.5	10.8	8.3	5.9	5.3	3.6	2.2	—	—	—	—
	St 32	44.3	32.3	—	15.0	13.8	12.5	11.8	8.3	5.9	4.3	3.6	2.2	—	—	—	—
	St 37	46.4	36.6	—	17.1	15.6	14.1	13.4	8.3	5.9	4.3	3.6	2.2	—	—	—	—

(Continued)

TABLE 19 ALLOWABLE STRESS VALUES FOR CARBON AND LOW ALLOY STEEL IN TENSION — *Contd*

MATERIAL SPECIFICATION	GRADE OR DESIGNATION	MECHANICAL PROPERTIES			ALLOWABLE STRESS VALUES IN kgf/mm² AT DESIGN TEMPERATURE °C												
		Tensile Strength *Min* kgf/mm² R_{20}	Yield Stress *Min* kgf/mm² E_{20}	Percentage Elongation *Min* on Gauge Length $=5.65\sqrt{S_o}$	Up to 250	Up to 300	Up to 350	Up to 375	Up to 400	Up to 425	Up to 450	Up to 475	Up to 500	Up to 525	Up to 550	Up to 575	Up to 600
				*Castings**													
IS : 3038-1965	Grade 1	55	35	17	12.2	11.2	10.1	9.6	6.2	4.4	3.2	2.7	1.6	—	—	—	—
	Grade 2	47	25	17	9.6	8.8	8.2	8.0	7.7	7.5	7.2	5.8	4.2	2.8	1.7	1.0	—
	Grade 3	52	31	15	11.9	11.0	10.2	9.9	9.6	9.3	8.4	5.8	4.2	2.8	1.7	1.0	—
	Grade 4	49	28	17	11.2	10.6	10.1	9.7	9.3	9.1	8.8	8.5	6.5	4.4	2.6	1.7	1.0
	Grade 5	52	31	17	13.0	12.5	11.9	11.7	11.4	11.1	10.8	9.5	7.2	5.3	3.7	2.4	1.7
	Grade 6	63	43	15	17.2	16.3	15.5	14.9	14.4	14.0	13.5	6.7	4.9	3.5	2.6	1.7	0.9
IS : 2856-1964	C Sw-C20	42	21	20	7.3	6.7	6.1	5.7	5.5	4.4	3.2	2.7	1.6	—	—	—	—
	C Sw-C25	49	25	18	8.7	8.0	7.2	6.8	6.2	4.4	3.2	2.7	1.6	—	—	—	—
			Rivet and Stay Bar														
IS : 1990-1962		37	0.55 R_{20}	26	8.6	7.9	7.1	6.8	6.5	5.9	4.3	3.6	2.2	—	—	—	—
		42	0.55 R_{20}	23	11.2	9.8	8.9	8.4	8.1	5.9	4.3	3.6	2.2	—	—	—	—
			Structural Steel Sections, Plates and Bars														
IS : 226-1962	St 42-S	42	24	23	11.2	10.1	9.2										
IS : 961-1962	St 55 HTW	50	29	20	13.3	12.0	11.0										
IS : 2062-1962	St 42-W	42	23	23	11.2	10.1	9.2										

*These values have been based on a quality factor of 0.75. For additional inspection as detailed in Note to Table 2, a quality factor of 0.9 will be used and the above stress values increased proportionally.

TABLE 20 ALLOWABLE STRESS VALUES FOR HIGH ALLOY STEELS IN TENSION

(*Clauses* 5.2.2 *and* 6.2.1.1)

MATERIAL SPECIFICATION	DESIGNATION	PRODUCT	REMARKS	MECHANICAL PROPERTIES			ALLOWABLE STRESS VALUES IN kgf/mm^2 AT DESIGN TEMPERATURE °C							
				Tensile Strength kgf/mm^2 *Min* R_{20}	Yield Stress kgf/mm^2 *Min* E_{20}	Elongation per-cent *Min* Gauge Length $= 5.65\sqrt{S_o}$	Up to 50	Up to 100	Up to 150	Up to 200	Up to 250	Up to 300	Up to 350	Up to 400
IS : 1570-1961	O4Cr19Ni9	Plates, sections, bars, forgings and seamless tubes	Austenitic stainless steels	55	24	28	13.62	12.58	11.30	10.06	9.45	8.82	8.55	8.43
	O4Cr19Ni9 Ti20			55	24	28	14.12	14.12	13.86	13.20	12.70	12.32	12.10	11.85
	O4Cr19Ni9 Nb40			55	24	28	14.12	14.12	13.86	13.20	12.70	12.32	12.10	11.85
	O5Cr18Ni11 Mo3			55	24	28	14.12	13.84	12.60	11.30	10.69	10.05	9.80	9.70
	O5Cr19Ni9 Mo3Ti20			55	24	28	14.12	13.84	12.60	11.30	10.69	10.05	9.80	9.70
IS : 3444-1966	Grade 7	Castings*	—	47	21	21	10.60	10.60	10.40	9.90	9.52	9.25	9.06	8.90
	Grade 8	Castings*	—	47	21	21	10.60	10.60	10.40	9.90	9.52	9.25	9.06	8.90
	Grade 11	Castings*	—	47	21	15	10.60	10.40	9.45	8.47	8.00	7.55	7.35	7.26
	Grade 13	Castings*	—	47	21	15	10.40	10.40	9.45	8.87	8.00	7.55	7.35	7.26

*These values have been based on a quality factor of 0.75. For additional inspection as detailed in Note to Table 2, a quality factor of 0.9 shall be used and the above stress values increased accordingly.

TABLE 21 ALLOWABLE STRESS VALUES FOR ALUMINIUM AND ALUMINIUM ALLOYS IN TENSION

(*Clauses* 5.2.2 *and* 6.1.1)

Material Specification	Grade	Products	Condition	Mechanical Properties: Tensile Strength *Min* kgf/mm^2	Mechanical Properties: 0.1 percent Proof Stress *Min* kgf/mm^2	Mechanical Properties: Elongation on $4\sqrt{S_o}$ *Min* Percent	Allowable Stress Values in kgf/mm^2 at Design Temperature °C: Up to 50	Up to 75	Up to 100	Up to 125	Up to 150	Up to 175	Up to 200	Remarks
IS : 736-1965	PIB	Plate	M	6.5		30								
IS : 737-1965	SIB	Sheet, strip	O	6.5		30	1.36	1.27	1.16	1.05	0.95	0.84	0.74	
IS : 733-1967	EIB	Bars, rods	M	6.5		25								
IS : 1285-1968	VIB	Extruded	M	6.5		25								
IS : 736-1965	PIB	Plate	½H	10		8	2.11	2.08	2.00	1.90	1.65	1.41	1.12	Mechanical properties are those of solution and precipitation heated material
IS : 737-1965	SIB	Sheet, strip	½H	10		8								
IS : 736-1965	NP3	Plate	O	9.5		25	2.30	2.22	2.00	1.89	1.69	1.48	1.26	
IS : 737-1965	NS3	Sheet, strip	O	10		30	2.30	2.22	2.00	1.89	1.69	1.48	1.26	
IS : 737-1965	NS3	Sheet, strip	½H	14		7	3.46	3.37	3.25	3.09	2.82	2.46	2.18	
IS : 736-1965	NP4	Plate	M	19		12								
IS : 737-1965	NS4	Sheet, strip	O	17.5		18								
IS : 733-1967	NE4	Bars, rods	M	17.5		18	4.35	4.35	4.32	4.20	3.80	3.27	2.46	
IS : 738-1966	NT4	Drawn tube	O	17.5		18								
IS : 1285-1968	NV4	Extruded tubes	M	17.5		18								
IS : 737-1965	NS4	Sheet, strip	½H	20.5		8	5.45	5.42	5.27	4.98	4.50	3.94	2.46	
IS : 738-1966	NT4	Drawn tube	½H	25	12.5	5	5.97	5.95	5.78	5.40	4.85	4.28	2.46	
IS : 737-1965	NS4	Sheet, strip	½H	23.5	17.5	5								
IS : 737-1965	NS5	Sheet, strip	O	22		18								
IS : 733-1967	NE5	Bars, rods and sections	M	22		18	5.49*	—	—	—	—	—	—	
IS : 738-1967	NT5	Drawn tubes	O	22		18								
IS : 1285-1968	NV5	Hollow section	M	22		18								
IS : 737-1965	NS6	Sheet, strip	O	27		18								
IS : 738-1966	NT6	Drawn tubes	O	27	12.5	18								
IS : 736-1965	NP6	Plate	O	27	10	20	6.68*	—	—	—	—	—	—	
IS : 733-1967	NE6	Bars, rods	M	27		18								
IS : 1285-1968	NV6	Extruded tubes	M	27		18								

*Up to 65°C.

(*Continued*)

TABLE 21 ALLOWABLE STRESS VALUES FOR ALUMINIUM AND ALUMINIUM ALLOYS IN TENSION — *Contd*

Material Specification	Grade	Products	Condition	Mechanical Properties			Allowable Stress Values in kgf/mm² at Design Temperature °C							Remarks
				Tensile Strength *Min* kgf/mm²	0.1 Percent Proof Stress *Min* kgf/mm²	Elongation on $4\sqrt{S_o}$ *Min* Percent	Up to 50	Up to 75	Up to 100	Up to 125	Up to 150	Up to 175	Up to 200	
IS : 733-1967	NE8	Bars, rods and sections	O	27	12.5	16	7.02	—	—	—	—	—	—	
IS : 1285-1968	HV9	Extruded round tubes hollow section	M	11		15	2.97	2.90	2.78	2.67	2.53	1.93	1.33	
IS : 1285-1968	HV9	,,	P	15.5	11.0	10	3.74	3.61	3.38	3.24	2.95	2.18	1.41	
IS : 1285-1968	HV9	,,	WP	19	15.5	12	5.15	4.91	4.65	4.29	3.16	2.18	1.41	
IS : 736-1966	HP30	Plate	W	20.5	11.0	15								
IS : 734-1967	HF30	Forging	W	19.0	11.0	18								
IS : 737-1965	HS30	Sheet, strip	W	20.5	11.0	15	5.18	5.01	4.86	4.71	4.50	3.94	2.81	
IS : 733-1967	HE30	Bars, rods and sections	W	19.0	11.0	18								
IS : 738-1966	HT30	Drawn tube	W	22.0	11.0	16								
IS : 738-1966	HT30	Drawn tube	WP	31.5	25.0	7								
IS : 736-1966	HP30	Plate	WP	30	23.5	8								
IS : 734-1967	HF30	Forging	WP	30	25	10	7.29	7.10	6.85	6.60	5.56	4.36	3.10	
IS : 737-1965	HS30	Sheet, strip	WP	30	25.5	8								
IS : 733-1967	HE30	Bars, rods and sections	WP	30	25.0	10								
IS : 1284-1966	HB15	Bolting alloy	WP	44	38.0	8.82	8.82	8.45	7.95	7.30	5.06	3.09	2.11	
IS : 1284-1966	NB6	Bolting alloy	½H	31.5	23.5	—	7.65	—	—	—	—	—	—	
IS : 1284-1966	HB30	Bolting alloy	WP	31.5	27	—	5.85	5.70	5.48	5.27	4.43	3.44	2.32	
IS : 617-1959	A-3	Casting alloy	M (sand cast)	16.5	—	8.0*	2.59	2.36	2.25	2.14	1.90	1.72	1.55	
			M (chill cast)	18.9	—	12.0*	2.96	2.66	2.56	2.46	2.18	1.97	1.76	

*The values are based on 50.8 mm test piece.

TABLE 22 ALLOWABLE STRESS VALUES FOR COPPER AND COPPER ALLOYS IN TENSION

(*Clauses* 5.2.1 *and* 6.1.1)

Material Specification	Grade	Mechanical Properties: Tensile Strength *Min* kgf/mm²	Mechanical Properties: Yield Stress *Min* kgf/mm²	Mechanical Properties: Elongation Per-cent *Min*	Allowable Stress Values in kgf/mm² at Design Temperature °C: Up to 50	Up to 75	Up to 100	Up to 125	Up to 150	Up to 175	Up to 200	Up to 225	Up to 250	Up to 275	Up to 300	Up to 325	Up to 350
Plate, Sheet and Strip																	
IS : 410-1967	CuZn 30	28	—	45	7.03	7.03	7.03	7.03	6.96	5.70	3.83	2.46	—	—	—	—	—
	CuZn 37	28	—	45	8.79	8.67	8.30	7.81	7.28	5.38	2.00	—	—	—	—	—	—
	CuZn 40	28	—	30	8.79	8.67	8.30	7.81	7.28	5.38	2.00	—	—	—	—	—	—
IS : 1972-1961	All grades	22.5	—	35	4.71	4.66	4.54	4.30	3.47	2.71	1.90	—	—	—	—	—	—
Bars and Rods																	
IS : 288-1960		40	—	22	7.03	7.03	7.03	7.03	6.96	5.70	3.83	2.46	—	—	—	—	—
IS : 4171-1967		40	—	22	7.03	7.03	7.03	7.03	6.96	5.70	3.83	2.46	—	—	—	—	—
Bolting Material																	
IS : 288-1960		40	—	22	1.76	1.76	1.76	1.67	1.54	1.48	1.41	—	—	—	—	—	—
IS : 4171-1967		40	—	22	1.76	1.76	1.76	1.67	1.54	1.48	1.41	—	—	—	—	—	—
Sections																	
IS : 291-1966	Grade 1	35	—	20	8.79	8.67	8.30	7.81	7.28	5.38	2.00	—	—	—	—	—	—
	Grade 2	35	—	20	8.79	8.67	8.30	7.81	7.28	5.38	2.00	—	—	—	—	—	—
Tubes																	
IS : 407-1961	Alloy 1	29	—	—	7.03	7.03	7.03	7.03	6.96	5.70	3.83	—	—	—	—	—	—
	Alloy 2	29	—	—	8.79	8.67	8.30	7.81	7.28	5.38	2.00	—	—	—	—	—	—
IS : 1545-1969	CuZn 30As	—	—	—	7.03	7.03	7.03	7.03	6.96	5.70	3.83	—	—	—	—	—	—
	CuZn29Sn1As	—	—	—	8.44	8.44	8.44	8.44	8.28	5.43	2.58	1.58	—	—	—	—	—
	CuZnAl2As CuAl7	—	—	—	8.76	8.67	8.53	8.34	8.09	7.09	4.64	3.16	1.88	—	—	—	—
	CuZn21Al2As	32	—	—	8.44	8.44	8.44	8.44	8.28	5.43	2.58	1.58	—	—	—	—	—
	CuNi31Mn1Fe	42	—	—	8.31	8.08	7.89	7.71	7.59	7.58	7.27	7.14	7.11	6.92	6.83	6.73	6.66
IS : 2501-1963		—	—	—	4.22	4.19	4.13	4.00	3.47	2.71	1.90	—	—	—	—	—	—
Castings																	
IS : 318-1962	Grade 1	22	11.5	12	5.94	5.88	5.82	5.76	5.69	5.56	5.38	5.13	4.78	4.00	—	—	—
	Grade 2	19	11	7.5	5.21	5.09	4.96	4.84	4.77	4.65	4.58	—	—	—	—	—	—
	Grade 3	17.5	7.5	7.0	4.30	4.12	3.90	3.78	3.65	3.52	3.50	—	—	—	—	—	—

C-2. LIST OF INDIAN STANDARDS ON MATERIAL SPECIFIED IN TABLES 19 TO 22

Sl No.	*No. of the Standard*	*Title*
1)	*IS : 226-1962	Specification for Structural Steel (Standard Quality)
2)	IS : 288-1960	Specification for Copper Rods for Boiler Stay Bolts and Rivets (*Revised*)
3)	IS : 291-1956	Specification for Naval Brass Rods and Sections (*Revised*)
4)	IS : 318-1962	Leaded Tin Bronze Ingots and Castings (*Revised*)
5)	*IS : 407-1961	Specification for Brass Tubes for General Purposes (*Revised*)
6)	IS : 410-1967	Specification for Rolled Brass Plate, Sheet, Strip and Foil (*Second Revision*)
7)	IS : 617-1959	Specification for Aluminium and Aluminium Alloy Ingots and Castings for General Engineering Purposes (*Revised*)
8)	IS : 733-1967	Specification for Wrought Aluminium and Aluminium Alloys, Bars, Rods and Sections (for General Engineering Purposes) (*First Revision*)
9)	IS : 734-1967	Specification for Wrought Aluminium and Aluminium Alloys, Forgings (for General Engineering Purposes) (*First Revision*)
10)	IS : 736-1965	Specification for Wrought Aluminium and Aluminium Alloys, Plate for General Engineering Purposes (*Revised*)
11)	IS : 737-1965	Specification for Wrought Aluminium and Aluminium Alloys, Sheet and Strip (for General Engineering Purposes) (*Revised*)
12)	IS : 738-1966	Specification for Wrought Aluminium and Aluminium Alloys, Drawn Tube (for General Engineering Purposes) (*Revised*)
13)	IS : 961-1962	Specification for Structural Steel (High Tensile) (*Revised*)
14)	IS : 1284-1966	Specification for Wrought Aluminium Alloys, Bolt and Screw Stock (for General Engineering Purposes) (*Revised*)
15)	IS : 1285-1968	Specification for Wrought Aluminium and Aluminium Alloys, Extruded Round Tube and Hollow Sections (for General Engineering Purposes) (*Revised*)

*Since revised.

Sl No.	*No. of the Standard*	*Title*
16)	IS : 1545-1969	Specification for Solid Drawn Copper Alloy Tubes (*First Revision*)
17)	IS : 1570-1961	Schedules for Wrought Steels for General Engineering Purposes
18)	IS : 1914-1961	Specification for Carbon Steel Boiler Tubes and Superheater Tubes
19)	IS : 1972-1961	Specification for Copper Plate, Sheet and Strip for Industrial Purposes
20)	IS : 1978-1961	Specification for Line Pipe
21)	IS : 1979-1961	Specification for High-Test Line Pipe
22)	IS : 1990-1962	Specification for Steel Rivet and Stay Bars for Boilers
23)	IS : 2002-1962	Specification for Steel Plates for Boilers
24)	IS : 2004-1962	Specification for Carbon Steel forgings (for General Engineering Purposes)
25)	IS : 2011-1962	Specification for Steel Plates for Pressure Vessels
26)	*IS : 2062-1962	Specification for Structural Steel (Fusion Welding Quality)
27)	IS : 2416-1963	Specification for Boiler and Superheater Tubes for Marine and Naval Purposes
28)	IS : 2501-1963	Specification for Copper Tubes for General Engineering Purposes
29)	IS : 2611-1964	Specification for Carbon Chromium Molybdenum Steel Forgings for High Temperature Service
30)	IS : 2856-1964	Specification for Carbon Steel Castings Suitable for High Temperature Service (Fusion Welding Quality)
31)	IS : 3038-1965	Specification for Alloy Steel Castings for Pressure Containing Parts Suitable for High Temperature Service
32)	IS : 3444-1966	Specification for Corrosion Resistant Steel Castings
33)	IS : 3609-1966	Specification for Chrome Molybdenum Steel, Seamless Boiler and Superheater Tubes
34)	IS : 4171-1967	Specification for Copper Rods for General Engineering Purposes

*Since revised.

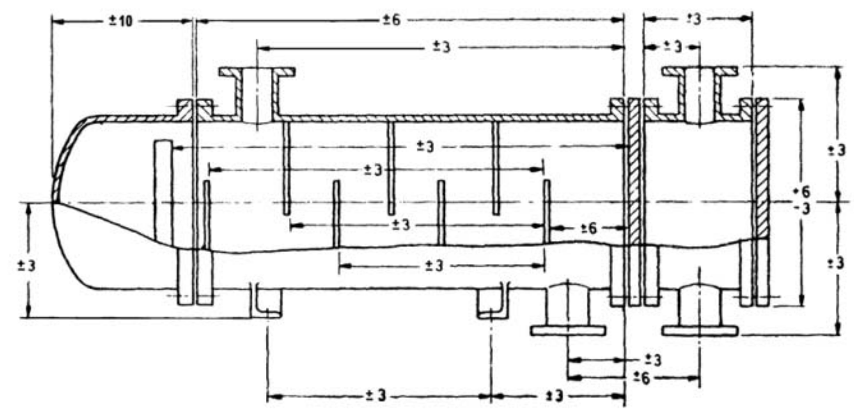
APPENDIX D

(*Clauses* 9.3.1 *and* 19.4)

STANDARD TOLERANCES FOR EXTERNAL DIMENSIONS, NOZZLES AND SUPPORT LOCATIONS

All dimensions in millimetres.

(Tolerances are not cumulative)



APPENDIX E

(*Clause* 11.1.3)

TUBE SHEET THICKNESS CALCULATION

E-1. SYMBOLS

E-1.1 The following symbols and values shall be used in the design procedure for determining the tube plate thickness:

A = cross-sectional area of bore of shell

$$= \frac{\pi D^2}{4} \text{ mm}^2$$

a = cross-sectional area of metal in one tube, in mm^2

B = cross-sectional area of shell plate

$$= \pi\ (D + t)t \text{ mm}^2$$

C = cross-sectional area of tube holes in the tube plate

$$= \frac{n\pi d^2}{4} \text{ mm}^2$$

c = corrosion allowance in mm

D = bore of cylindrical shell in mm

D_i = diameter of the largest inscribed circle which can be drawn within an unpierced portion of the tube plate in mm

d = outside diameter of tubes in mm

E_s = modulus of elasticity* for shell, in kgf/mm^2

E_t = modulus of elasticity* for tubes, in kgf/mm^2

f = design stress in kgf/mm^2

$\left.\begin{matrix} G_1 \\ G_2 \\ G_3 \end{matrix}\right\}$ = non-dimensional functions of k (*see* Fig. 9, 10 and 11)

h = thickness of the tube plate, excluding corrosion allowance, in mm

*For values of modulus of elasticity for various materials such as ferrous, aluminium, copper and nickel at different temperatures, *see* Tables 3.1 to 3.4 of IS : 2825-1969.

k = non-dimensional factor dependent upon heat exchanger dimensions [*see* **E-2.1** (b)]

L = effective length of the tubes, mm

n = number of tubes

P_r = radial stress in tube plate, kgf/mm^2

P_t = longitudinal stress in tubes, kgf/mm^2

p = equivalent pressure difference

$$= p_1 - p_2 - p_2 \frac{na}{A - C} \text{kgf/cm}^2$$

$= p_1 - p_2 (1 + \beta)$ kgf/cm^2 where β is defined below:

p_1 = gauge pressure outside tubes, kgf/cm^2

p_2 = gauge pressure outside tubes, kgf/cm^2

p_d = maximum pressure difference which can occur across tube plate in service, kgf/cm^2

$$p_b = p_1 - p_2 \left(1 + \beta + \frac{Q}{\lambda} \right) + 100\, \beta\, y\, E_t$$

p_r = effective pressure difference due to the combined pressure difference p and the differential expansion y,

$$= p + 100 \times \frac{yE_t\, \eta a}{A - C} = p + 100\, \beta\, y\, E_t \text{ kgf/cm}^2$$

$$Q = \frac{E_t\, \eta .\, a}{E_s - B}$$

t = thickness of shell, mm

α_s = coefficient of linear expansion* of the shell per deg C

α_t = coefficient of linear expansion* of the tube per deg C

y = total differential strain

$$\alpha_t (\theta_t - \theta_r) - \alpha_s (\theta_s - \theta_r)$$

$$\lambda = \frac{A - C}{A}$$

*See Appendix B, for values of coefficient of thermal expansion.

μ = ligament efficiency assumed equal to 0.4 for single-pass heat exchangers, 0.5 for two-pass heat exchangers, 0.6 for four-pass heat exchangers in the absence of an authoritative alternative.

η = deflection efficiency assumed equal to λ in the absence of an authoritative alternative

θ_s = temperature of the shell, °C

θ_t = temperature of the tubes, °C

θ_r = assembly temperature, °C

$\beta = \frac{na}{A - C}$

E-2. THICKNESS OF TUBE PLATES

E-2.1 A summary of the design formulæ to be used for determining the thickness of tube plates is given in Table 23. These are not suitable for direct determination and a process of trial and error must be followed, the procedure for which is as follows:

a) Assume a likely value for the plate thickness, h.

   Where the tubes are roller-expanded into the tube plate, the thickness of the plate shall be sufficient to ensure an adequate grip between the tubes and plate. A plate thickness of not less than $d/2$ and not more than d is likely to be required for this purpose.

b) Obtain the value of k from Equation E-1:

$$k^2 = 1.32 \frac{D}{h} \sqrt{\frac{n.a}{\eta L.h}} \qquad \ldots \qquad \text{(E-1)}$$

c) From Fig. 9, 10 and 11 obtain the values of G_1, G_2, G_3 using the following criteria to decide the type of support which is applicable

Plate held in joint which effectively prevents angular deflection at the periphery and full faced joint	Clamped support
Narrow joint face or trapped ring	Simple support
Wide gasket joint inside bolt holes	Half-way between simple and clamped support.

d) Using the appropriate formulæ in Table 23 determine the value of $P_{r\,\mathrm{Max}}$ and $P_{t\,\mathrm{Max}}$.

e) Depending upon the magnitudes of the values obtained for $P_{r\,\mathrm{Max}}$ and $P_{t\,\mathrm{Max}}$ as compared with the design stresses given in Tables 19 to 22 choose where necessary another value of h to bring one of the values of $P_{r\,\mathrm{Max}}$ and $P_{t\,\mathrm{Max}}$ close to, but neither exceeding, the design stress permitted.

f) Add the appropriate corrosion allowance c to the value obtained for h.

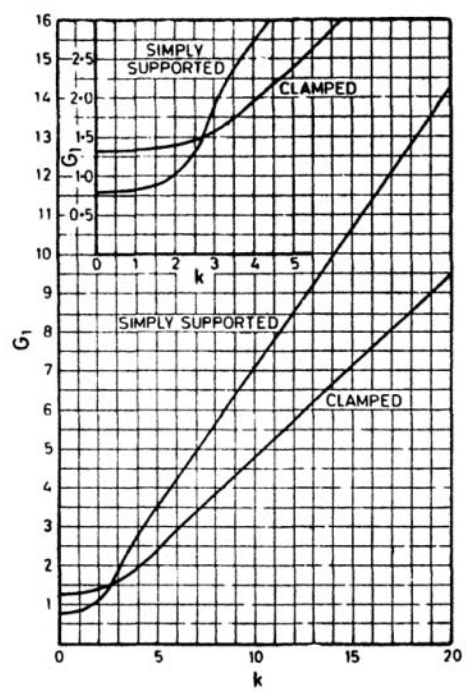


FIG. 9 VALUES FOR G_1

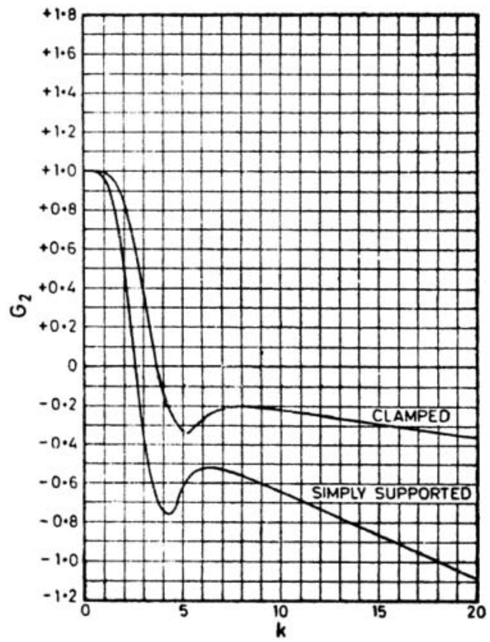


FIG. 10 VALUES FOR G_2

E-3. THICKNESS OF NON-UNIFORMLY PIERCED TUBE PLATES

E-3.1 Tube plates in which the tubes are not spaced uniformly over their whole area may contain unpierced portions of appreciable extent deriving no support from the tube bundle. The thickness of such a tube plate shall be not less than:

$$c + \frac{D_i}{10}\sqrt{\frac{p_d}{2f}} \quad \ldots \quad \ldots \quad \text{(E-2)}$$

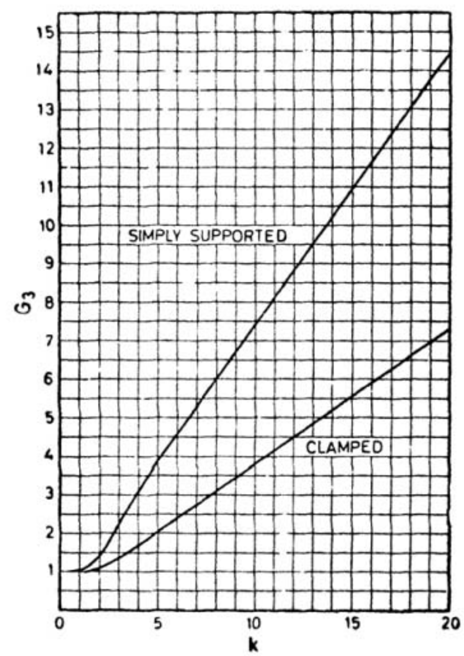


FIG. 11 VALUES FOR G_3

TABLE 23 SUMMARY OF DESIGN FORMULAE FOR HEAT EXCHANGER TUBE PLATES
[*Clause* D-2.1 (d)]

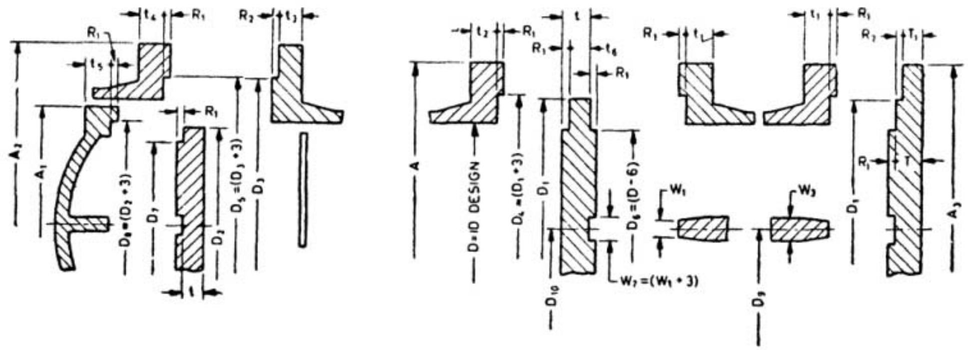
TYPE OF HEAT EXCHANGER	P_r *Max* (Value may be either positive or negative depending upon the side of the tube plate to which the stress applies)	P_t *Max* (Positive value denotes tensile stress Negative value denotes compressive stress)	DESIGN CONDITIONS TO CONSIDER
Fixed Tube Plate (*see* Fig. 1)	$\frac{\lambda_{pb}}{400\ \mu\ G_1(Q+G_3)}\left(\frac{D}{h}\right)^2$	Either $\frac{1}{100\beta}\left(p-\frac{p_b G_2}{Q+G_3}\right)$ or $\frac{1}{100\beta}\left(p-\frac{p_b G_3}{Q+G_3}\right)$	Simultaneous values of p_1, p_2 and y which may occur in service giving rise to the highest numerical value of P_b.
Floating Head (*see* Fig. 4, 5 & 6)	$\frac{p_1-p_2}{400\ \mu\ G_1}\left(\frac{D}{h}\right)^2$	Either $\frac{1}{100\beta}\left(p-\frac{(p_1-p_2)G_2}{\lambda}\right)$ or $\frac{1}{100\beta}\left(p-\frac{(p_1-p_2)G_3}{\lambda}\right)$	Simultaneous values of p_1 and p_2 which may occur in service giving rise to the highest numerical value of p_1-p_2.
Floating Head External Packed (*see* Fig. 7)	$\frac{p_2}{400\ \mu\ G_1}\left(\frac{D}{h}\right)^2$	Either $\frac{1}{100\beta}\left(p+\frac{p_2 G_2}{\lambda}\right)$ or $\frac{1}{100\beta}\left(p+\frac{p_2 G_3}{\lambda}\right)$	The highest value of p_2 which may occur in service.
Hair-Pin U-Tube (*see* Fig. 2 & 3)	$\frac{0.309\ (p_1-p_2)}{100\ \mu}\left(\frac{D}{h}\right)^2$ (simply supported) $\frac{0.187\ 5\ (p_1-p_2)}{100\ \mu}\left(\frac{D}{h}\right)^2$ (clamped)	$\frac{(p_1-p_2).C}{100\ n.a}-P_2$	Simultaneous values of p_1 and p_2 which may occur in service giving rise to the highest numerical value of p_1-p_2.

APPENDIX F

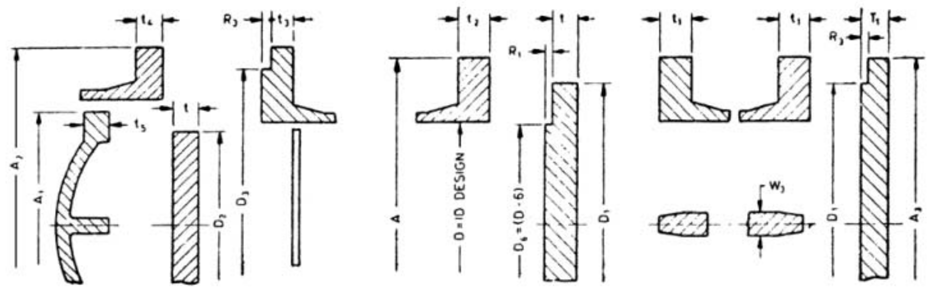
(*Clauses* 11.2.10 *and* 15.5.2)

STANDARD TOLERANCES FOR TUBE SHEETS PARTITIONS, COVERS AND SHELL FLANGES

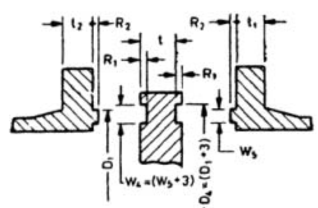
All dimensions in millimetres.



STANDARD CONFINED JOINT CONSTRUCTION



STANDARD UNCONFINED PLAIN FACE JOINT CONSTRUCTION



ALTERNATE TONGUE AND GROOVE JOINT

DIMENSIONS	TOLERANCES
A, A_1, A_2, A_3	$+6$ -3
D_1, D_2, D_3, D_4, D_5, D_8	± 1
D_6, D_7	± 1.5
D_9	± 1
D_{10}	± 0.5
R_1	$+0$ -1
R_2, R_3	$+1$ -0
t, t_6	± 1
t_1, t_2, t_3, t_4, t_5	± 1.5
T, T_1	$+3$ -1
W_1, W_3, W_5	± 1
W_2, W_4	$+1.5$ -0

APPENDIX G

[*Clause* 21.2.3 (c)]

TEST RING FOR HYDRAULIC TEST

G-1. When the shell side of a heat exchanger is being pressure tested, it is usual to remove the channel cover so that any leak between the tubes and the tube-sheet can be observed. In the case of internal floating head type exchangers (Fig. 4 and 5) because of the gap between the tube-sheet and the shell, it would not be possible to remove the cover during the pressure-test. This difficulty is overcome by fixing the floating tube-sheet to the shell by means of a test ring.

A typical test ring is shown in Fig: 12.

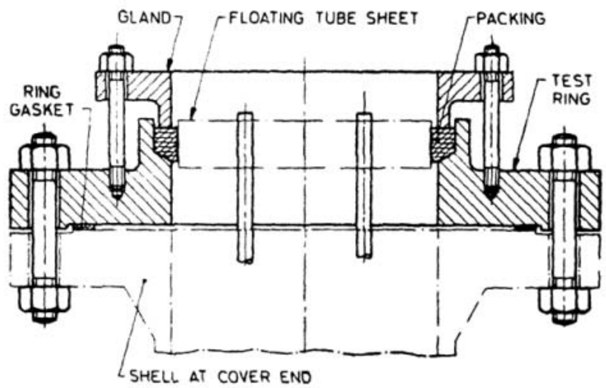


FIG. 12 TEST RING

(*Continued from page* 2)

Members	*Representing*
SHRI G. CODD	Lloyd's Register of Shipping, Bombay
SHRI P. K. A. NARAYANAN (*Alternate*)	
SHRI S. C. DEY	Government of Assam, Shillong
DR H. E. EDULJEE	Indian Chemical Manufacturer's Association, Calcutta
SHRI R. H. ACHARYA (*Alternate*)	
SHRI H. H. JETHANANDANI	The Fertilizer Corporation of India Ltd, Sindri
SHRI R. V. KULKARNI	National Chemical Laboratory (CSIR), Poona
PROF N. R. KULOOR	Indian Institute of Science, Bangalore
SHRI J. B. MALIK	Burmah-Shell Refineries Ltd, Bombay
SHRI P. C. SILAICHIA (*Alternate*)	
SHRI N. R. PATRAWALA	Itlab Engineering Private Ltd, Bombay
SHRI G. K. RAJU	ACC-Vickers Babcock Ltd, Durgapur
SHRI P. K. SEN (*Alternate*)	
SHRI S. S. SACHDEVA	Indian Institute of Petroleum (CSIR), Dehra Dun
SHRI H. K. MULCHANDANI (*Alternate*)	
SHRI N. P. SINGH	Heavy Electricals (India) Ltd, Bhopal
SHRI N. THANDAVAN	The A. P. V. Engineering Co Private Ltd, Calcutta

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards : Monthly Additions'.

This Indian Standard has been developed by Technical Committee : EDC 57

Amendments Issued Since Publication

Amend No.	Date of Issue
Amd. No. 1	Incorporated earlier
Amd. No. 2	Incorporated earlier
Amd. No. 3	July 1983

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002. Telegrams: Manaksanstha
Telephones: 323 01 31, 323 33 75, 323 94 02 (Common to all offices)

Regional Offices:		Telephone
Central	: Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	323 76 17 323 38 41
Eastern	: 1/14 C. I. T. Scheme VII M, V. I. P. Road, Kankurgachi KOLKATA 700054	337 84 99, 337 85 61 337 86 26, 337 91 20
Northern	: SCO 335-336, Sector 34-A, CHANDIGARH 160022	60 38 43 60 20 25
Southern	: C. I. T. Campus, IV Cross Road, CHENNAI 600113	235 02 16, 235 04 42 235 15 19, 235 23 15
Western	: Manakalaya, E9 MIDC, Marol, Andheri (East) MUMBAI 400093	832 92 95, 832 78 58 832 78 91, 832 78 92

Branches : AHMEDABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR. NALAGARH. PATNA. PUNE. RAJKOT. THIRUVANANTHAPURAM. VISHAKHAPATNAM