

JIS

JAPANESE INDUSTRIAL STANDARD

Shell and Tube Heat Exchangers

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JAPANESE INDUSTRIAL STANDARD

J I S

Shell and Tube Heat Exchangers

B 8249-1978

1. General

1.1 Scope This Japanese Industrial Standard specifies the evaporators, heaters, condensers, coolers and metallic shell and tube heat exchangers corresponding to those, hereinafter referred to as the "heat exchangers", which are manufactured in accordance with JIS B 8243 and to be used in general industries (Class I⁽¹⁾ equivalent), chemical industries (Class II⁽²⁾ equivalent) and oil industries (Class III⁽³⁾ equivalent). Those which are listed in the following, however, are excluded:

- (1) Heat exchangers whose heat exchanger tubes are of fin-tube type and the like.
- (2) Heat exchangers whose inside diameter of the shell exceeds 1500 mm. However, the inside diameter of kettle type shell is not included.
- (3) Heat exchangers whose design pressure exceeds 300 kgf/cm^2 { 30 MPa }.
- (4) Heat exchangers whose design temperature exceeds 550 °C.
- (5) Heat exchangers whose operational conditions exhibit extraordinary conditions, such as extreme thermal stresses and thermal shocks.

Notes (1) The heat exchanger is operated under comparatively mild conditions. Principally for general industries.

(2) The heat exchanger is operated under comparatively moderate conditions. Principally for chemical industries.

(3) The heat exchanger is operated under comparatively severe condition. Principally for oil industries.

Remark: In this standard, units and numerical values given in { } are in accordance with the International System of Units (SI), and are given for reference.

1.2 Range to Be Defined as Heat Exchanger The range to be defined as the heat exchanger shall cover from the heat exchanger body proper up to the part nearest to the heat exchanger of the welding joint, flange joint or screw joint, with which the apparatus outside the heat exchanger is jointed.

1.3 Definitions For the purpose of this standard, the following main definitions apply:

- (1) Shell side - The part through which the flow outside of the heat exchanger tubes passes.
- (2) Tube side - The part through which the flow inside of the heat exchanger tubes passes.
- (3) Heating surface area - This is expressed by the area of the part (total area of the external surface of the heat exchanger tubes within the shell-side face of the tube plates) (m^2) on which the giving and receiving of heat are performed between the shell-side and tube-side flows to each other. Whether the bent portions of the U- tubes are to be included or not shall be as agreed upon between the parties concerned.

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- (4) Pass - A passage of flow along which the fluid flows in the mass from the inlet nozzle stub to the outlet nozzle stub over the lengthwise direction of the shell or lengthwise direction of the heat exchanger tubes.
- (5) Number of passes - A number of change of flow direction by 180 degrees in the lengthwise direction of the heat exchanger plus one, is defined as a number of passes.

1.4 Classification and Names

1.4.1 Classification The heat exchangers shall be classified according to the shape of the stationary head, shell and rear head, and be in accordance with Fig. 1.

Furthermore, the heat exchangers are expressed by arranging the classification symbols of each part in the order of stationary head, shell and rear head. The representative examples are shown in Fig. 2.

Fig. 1

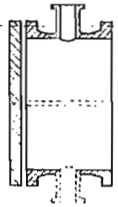
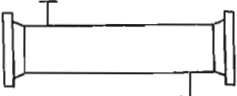
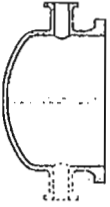
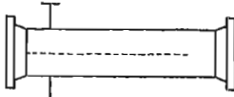
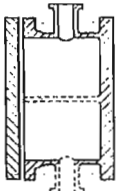
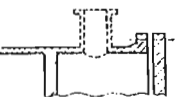
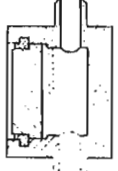
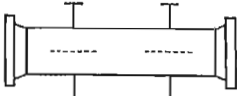
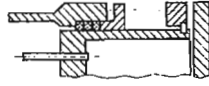
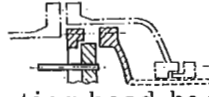
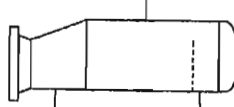
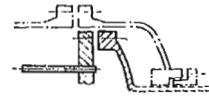
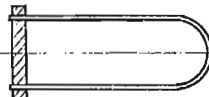
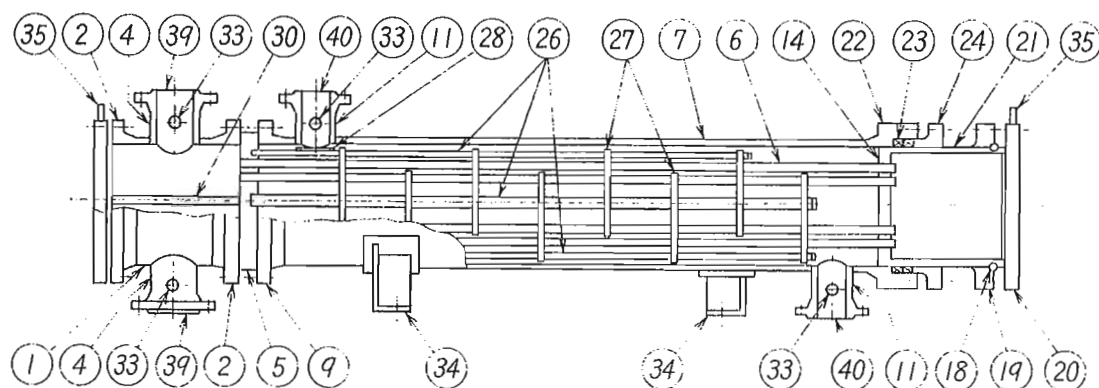
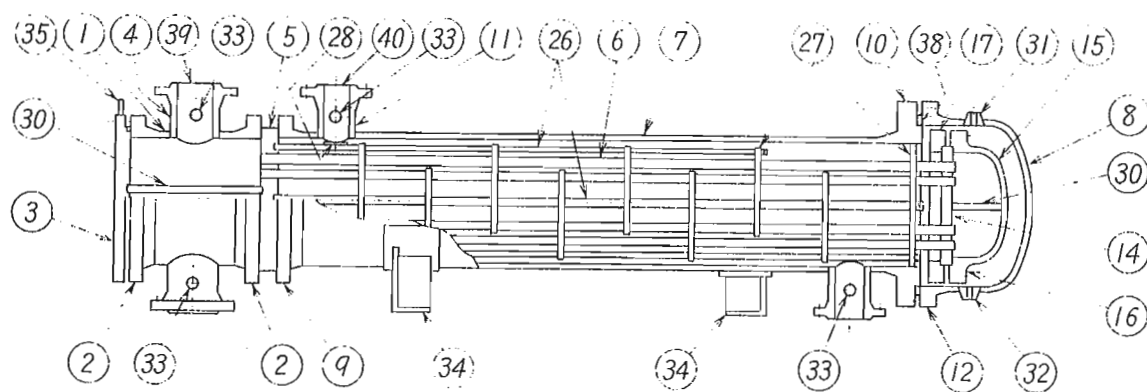
Sym- bol	Classification of stationary head	Sym- bol	Classification of shell	Sym- bol	Classification of rear head
A	 Removal cover type	E	 One pass type	L	 Stationary tube plate type similar to A
B	 Bonnet type (integral cover)	F	 Two pass type with longitudinal baffle plate	M	 Stationary tube plate type similar to B
C	 Integral tube plate type	G	 Split flow type	N	 Stationary tube plate type similar to C
D	 Special high pressure type	H	 Double split flow type	P	 Floating head gland type
		J	 Divided flow type	S	 Floating head backing flange type
		K	 Kettle type	T	 Pull through floating head type
				U	 U-tube type
				W	 Floating tube plate type (with lantern ring)

Fig. 2

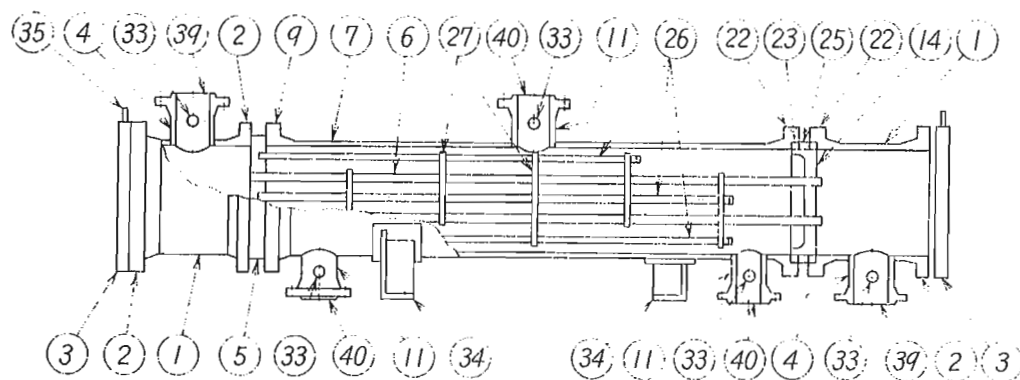
(a) AEP



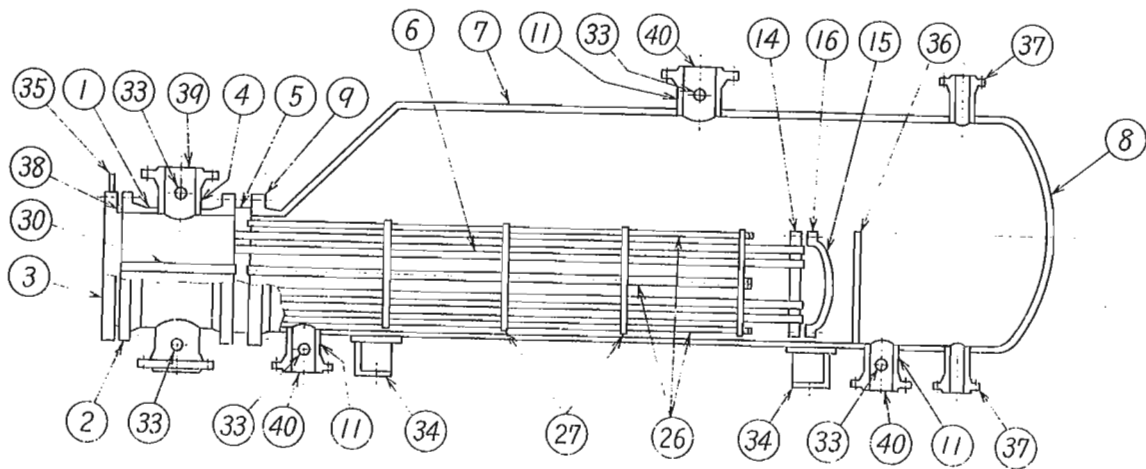
(b) AES



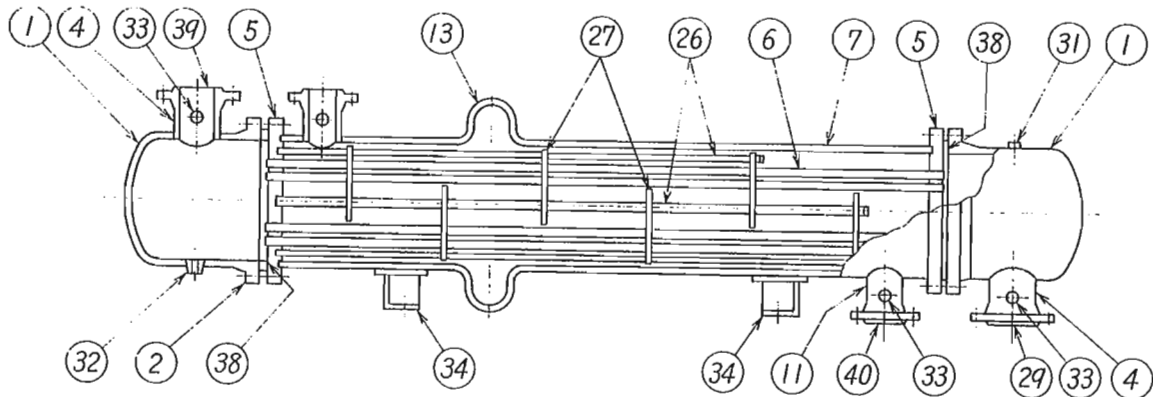
(c) AJW



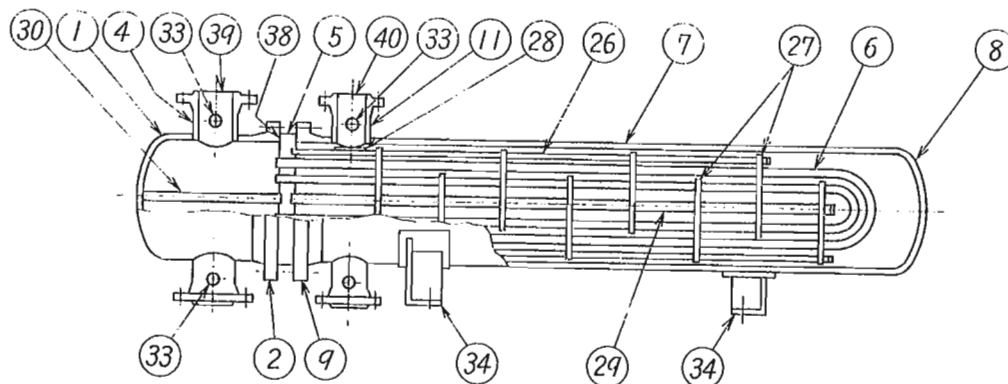
(d) AKT



(e) BEM



(f) BFU



1.4.2 Names The name of each part of the heat exchanger shall be as given in Table 1. [Number of each part shall refer to Fig. 2 (a) to (f).]

Table 1

No.	Name	No.	Name
1	Stationary head	21	Floating tube plate skirt
2	Stationary head flange	22	Gland flange
3	Stationary head cover	23	Packing
4	Partitioned chamber nozzle stub	24	Packing gland
5	Stationary tube plate	25	Lantern ring
6	Heat exchanger tube	26	Tie rods and spacers
7	Shell	27	Baffle plates or support plates
8	Shell cover	28	Buffer plate
9	Stationary head side shell flange	29	Longitudinal baffle plate
10	Shell cover side shell flange	30	Pass partition plate
11	Shell nozzle stub	31	Gas vent connection
12	Shell cover flange	32	Drain extractor connection
13	Shell expansion joint	33	Instrument connection
14	Floating tube plate	34	Support saddle
15	Floating head cover	35	Lifting lug
16	Floating head flange	36	Weir
17	Floating head backing flange	37	Liquid level connection
18	Split ring	38	Gasket
19	Floating head plate flange	39	Stationary head nozzle stub flange
20	Floating head cover	40	Shell nozzle stub flange

2. Materials

2.1 Heat Exchanger Tubes The materials for the heat exchanger tubes shall be of cold finished tubes which are conforming to the following standards:

(1) Carbon Steel Materials

JIS G 3461

(2) Low Alloy Steel Materials

JIS G 3462

JIS G 3464

(3) High Alloy Steel Materials

JIS G 3463

JIS G 4904

(4) Copper and Copper-Alloy Materials C 1020 T, C 1020 TS, C 1100 T, C 1100 TS, C 1201 T, C 1201 TS, C 1220 T, C 1220 TS, C 1221 T, C 1221 TS, C 6561 T, C 4430 T, C 4430 TS, C 6870 T, C 6870 TS, C 6871 T, C 6871 TS, C 6872 T, C 6872 TS, C 7060 T, C 7060 TS, C 7100 T, C 7100 TS, C 7150 T and C 7150 TS of JIS H 3300(5) Aluminium and Aluminium-Alloy Materials

JIS H 4080

(6) Other Alloy Materials

JIS H 4552

JIS H 4631

2.2 Shell and Shell Cover The materials for the shell and shell cover shall conform to the following standards:

(1) Tube Materials(a) Carbon Steel Materials

JIS G 3452

JIS G 3454

JIS G 3455

JIS G 3456

JIS G 3457

(b) Low Alloy Steel Materials

JIS G 3458

JIS G 3460

(c) High Alloy Steel Materials

JIS G 3459

JIS G 4903

(d) Copper and Copper Alloy Materials

C 1100 T, C 1100 TS, C 1201 T, C 1201 TS, C 1220 T, C 1220 TS, C 1221 T and C 1221 TS of JIS H 3300

(e) Aluminium and Aluminium Alloy Materials

JIS H 4080

JIS H 4090

(2) Plate Materials(a) Carbon Steel Materials

JIS G 3101	JIS G 3103	JIS G 3106
JIS G 3115	JIS G 3118	JIS G 3126

(b) Low Alloy Steel Materials

JIS G 3103	JIS G 3119	JIS G 3120
JIS G 4109		

(c) High Alloy Steel Materials

JIS G 4304	JIS G 4305	JIS G 4902
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(d) Copper and Copper Alloy Materials

C 1100 P, C 1201 P, C 4621 P, C 4640 P, C 6161 P, C 6280 P,
C 6301 P, C 7060 P and C 7150 P of JIS H 3100

(e) Aluminium and Aluminium Alloy Materials

JIS H 4000

(f) Other Alloy Materials

JIS H 4551
JIS H 4600

(3) Casting Materials(a) Carbon Steel Materials

Classes 1 and 2 of JIS G 5151	JIS G 5101	
Class 1 of JIS G 5152	JIS G 5501	JIS G 5704

(b) Low Alloy Steel Materials

Classes 11, 21, 22, 23, 32 and 61 of JIS G 5151
Classes 11, 21 and 31 of JIS G 5152

(c) High Alloy Steel Materials

JIS G 5121

(d) Copper and Copper Alloy Materials

JIS H 5111

(e) Aluminium and Aluminium Alloy Materials

JIS H 5202

(4) Forging Materials(a) Carbon Steel Materials

JIS G 3201

JIS G 3211

JIS G 3212

JIS G 4051

(b) Low Alloy Steel Materials

JIS G 3211

JIS G 3212

JIS G 4102

JIS G 4103

JIS G 4104

JIS G 4105

JIS G 4106

JIS G 4202

(c) High Alloy Steel Materials

JIS G 3214

2.3 Baffle Plate, Support Plate, Tie Rod and Spacer The materials for the baffle plate, support plate, tie rod and spacer shall conform to the following standards:

- (1) Baffle Plate and Support Plate To be in accordance with 2.2 (2).
- (2) Tie Rod Materials of the same system as (1).
- (3) Spacer Materials of the same system as the heat exchanger tube or baffle plate

2.4 Floating Head The materials for the floating head shall conform to the following standards:

- (1) Plate Material To be in accordance with 2.2 (2).
- (2) Casting Material To be in accordance with 2.2 (3).
- (3) Forging Material To be in accordance with 2.2 (4).

2.5 Gasket and Packing The materials for the gasket and packing shall conform to the following standards:

(1) Asbestos Materials

JIS R 3452

JIS R 3453

- (2) Others These shall be as agreed upon between the parties concerned.

2.6 Tube Plate The materials for the tube plate shall conform to the following standards:

- (1) Plate Material To be in accordance with 2.2 (2).
- (2) Forging Material To be in accordance with 2.2 (4).

2.7 Stationary Head and Cover The materials for the stationary head and cover shall be in accordance with 2.2.

2.8 Nozzle Stubs The materials for the nozzle stubs shall be in accordance with 2.2.

2.9 Flanges and Bolts and Nuts The materials for the flanges and bolts and nuts shall conform to the following standards:

(1) Flanges To be in accordance with (2), (3) and (4) of 2.2.

(2) Bolts and Nuts

JIS G 3101

JIS G 4051

JIS G 4107

JIS G 4108

3. Construction

3.1 Class I

3.1.1 Construction in General The heat exchanger and its accessories shall provide enough strength and be sufficiently safe in operating conditions to the local stresses due to support saddle and the like, thermal expansions on the shell side and tube side and influences of liquid heads, and moreover, a heat exchanger that bears a load on itself shall be endurable to that load.

Furthermore, the external stresses, such as wind pressures and earthquake vibrations shall be taken into considerations, as required.

3.1.1.1 Corrosion Allowance The selection of corrosion allowances in using the following materials for the parts of heat exchanger, which is subjected to pressure, shall be in accordance with the following:

- (1) The corrosion allowances for the carbon steel (including low alloy steel) parts shall be taken as 1.0 mm and be in accordance with the following, except the heat exchanger tubes.
 - (a) The both faces of the tube plate and inside face of the stationary head cover shall be provided with the corrosion allowances, respectively.
 - (b) In the case where the partition grooves are provided on the tube plate and stationary head cover, the depths of the grooves shall be regarded as the corrosion allowances. Provided that the corrosion allowance is larger than the depth of the groove, the difference of the two shall be taken for the corrosion allowance.
 - (c) Both faces of the floating head cover shall be provided with the corrosion allowances respectively.
 - (d) The shell flange, stationary head flange and floating head flange shall be provided with corrosion allowances only on their inside diameter sides.
 - (e) No corrosion allowance shall be given for the floating head backing flange and interior bolts.

Remark: No corrosion allowance shall be given for the parts to which no pressure is loaded, such as tie rods, spacers, baffle plates and support plates.

- (2) The corrosion allowance may be taken as zero for the high alloy steel and nonferrous metal parts, where the high alloy steel and non-ferrous metal materials are used as the corrosion resistance materials.
- (3) The corrosion allowance of the cast iron part shall be taken as 1.0 mm.

3.1.1.2 Strength of Lining When the lining is processed in order to prevent corrosion or abrasion, the strength of the lining shall not be included in the calculation of the strength of the heat exchanger.

3.1.1.3 Dimensional Tolerances The dimensional tolerances shall be in accordance with the following:

- (1) External dimensions and nozzle stubs and support saddle The tolerances for the external dimensions and the positions of the nozzle stubs and support saddle of the heat exchanger shall conform to Fig. 3.
 - (a) The tolerances for each part shall not be added.
 - (b) The dimensional tolerances for the nozzle stubs and support saddle of the heat exchanger being piled up two units or more, shall be within the individual tolerances, and moreover particular considerations for piling up shall be taken.

(1) Dimensional Tolerances for Heat Exchanger Assembly

[illegible]

Technical drawing of a mechanical part, likely a valve or a similar component, showing dimensions in millimeters (mm). The drawing includes a central circular body with a flange and a handle. Dimensions are indicated by arrows and numerical values:

- Top horizontal dimension: ± 3
- Right vertical dimension: ± 3
- Bottom horizontal dimension: ± 3
- Left vertical dimension: ± 3
- Internal horizontal dimensions: ± 3 (twice), ± 3 (total)
- Internal vertical dimension: ± 3
- Dimension G is indicated on the right side, representing a distance or offset.

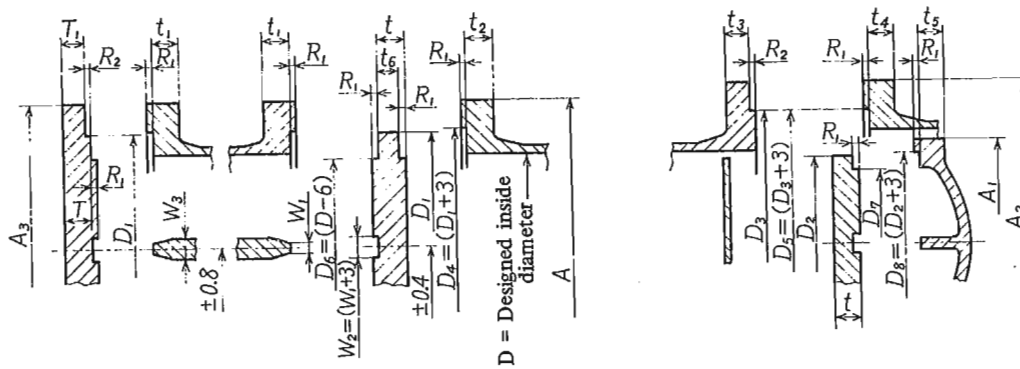
Nominal diameter of nozzle stubs	Maximum value of G
2B to 4B incl.	1.5
6B to 12B incl.	2.5
Over 12B	4.5

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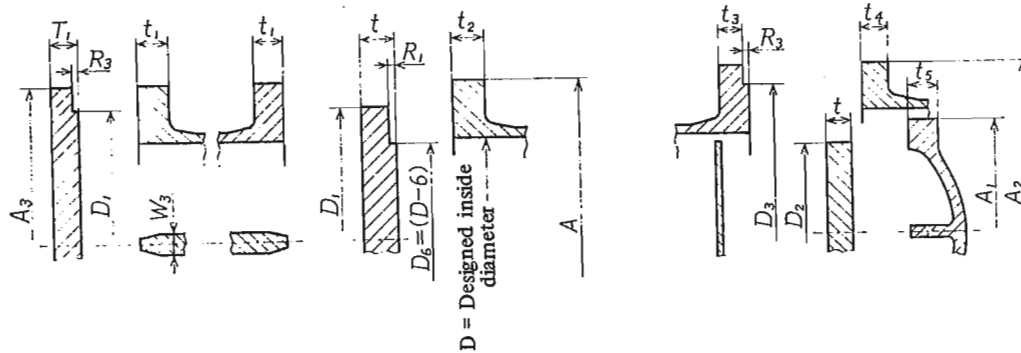
Fig. 4

Male-Female Type Joint Construction

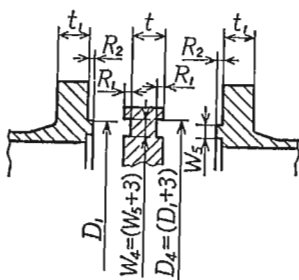
Unit: mm



Raised Face Joint Construction



Tongue and Groove Joint Construction



Unit: mm

Symbol	Dimensional tolerances
A, A_1, A_2, A_3	+6 -3
$D_1, D_2, D_3, D_4, D_5, D_8$	± 0.8
D_6, D_7	± 1.5
$R_1 (=3t_5)$	0 -0.8
$R_2 (=R_1+1), R_3 (=1.5)$	+0.8 0
t, t_6	± 0.8
t_1, t_2, t_3, t_4, t_5	± 1.5
T, T_1	+3 -0.8
W_1, W_3, W_5	± 0.8
W_2, W_4	+1.5 0

3.1.2 Heat Exchanger Tubes

3.1.2.1 Lengths of Heat Exchanger Tubes The lengths of the heat exchanger tubes shall be 2500 mm, 3000 mm, 5000 mm and 6000 mm.

3.1.2.2 Outside Diameters and Minimum Thicknesses of Heat Exchanger Tubes The outside diameters and the minimum thicknesses of the heat exchanger tubes shall conform to Table 2.

Table 2

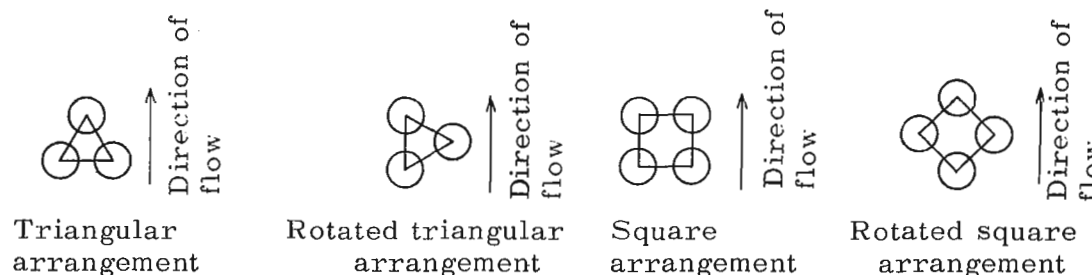
Unit: mm

Outside diameter	Minimum thickness			
	Carbon steel and low alloy steel	High alloy steel	Copper and copper alloy	Aluminium and aluminium alloy
15.9	1.6	1.2	1.2	1.6
19.0	1.6	1.2	1.2	1.6
25.4	2.0	1.2	1.6	2.0
31.8	2.0	1.6	2.0	2.0
38.1	2.0	2.0	2.0	2.0

3.1.2.3 Arrangements of Heat Exchanger Tubes The arrangements of the heat exchanger tubes shall be the triangular arrangement, rotated triangular arrangement, square arrangement and rotated square arrangement.

- (1) The triangular arrangement and rotated triangular arrangement are recommended to apply to shell-side flow of less dirts.
- (2) The square arrangement and rotated square arrangement shall be so arranged that the gaps between tubes are on straight lines.

Fig. 5



3.1.2.4 Center to Center Distance of Heat Exchanger Tubes The center to center distance of the heat exchanger tubes, hereinafter referred to as the "pitch", shall be in accordance with the following:

- (1) The pitch of the heat exchanger tubes shall conform to Table 3.
- (2) The minimum distance between the center of pass partition plate gasket groove and the center of heat exchanger tube shall be $1/2$ of the value of pitch of heat exchanger tube plus width of gasket groove.

Table 3

Unit: mm

Outside diameter of heat exchanger tube	Pitch
15.9	22
19.0	25
25.4	32
31.8	40
38.1	48

Remark: In the case where the shell-side flow is less dirty, a smaller value than given in Table may be taken.

3.1.2.5 Tolerances on Outside Diameter of Heat Exchanger Tube The tolerances on outside diameter of the carbon steel and low alloy steel heat exchanger tubes shall conform to Table 4.

Table 4

Unit: mm

Outside diameter of heat exchanger tube	Tolerances
15.9	± 0.10
19.0	± 0.10
25.4	± 0.15
31.8	± 0.15
38.1	± 0.15

Remark: When the austenitic stainless steel tubes are used for corrosion prevention, it is preferable to take the tolerances for outside diameter given in Table 4 in order to minimize the work hardening and the degree of degradation of corrosion resistance due to work hardening.

3.1.3 Shells and Shell Covers

3.1.3.1 Shell Diameters The shell diameters shall be in accordance with the following:

- (1) When the pipe is used for the shell, the diameter shall conform to Table 5.

Table 5

Unit: mm

Nominal diameter of shell	Outside diameter of shell
6 B	165.2
8 B	216.3
10 B	267.4
12 B	318.5
14 B	355.6
16 B	406.4

- (2) When the shell is manufactured by plate bending, the diameter shall conform to Table 6.

Table 6

Unit: mm

Nominal diameter of shell	Inside diameter of shell	Nominal diameter of shell	Inside diameter of shell
150	150	850	850
200	200	900	900
250	250	950	950
300	300	1000	1000
350	350	1050	1050
400	400	1100	1100
450	450	1150	1150
500	500	1200	1200
550	550	1250	1250
600	600	1300	1300
650	650	1350	1350
700	700	1400	1400
750	750	1450	1450
800	800	1500	1500

3.1.3.2 Tolerances on Diameter of Shell The tolerances on the diameter of the shell shall be in accordance with the following:



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(1) When Pipe Is Used for Shell

- (a) The plus side tolerance on the inside diameter of shell shall be in accordance with the tolerance of the standards of tube materials in 2.2 (1).
- (b) The minus side tolerance on the inside diameter of shell shall conform to Table 7.

Table 7

Unit: mm

Nominal diameter of shell	(-) side tolerance on designed shell inside diameter
6 B to 12 B incl.	2
14 B, 16 B	2.5

- (2) When Shell Is Manufactured by Plate Bending The permissible value for the difference between the inside diameter of shell calculated from the circumferential measurement and the designed inside diameter shall be taken as $+3_0$ mm.

3.1.3.3 Minimum Thickness of Shell The minimum thickness of the shell shall be in accordance with Table 8. The minimum thickness of the shell made of the clad steel shall be the same as that of carbon steel shell.

Table 8

Unit: mm

Nominal diameter of shell		Minimum thickness of shell		
Pipe shell	Bent-plate shell	Carbon steel and low alloy steel		High alloy steel
		Pipe shell	Bent-plate shell	
6B to 16B incl.	150 to 550 incl.	Schedule 20	4	3
—	600 to 700 incl.	—	5	4
	750 to 950 incl.	—	6	5
	1000 to 1500 incl.	—	7	6

3.1.3.4 Thickness of Shell Cover The thickness of the shell cover before forming shall be not less than the minimum thickness of shell shown in Table 8, and that after forming shall be not less than the thickness calculated in accordance with JIS B 8243.

3.1.3.5 Countermeasures for Thermal Expansion of Shell In the case when the heat exchanger tubes or the shell is subjected to the large stress due to temperature difference, the heat exchanger tube and shell, for the stationary tube plate type heat exchanger, some suitable measures, such as the use of shell expansion joint and so forth shall be taken against the thermal expansion.

3.1.4 Baffle Plate or Support Plate

3.1.4.1 Shape of Baffle Plate The shape of the baffle plate shall be of crescent shape, and the baffle cut plate shall be expressed by the ratio of the height of segment opening to the shell inside diameter.

3.1.4.2 Diameter of Hole for Heat Exchanger Tube of Baffle Plate The diameter of the holes for the heat exchanger tube of the baffle plate shall be in accordance with the following:

- (1) The difference between the diameter of heat exchanger tube hole and the outside diameter of heat exchanger tube shall be 1.0 mm or less for the supporting interval of heat exchanger tube of 900 mm or under and be 0.5 mm or less for that of over 900 mm.
- (2) The diameter of hole for the heat exchanger tube for the flow with pulsation shall be made smaller than the value given in (1).

3.1.4.3 Clearance between Shell and Baffle Plate or Support Plate The clearance between the outside diameter of baffle plate or support plate and the designed shell inside diameter shall be taken as not more than the value given in Table 9. Provided that it is less influential to the coefficient of heat-transfer of shell side and mean temperature difference, the value may be increased up to twice the value of Table 9.

Table 9

Unit: mm

Nominal diameter of shell		Clearance (Designed shell inside diameter - outside diameter of baffle plate or support plate)
Pipe shell	Bent-plate shell	
6B to 12B incl.	150 to 300 incl.	3.0
14 B and 16B	350 and 400	3.5
—	450 to 550 incl.	4.0
	600 to 950 incl.	4.5
	1000 to 1350 incl.	6.0
	1400 to 1500 incl.	8.0

3.1.4.4 Minimum Thickness of Baffle Plate or Support Plate The minimum thickness of the baffle plate or support plate shall be in accordance with Table 10.

Table 10

Unit: mm

Nominal diameter of shell		Minimum thickness of baffle plate or support plate					
Pipe shell	Bent-plate shell	Interval of baffle plates or support plates (For supporting of total tubes, interval shall be taken as 1/2.)					
		150 max.	Over 150 to 300 incl.	Over 300 to 450 incl.	Over 450 to 600 incl.	Over 600 to 750 incl.	Over 750
6B to 14B incl.	150 to 350 incl.	1.6	3.2	4.5	4.5	4.5	6
16B	400 to 700 incl.	3.2	4.5	4.5	6	6	8
—	750 to 950 incl.	4.5	6	6	8	9	12
—	1000 to 1500 incl.	—	6	6	8	9	12

Remarks 1. The thicknesses for the column for 150 mm or under shown in Table 10 shall be applied only to the shell-side flow free from corrosion or pulsation.

2. Particular care shall be taken for the thickness, where the shell-side flow pulsates.

3.1.4.5 Minimum Thickness of Longitudinal Baffle Plate The minimum thickness of the longitudinal baffle plate shall be 4.5 mm for carbon steel (including low alloy steel), and be 3 mm for high alloy steel.

Remark: Particular care shall be taken for the thickness, where the pressure difference between both sides of the longitudinal baffle plate is large.

3.1.4.6 Spacing of Baffle Plates or Support Plates The spacing of the baffle plates or support plates shall be in accordance with the following:

- (1) The minimum spacing of the baffle plates shall be either 1/5 of the shell inside diameter or 50 mm, whichever is greater.
- (2) The maximum length between the neighboring supports of the heat exchanger tube shall be in accordance with Table 11.

Remark: Excepting the vertical heat exchanger with no pulsation in shell-side flow and requiring special consideration in transportation and so forth.

Table 11

Unit: mm

Outside diameter of heat exchanger tube	Maximum length between supports	
	Quality of heat exchanger tube material and temperature limit	
	Carbon steel and high alloy steel Low alloy steel Nickel copper alloy Ni-Cr-Fe alloy	Aluminium and aluminium alloy, copper and copper alloy (temperature limit shall conform to JIS B 8243)
15.9	1320	1140
19.0	1520	1320
25.4	1880	1630
31.8	2235	1930
38.1	2540	2210

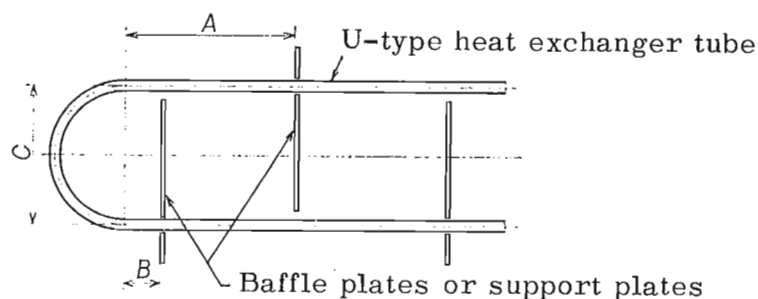
Remarks 1. The unsupported maximum length, in the case of exceeding the temperature limit of metal shown in Table 11, shall be shortened in proportion to fourth root of a ratio of the elastic modulus at its temperature and that at the temperature limit given in Table 11.

2. In the case when pulsations exist in the shell-side flow, the support spacing shall be shortened as smaller as possible within a permissible range of pressure loss.

Even in this case, if the value approaches to that given in Table 11, the flowing method of the flow shall be so considered as to shorten the supporting length as well, within a given pressure loss.

3.1.4.7 Supporting Length of U-Tube End The supporting length of curved part of individual U-tube end of the U-tube type heat exchanger (total length shown in Fig. 6) shall not exceed the value given in Table 11.

Fig. 6



$$\text{Total length} = A + B + C$$

3.1.4.8 Working of Baffle Plate or Support Plate The outer rims and holes for heat exchanger tubes of the baffle plate or support plate shall be smoothly finished and all of the corner parts be chamfered.

3.1.4.9 Buffer Plate The buffer plate shall be in accordance with the following:

If it is necessary to protect the heat exchanger tube from the shock due to inflow of the shell-side flow, the buffer plate shall be installed at the inlet part of the flow.

3.1.4.10 Minimum Thickness of Buffer Plate The minimum thickness of the buffer plate shall be 4.5 mm for carbon steel (including low alloy steel) and 3 mm for high alloy steel.

3.1.4.11 Inlet and Outlet Areas of Shell-Side Flow The area of passage between the shell and bundle of tubes at the inlet and outlet of the shell-side flow shall be in accordance with the following:

- (1) The area of passage of flow of clearance between the shell inside face and the buffer plate, when the buffer plate is to be installed, shall be not less than the cross-sectional area of the nozzle stub at the inlet.
- (2) The outlet part of the heat exchanger generating vapor shall provide a necessary area to pass the vapor or mixed flow of vapor and water through that.

3.1.4.12 Tie Rods and Spacers The baffle plates or support plates shall be supported at accurate positions by such a means as directly installing the tie rods and spacers or round bars or flat bars to the baffle plates with welding.

3.1.4.13 Diameter and Number of Tie Rods The diameter and number of tie rods corresponding to each shell diameter shall be in accordance with Table 12. Provided that the diameter and number of tie rods are equal or more in total cross-sectional area, other combinations may be used. The diameter of the tie rods shall be 6 mm or over and the number, however, be four pieces or more.

Table 12

Unit: mm

Nominal diameter of shell		Diameter of tie rod	Number of tie rod
Pipe shell	Bent-plate shell		
6B to 14B incl.	150 to 350 incl.	6 (M6)	4
16B	400 to 650 incl.	10 (M10)	6
—	700 to 800 incl.	12 (M12)	6
	850 to 1200 incl.	12 (M12)	8
	1250 to 1500 incl.	12 (M12)	10

Remark: The numerals given in parentheses indicate the designations of screw thread, where the tie rods are to be threaded.