CH2407 Process Equipment Design II

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Heat Exchanger Design

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- Single pass and multi-pass exchangers
- Heat transfer rate
- Temperature difference between two streams
- Heat transfer coefficient estimations
- Allocation of fluid in shell and tube exchangers
- Baffle spacing
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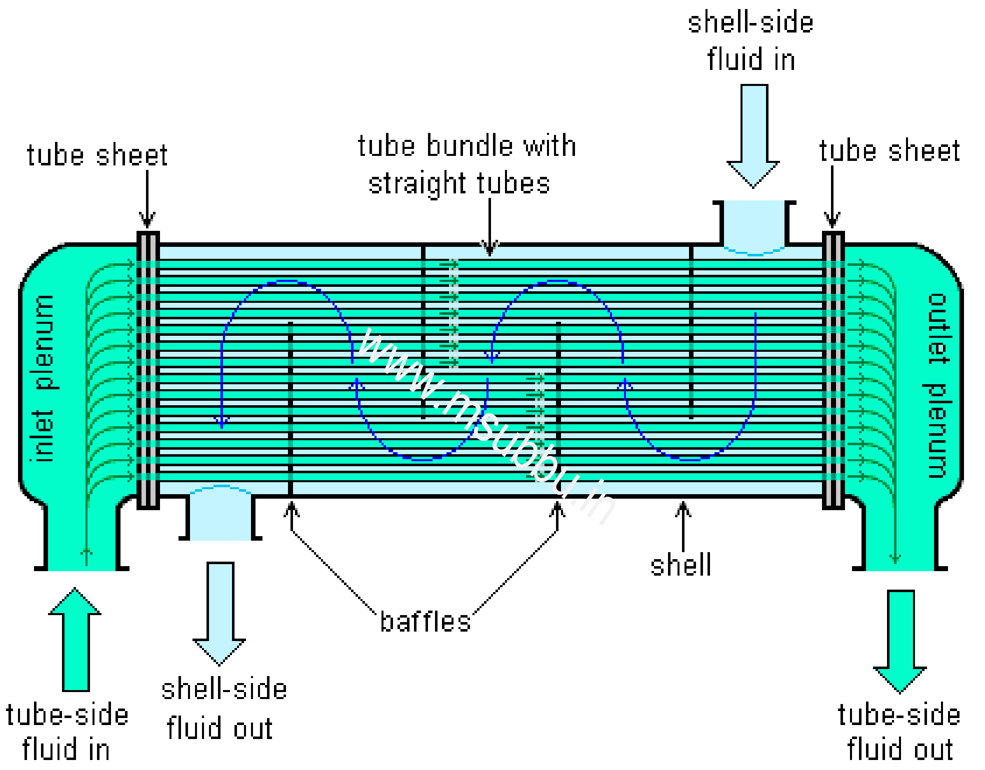
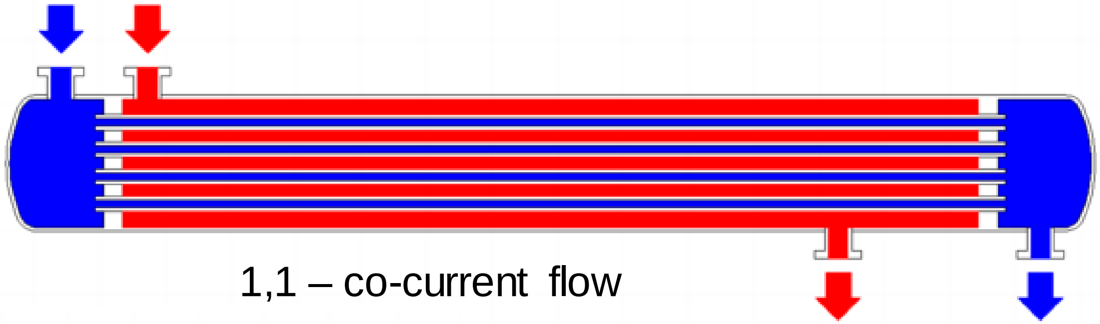
- Design codes

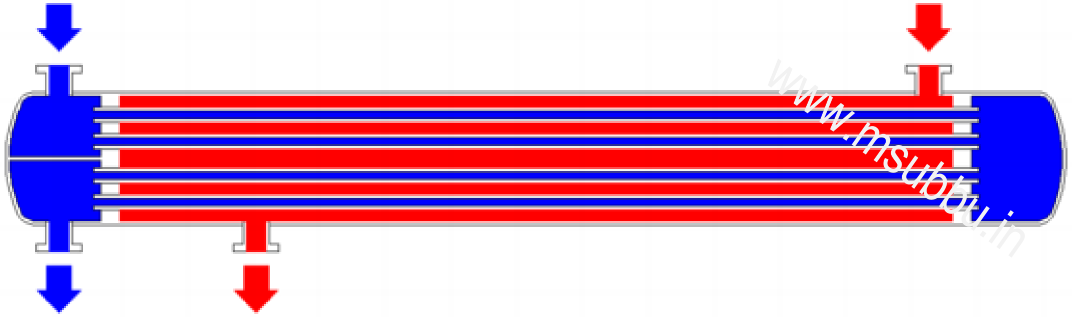
Shell and Tube Heat Exchanger



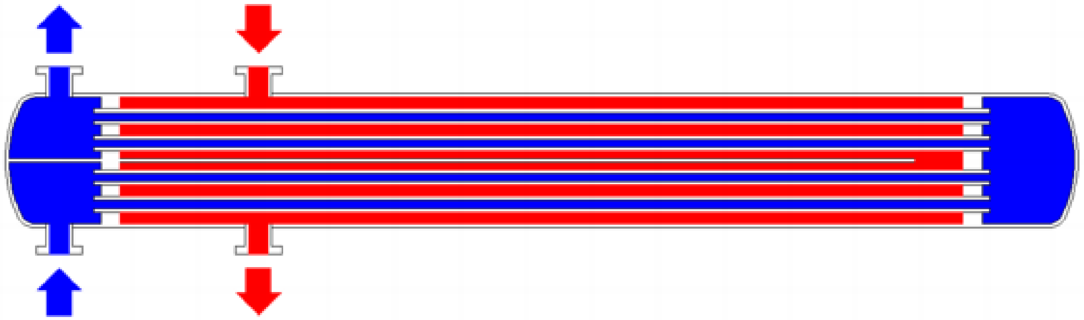
Pass Arrangements



1,1 – co-current flow



1,2 shell and tube exchanger



2,2 shell and tube exchanger

Heat Transfer Rate

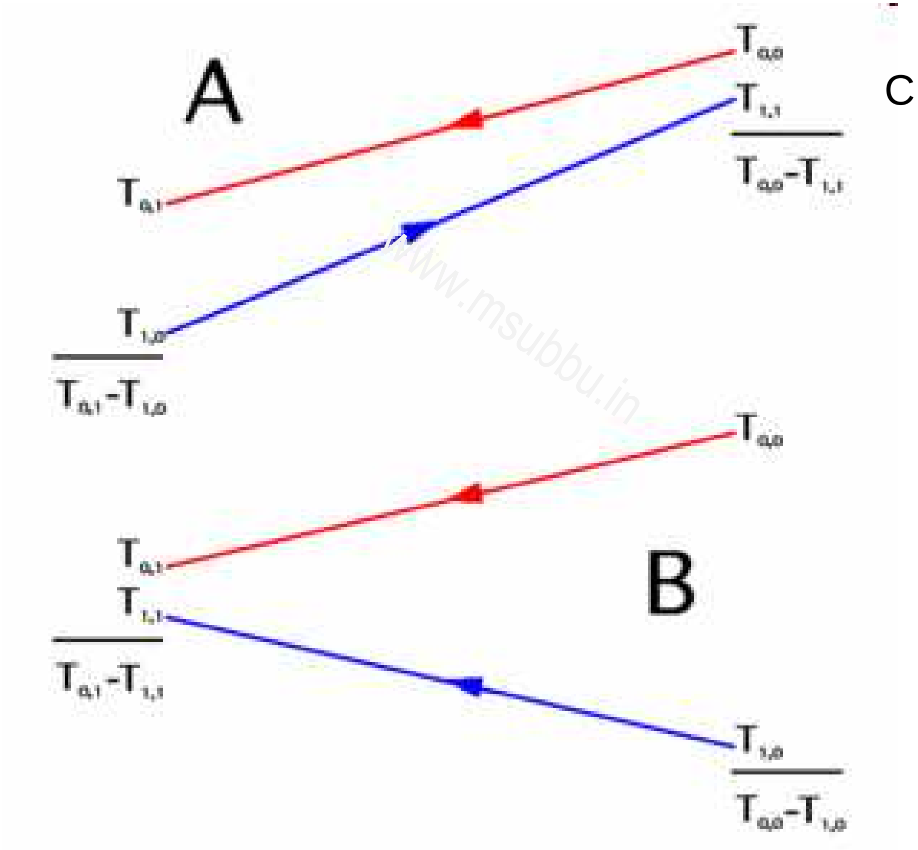
$$Q = UA\Delta T_m \longrightarrow 1$$

where Q = heat transferred per unit time, W,
U = the overall heat transfer coefficient, $W/m^2\,°C$,
A = heat-transfer area, m^2,
ΔT_m = the mean temperature difference, the temperature driving force, °C.

From first law of thermodynamics,

$$Q = mC_p dT$$

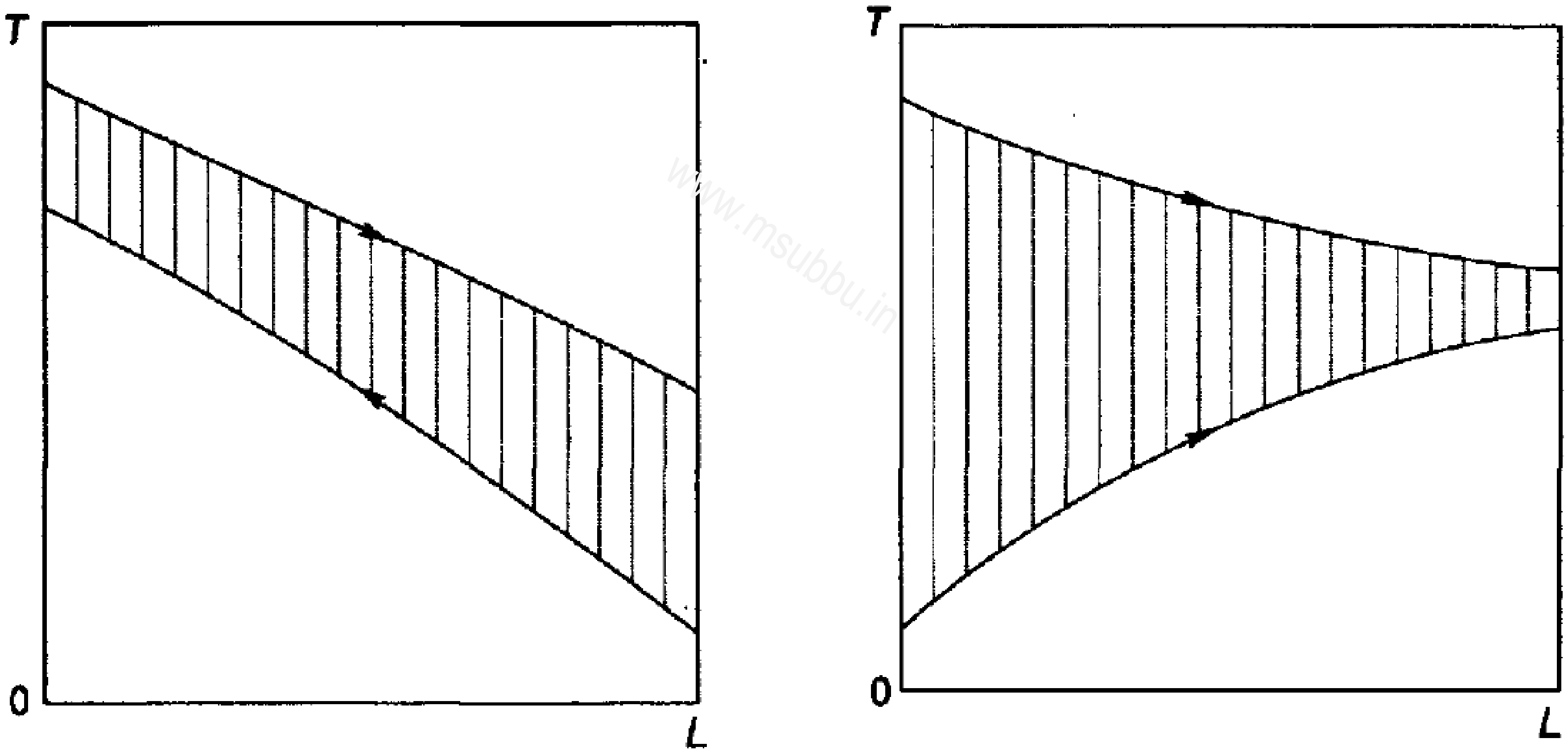
Temperature profile



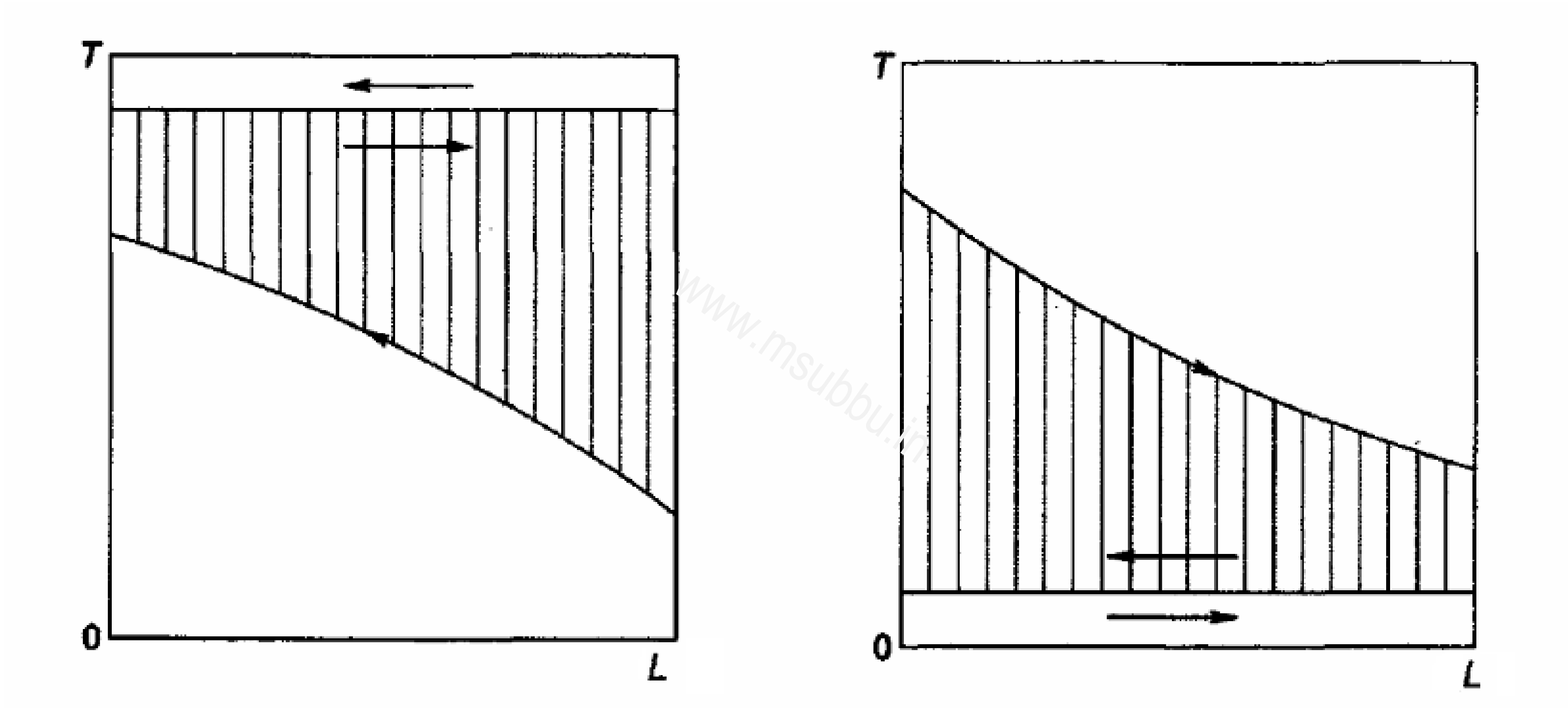
Counter-current flow

Co-current flow

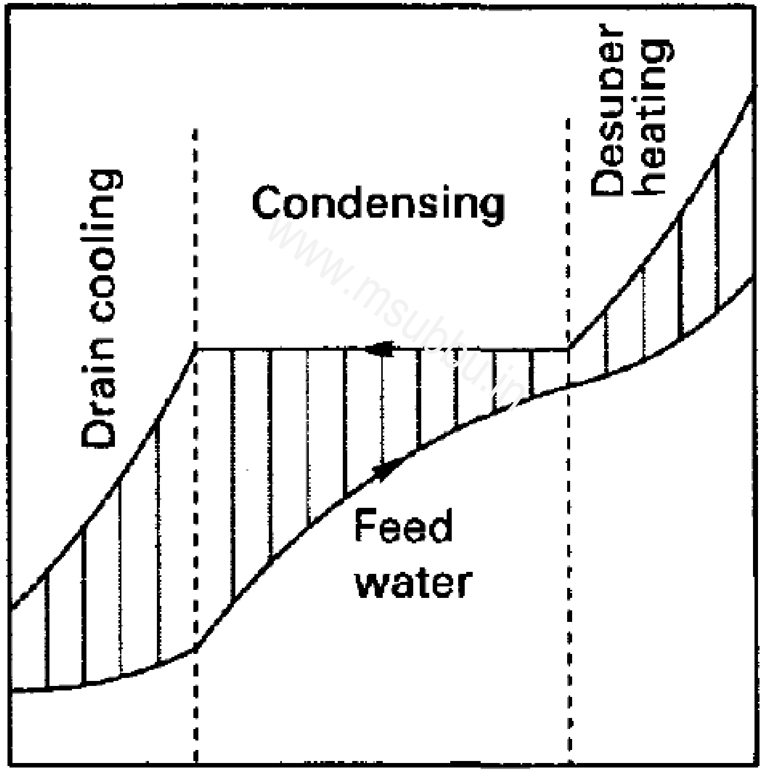
Co-current and counter-current flows



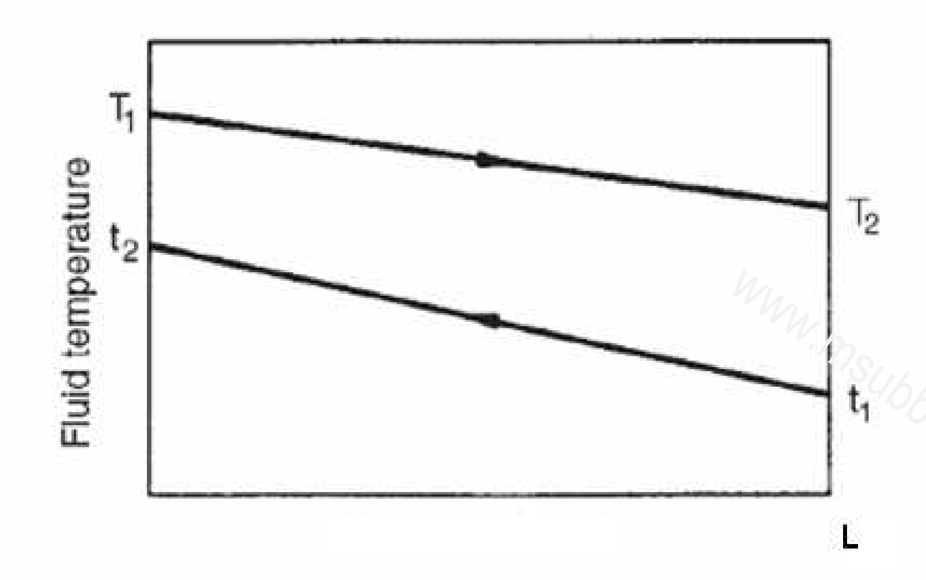
One fluid at constant temperature



Temperature profile of condenser with de-superheating

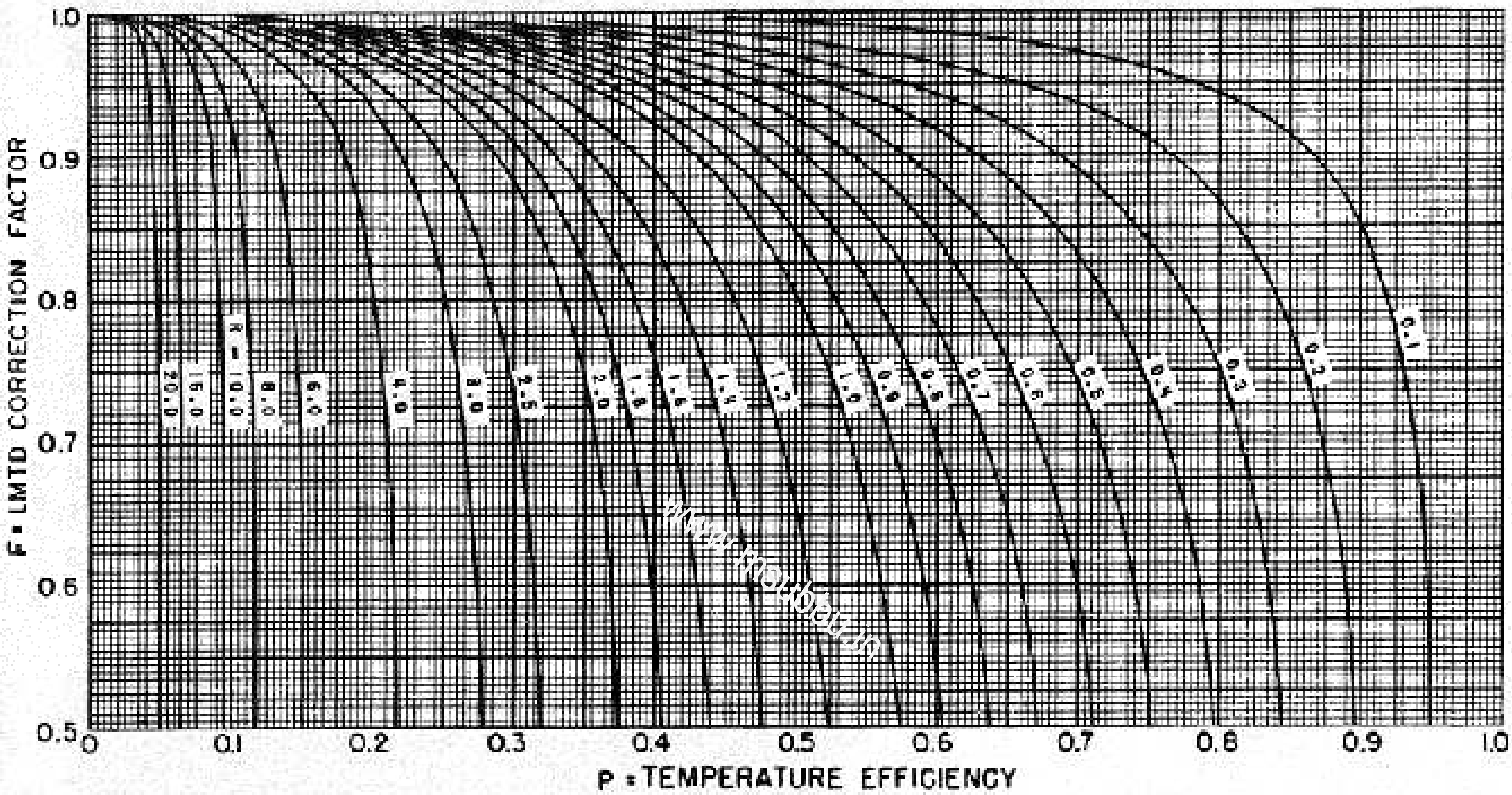


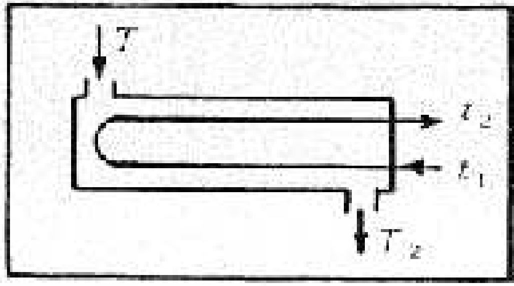
Temperature Difference



$$\Delta T_{1m} = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln \dfrac{(T_1 - t_2)}{(T_2 - t_1)}}$$

$$\Delta T_m = F_t \Delta T_{1m}$$





LMTD CORRECTION FACTOR

1 SHELL PASS EVEN NUMBER OF TUBE PASSES

$$P = \frac{t_2 - t_1}{T_1 - t_1} \qquad R = \frac{T_1 - T_2}{t_2 - t_1}$$

TEMA

Overall Heat Transfer Coefficient

$$\frac{1}{U_o} = \frac{1}{h_o} + \frac{1}{h_{od}} + \frac{d_o \ln\left(\frac{d_o}{d_i}\right)}{2k_w} + \frac{d_o}{d_i} \times \frac{1}{h_{id}} + \frac{d_o}{d_i} \times \frac{1}{h_i}$$

where U_o = the overall coefficient based on the outside area of the tube, W/m^2°C,

h_o = outside fluid film coefficient, W/m^2°C,

h_i = inside fluid film coefficient, W/m^2°C,

h_{od} = outside dirt coefficient (fouling factor), W/m^2°C,

h_{id} = inside dirt coefficient, W/m^2°C,

k_w = thermal conductivity of the tube wall material, W/m°C,

d_i = tube inside diameter, m,

d_o = tube outside diameter, m.

Table 12.1. Typical overall coefficients

Shell and tube exchangers		
Hot fluid	Cold fluid	U (W/m^2 °C)
Heat exchangers		
Water	Water	800–1500
Organic solvents	Organic solvents	100–300
Light oils	Light oils	100–400
Heavy oils	Heavy oils	50–300
Gases	Gases	10–50
Coolers		
Organic solvents	Water	250–750
Light oils	Water	350–900
Heavy oils	Water	60–300
Gases	Water	20–300
Organic solvents	Brine	150–500
Water	Brine	600–1200
Gases	Brine	15–250
Heaters		
Steam	Water	1500–4000
Steam	Organic solvents	500–1000
Steam	Light oils	300–900
Steam	Heavy oils	60–450
Steam	Gases	30–300
Dowtherm	Heavy oils	50–300
Dowtherm	Gases	20–200
Flue gases	Steam	30–100
Flue	Hydrocarbon vapours	30–100
Condensers		
Aqueous vapours	Water	1000–1500
Organic vapours	Water	700–1000
Organics (some non-condensables)	Water	500–700
Vacuum condensers	Water	200–500
Vaporisers		
Steam	Aqueous solutions	1000–1500
Steam	Light organics	900–1200
Steam	Heavy organics	600–900

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Table 12.2. Fouling factors (coefficients), typical values

Fluid	Coefficient (W/m^2°C)	Factor (resistance) (m^2°C/W)
River water	3000–12,000	0.0003–0.0001
Sea water	1000–3000	0.001–0.0003
Cooling water (towers)	3000–6000	0.0003–0.00017
Towns water (soft)	3000–5000	0.0003–0.0002
Towns water (hard)	1000–2000	0.001–0.0005
Steam condensate	1500–5000	0.00067–0.0002
Steam (oil free)	4000–10,000	0.0025–0.0001
Steam (oil traces)	2000 5000	0.0005 0.0002
Refrigerated brine	3000–5000	0.0003–0.0002
Air and industrial gases	5000–10,000	0.0002–0.0001
Flue gases	2000–5000	0.0005–0.0002
Organic vapours	5000	0.0002
Organic liquids	5000	0.0002
Light hydrocarbons	5000	0.0002
Heavy hydrocarbons	2000	0.0005
Boiling organics	2500	0.0004
Condensing organics	5000	0.0002
Heat transfer fluids	5000	0.0002
Aqueous salt solutions	3000–5000	0.0003–0.0002

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Tube dimensions

- Length (ft): 6, 8, 12, 16, 20, 24
- The optimum tube length to shell diameter: 5 to 10

Table 12.3. Standard dimensions for steel tubes

Outside diameter (mm)	Wall thickness (mm)				
16	1.2	1.6	2.0	—	—
20	—	1.6	2.0	2.6	—
25	—	1.6	2.0	2.6	3.2
30	—	1.6	2.0	2.6	3.2
38	—	—	2.0	2.6	3.2
50	—	—	2.0	2.6	3.2

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Tube O.D. Inches	B.W.G. Gage	Thickness Inches	Internal Area Sq. Inch	Sq. Ft. External Surface Per Foot Length	Sq. Ft. Internal Surface Per Foot Length	Weight Per Ft. Length Steel Lbs.*	Tube I.D. Inches
1/4	22	0.028	0.0296	0.0654	0.0508	0.066	0.194
	24	0.022	0.0333	0.0654	0.0539	0.054	0.206
	26	0.018	0.0360	0.0654	0.0560	0.045	0.214
	27	0.016	0.0373	0.0654	0.0571	0.040	0.218
3/8	18	0.049	0.0603	0.0982	0.0725	0.171	0.277
	20	0.035	0.0731	0.0982	0.0798	0.127	0.305
	22	0.028	0.0799	0.0982	0.0835	0.104	0.319
	24	0.022	0.0860	0.0982	0.0867	0.083	0.331
1/2	16	0.065	0.1075	0.1309	0.0969	0.302	0.370
	18	0.049	0.1269	0.1309	0.1052	0.236	0.402
	20	0.035	0.1452	0.1309	0.1129	0.174	0.430
	22	0.028	0.1548	0.1309	0.1162	0.141	0.444
5/8	12	0.109	0.1301	0.1636	0.1066	0.601	0.407
	13	0.095	0.1486	0.1636	0.1139	0.538	0.435
	14	0.083	0.1655	0.1636	0.1202	0.481	0.459
	15	0.072	0.1817	0.1636	0.1259	0.426	0.481
	16	0.065	0.1924	0.1636	0.1296	0.389	0.495
	17	0.058	0.2035	0.1636	0.1333	0.352	0.509
	18	0.049	0.2181	0.1636	0.1380	0.302	0.527
	19	0.042	0.2299	0.1636	0.1416	0.262	0.541
	20	0.035	0.2419	0.1636	0.1453	0.221	0.555
3/4	10	0.134	0.1825	0.1963	0.1262	0.833	0.482
	11	0.120	0.2043	0.1963	0.1335	0.808	0.510
	12	0.109	0.2223	[illegible]	0.1393	0.747	0.532
	13	0.095	0.2463	0.1963	0.1466	0.665	0.560
	14	0.083	0.2679	0.1963	0.1529	0.592	0.584
	15	0.072	0.2884	0.1963	0.1587	0.522	0.606
	16	0.065	0.3019	0.1963	0.1623	0.476	0.620
	17	0.058	0.3157	0.1963	0.1660	0.429	0.634
	18	0.049	0.3339	0.1963	0.1707	0.367	0.652
	20	0.035	0.3632	0.1963	0.1780	0.268	0.680
7/8	10	0.134	0.2894	0.2291	0.1589	1.062	0.607
	11	0.120	0.3167	0.2291	0.1662	0.969	0.635
	12	0.109	0.3390	0.2291	0.1720	0.890	0.657
	13	0.095	0.3685	0.2291	0.1793	0.792	0.685
	14	0.083	0.3948	0.2291	0.1856	0.703	0.709
	15	0.072	0.4197	0.2291	0.1914	0.618	0.731
	16	0.065	0.4359	0.2291	0.1950	0.563	0.745
	17	0.058	0.4525	0.2291	0.1987	0.507	0.759
	18	0.049	0.4742	0.2291	0.2034	0.433	0.777
	20	0.035	0.5090	0.2291	0.2107	0.314	0.805
1	8	0.165	0.3526	0.2618	0.1754	1.473	0.670
	10	0.134	0.4208	0.2618	0.1916	1.241	0.732
	11	0.120	0.4536	0.2618	0.1990	1.129	0.760
	12	0.109	0.4803	0.2618	0.2047	1.038	0.782
	13	0.095	0.5153	0.2618	0.2121	0.919	0.810
	14	0.083	0.5463	0.2618	0.2183	0.814	0.834
	15	0.072	0.5755	0.2618	0.2241	0.714	0.856
	16	0.065	0.5945	0.2618	0.2278	0.650	0.870
	18	0.049	0.6390	0.2618	0.2361	0.498	0.902
	20	0.035	0.6793	0.2618	0.2435	0.361	0.930

Tube O.D. mm	B.W.G. Gage	Thickness mm	Internal Area Sq Cm	Sq M External Surface Per M Length	Sq M Internal Surface Per M Length	Weight Per M length Steel Kg*	Tube I.D. mm
6.35	22	0.711	0.1910	0.0199	0.0155	0.098	4.93
	24	0.559	0.2145	0.0199	0.0164	0.080	5.23
	26	0.457	0.2323	0.0199	0.0171	0.067	5.44
	27	0.406	0.2406	0.0199	0.0174	0.060	5.54
9.53	18	1.245	0.3892	0.0299	0.0221	0.254	7.04
	20	0.889	0.4710	0.0299	0.0243	0.183	7.75
	22	0.711	0.5155	0.0299	0.0255	0.155	8.10
	24	0.559	0.5546	0.0299	0.0264	0.124	8.41
12.7	16	1.651	0.6923	0.0399	0.0295	0.448	9.40
	18	1.245	0.8107	0.0399	0.0321	0.351	10.21
	20	0.889	0.9347	0.0399	0.0343	0.259	10.92
	22	0.711	0.9967	0.0399	0.0354	0.210	11.28
15.88	12	2.769	0.8084	0.0499	0.0325	0.894	10.34
	13	2.413	0.9567	0.0499	0.0347	0.801	11.05
	14	2.108	1.0577	0.0499	0.0366	0.716	11.66
	15	1.829	1.1723	0.0499	0.0384	0.634	12.22
	16	1.651	1.2413	0.0499	0.0395	0.575	12.57
	17	1.473	1.3129	0.0499	0.0406	0.524	12.93
	18	1.245	1.4071	0.0499	0.0421	0.448	13.39
	19	1.067	1.4832	0.0499	0.0432	0.390	13.74
	20	0.889	1.5606	0.0499	0.0443	0.329	14.10
19.05	10	3.404	1.1774	0.0598	0.0396	1.240	12.24
	11	3.048	1.3107	0.0598	0.0407	1.206	12.95
	12	2.769	1.4372	0.0598	0.0425	1.112	13.51
	13	2.413	1.5890	0.0598	0.0447	0.990	14.22
	14	2.108	1.7294	0.0598	0.0466	0.881	14.83
	15	1.829	1.8606	0.0598	0.0484	0.777	15.39
	16	1.651	1.9477	0.0598	0.0495	0.705	15.75
	17	1.473	2.0350	0.0598	0.0506	0.633	16.10
	18	1.245	2.1542	0.0598	0.0520	0.546	16.56
	20	0.889	2.3492	0.0598	0.0543	0.399	17.27
22.23	10	3.404	1.8677	0.0698	0.0484	1.530	15.42
	11	3.048	2.0432	0.0698	0.0507	1.442	16.13
	12	2.769	2.1871	0.0698	0.0524	1.320	16.69
	13	2.413	2.3774	0.0698	0.0547	1.170	17.40
	14	2.108	2.5471	0.0698	0.0566	1.045	18.01
	15	1.829	2.7077	0.0698	0.0583	0.920	18.57
	16	1.651	2.8123	0.0698	0.0594	0.839	18.92
	17	1.473	2.9193	0.0698	0.0605	0.754	19.28
	18	1.245	3.0593	0.0698	0.0620	0.644	19.74
	20	0.889	3.2839	0.0698	0.0642	0.467	20.45
25.4	8	4.191	2.2749	0.0798	0.0535	2.162	17.02
	10	3.404	2.7148	0.0798	0.0584	1.847	18.59
	11	3.048	2.9284	0.0798	0.0607	1.680	19.30
	12	2.769	3.0967	0.0798	0.0624	1.546	19.86
	13	2.413	3.3245	0.0798	0.0646	1.366	20.57
	14	2.108	3.5265	0.0798	0.0665	1.211	21.18
	15	1.829	3.7125	0.0798	0.0683	1.063	21.74
	16	1.651	3.8335	0.0798	0.0694	0.967	22.10
	18	1.245	4.1225	0.0798	0.0720	0.741	22.91
	20	0.889	4.3726	0.0798	0.0742	0.537	23.62

DIMENSIONS OF WELDED AND SEAMLESS PIPE

NOMINAL PIPE SIZE	OUT-SIDE DIAM	NOMINAL WALL THICKNESS FOR														
		SCHED. 5S*	SCHED. 10S*	SCHED. 10	SCHED. 20	SCHED. 30	STANDARD †	SCHED. 40	SCHED. 60	EXTRA STRONG §	SCHED. 80	SCHED. 100	SCHED. 120	SCHED. 140	SCHED. 160	XX STRONG
1/8	0.405		0.049				0.068	0.068		0.095	0.095					
1/4	0.540		0.065				0.088	0.088		0.119	0.119					
3/8	0.675		0.065				0.091	0.091		0.126	0.126					
1/2	0.840	0.065	0.083				0.109	0.109		0.147	0.147				0.188	0.294
3/4	1.050	0.065	0.083				0.113	0.113		0.154	0.154				0.219	0.308
1	1.315	0.065	0.109				0.133	0.133		0.179	0.179				0.250	0.358
1 1/4	1.660	0.065	0.109				0.140	0.140		0.191	0.191				0.250	0.382
1 1/2	1.900	0.065	0.109				0.145	0.145		0.200	0.200				0.281	0.400
2	2.375	0.065	0.109				0.154	0.154		0.218	0.218				0.344	0.436
2 1/2	2.875	0.083	0.120				0.203	0.203		0.276	0.276				0.375	0.552
3	3.5	0.083	0.120				0.216	0.216		0.300	0.300				0.438	0.600
3 1/2	4.0	0.083	0.120				0.226	0.226		0.318	0.318					
4	4.5	0.083	0.120				0.237	0.237		0.337	0.337		0.438		0.531	0.674
5	5.563	0.109	0.134				0.258	0.258		0.375	0.375		0.500		0.625	0.750
6	6.625	0.109	0.134				0.280	0.280		0.432	0.432		0.562		0.719	0.864
8	8.625	0.109	0.148		0.250	0.277	0.322	0.322	0.406	0.500	0.500	0.594	0.719	0.812	0.906	0.875
10	10.75	0.134	0.165		0.250	0.307	0.365	0.365	0.500	0.500	0.594	0.719	0.844	1.000	1.125	1.000
12	12.75	0.156	0.180		0.250	0.330	0.375	0.406	0.562	0.500	0.688	0.844	1.000	1.125	1.312	1.000
14 O.D.	14.0	0.156	0.188	0.250	0.312	0.375	0.375	0.438	0.594	0.500	0.750	0.938	1.094	1.250	1.406	
16 O.D.	16.0	0.165	0.188	0.250	0.312	0.375	0.375	0.500	0.656	0.500	0.844	1.031	1.219	1.438	1.594	
18 O.D.	18.0	0.165	0.188	0.250	0.312	0.438	0.375	0.562	0.750	0.500	0.938	1.156	1.375	1.562	1.781	
20 O.D.	20.0	0.188	0.218	0.250	0.375	0.500	0.375	0.594	0.812	0.500	1.031	1.281	1.500	1.750	1.969	
22 O.D.	22.0	0.188	0.218	0.250	0.375	0.500	0.375		0.875	0.500	1.125	1.375	1.625	1.875	2.125	
24 O.D.	24.0	0.218	0.250	0.250	0.375	0.562	0.375	0.688	0.969	0.500	1.218	1.531	1.812	2.062	2.344	
26 O.D.	26.0			0.312	0.500		0.375			0.500						
28 O.D.	28.0			0.312	0.500	0.625	0.375			0.500						
30 O.D.	30.0	0.250	0.312	0.312	0.500	0.625	0.375			0.500						
32 O.D.	32.0			0.312	0.500	0.625	0.375	0.688		0.500						
34 O.D.	34.0			0.312	0.500	0.625	0.375	0.688		0.500						
36 O.D.	36.0			0.312	0.500	0.625	0.375	0.750		0.500						
42 O.D.	42.0						0.375			0.500						

All dimensions are given in inches.

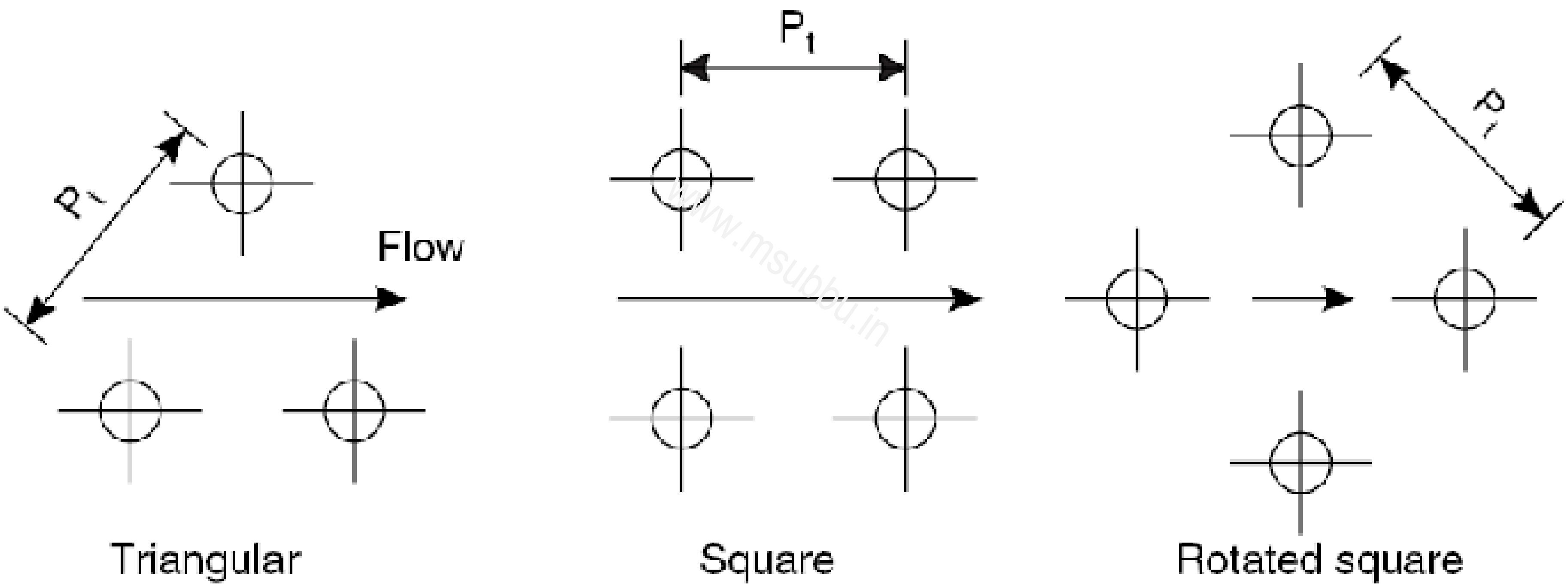
The decimal thicknesses listed for the respective pipe sizes represent their nominal or average wall dimensions. The actual thicknesses may be as much as 12.5% under the nominal thickness because of mill tolerance. Thicknesses shown in bold face are more readily available.

* Schedules 5S and 10S are available in corrosion resistant materials and Schedule 10S is also available in carbon steel.

† Thicknesses shown in italics are available also in stainless steel under the designation Schedule 40S.

§ Thicknesses shown in italics are available also in stainless steel under the designation Schedule 80S.

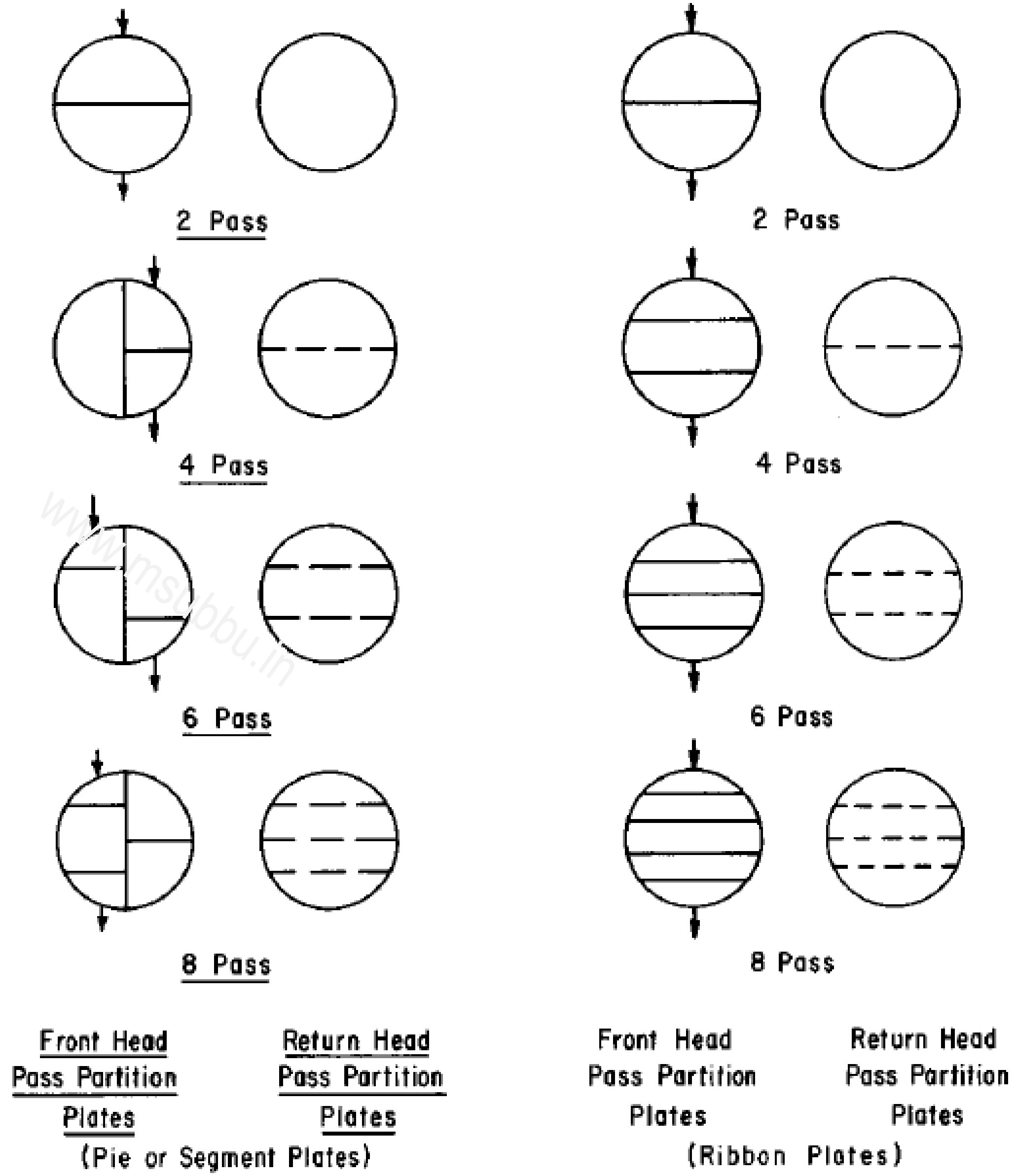
Tube Patterns



Tube side passes

- Practical construction limits the number of tube-side passes to 8—10, although a larger number of passes may be used on special designs
- Even number of passes are preferred
- The higher the number of passes, the more expensive the unit

Tube Side Passes



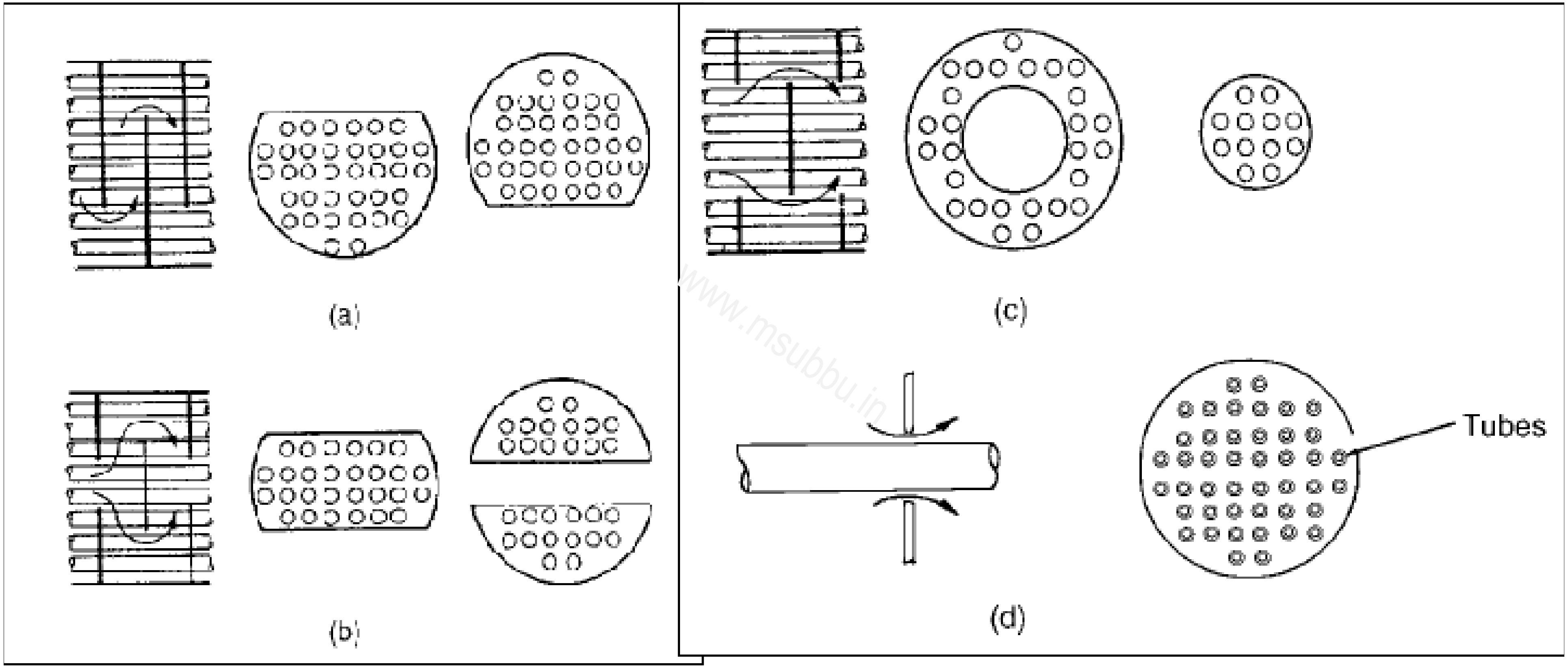
Shell Diameter

$$D_b = d_o \left(\frac{N_t}{K_1}\right)^{1/n_1}$$

where N_t = number of tubes,
D_b = bundle diameter, mm,
d_o = tube outside diameter, mm.

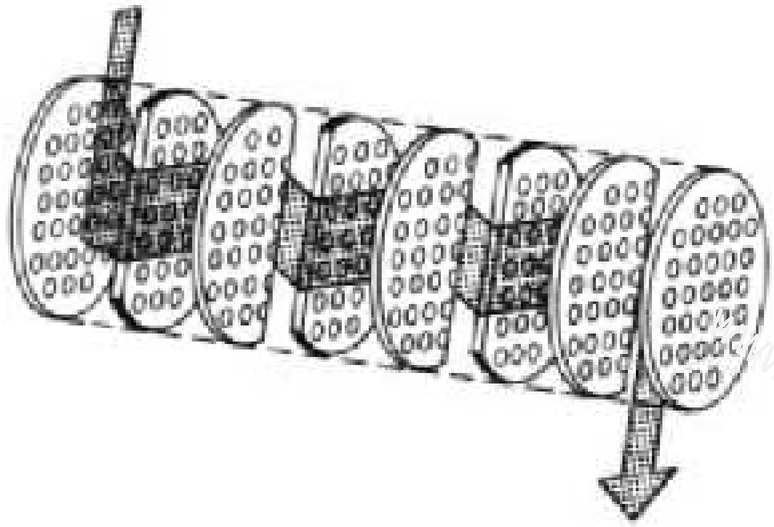
Triangular pitch, $p_t = 1.25d_o$					
No. passes	1	2	4	6	8
K_1	0.319	0.249	0.175	0.0743	0.0365
n_1	2.142	2.207	2.285	2.499	2.675
Square pitch, $p_t = 1.25d_o$					
No. passes	1	2	4	6	8
K_1	0.215	0.156	0.158	0.0402	0.0331
n_1	2.207	2.291	2.263	2.617	2.643

Baffles

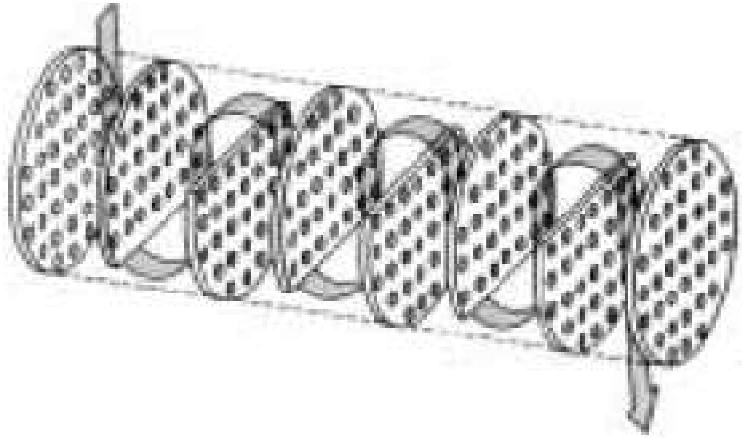


Types of baffle used in shell and tube heat exchangers. (*a*) Segmental (*b*) Segmental and strip (*c*) Disc and doughnut (*d*) Orifice

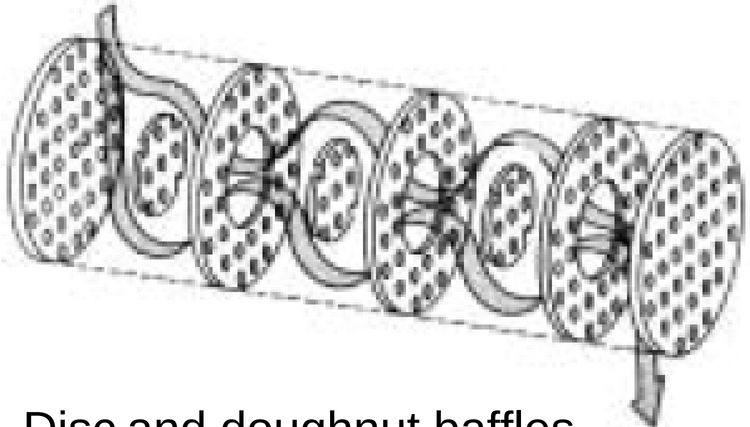
Baffles



Vertical cut segmental baffles



Horizontal cut segmental baffles



Disc and doughnut baffles

Fluid Allocation

- **Corrosion**: Fewer costly alloy components are needed if the corrosive fluid is inside the tubes. Corrosive fluid cannot be sent in the shell side, since the shell side fluid will affect both shell and tubes.
- **Fouling**: Placing the fouling fluid inside the tubes allow better velocity control; increased velocities tend to reduce fouling. Straight tubes allow mechanical cleaning without removing the tube bundle.
- **Temperature & Pressure**: For high temperature / pressure services requiring special or expensive alloy materials, fewer alloy components are needed when hot fluid is placed within the tubes
- **Flow rate**: Placing the fluid with the lower flow rate on the shell side usually results in a more economical design. Turbulence exists on the shell side at much lower velocities than within the tubes.

Fluid Velocities

- Liquids:
  - Tube side: 1 – 2 m/s; maximum 4 m/s if required to reduce fouling
  - Shell side: 0.3 – 1 m/s

- Gases:
  - Atmospheric pressure: 10 – 30 m/s

Tube side heat transfer coefficient
(turbulent flow)

$$Nu = C Re^{0.8} Pr^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14}$$

where $C = 0.021$ for gases,
$= 0.023$ for non-viscous liquids,
$= 0.027$ for viscous liquids.

where Nu = Nusselt number $= (h_i d_e / k_f)$,
Re = Reynolds number $= (\rho u_t d_e / \mu) = (G_t d_e / \mu)$,
Pr = Prandtl number $= (C_p \mu / k_f)$
and: h_i = inside coefficient, $W/m^2 {}^\circ C$,
d_e = equivalent (or hydraulic mean) diameter, m

$$d_e = \frac{4 \times \text{cross-sectional area for flow}}{\text{wetted perimeter}} = d_i \text{ for tubes},$$

u_t = fluid velocity, m/s,
k_f = fluid thermal conductivity, $W/m^\circ C$,
G_t = mass velocity, mass flow per unit area, $kg/m^2 s$,
μ = fluid viscosity at the bulk fluid temperature, Ns/m^2,
μ_w = fluid viscosity at the wall,
C_p = fluid specific heat, heat capacity, $J/kg^\circ C$.

Tube side heat transfer coefficient
(laminar flow)

$$Nu = 1.86(RePr)^{0.33}\left(\frac{d_e}{L}\right)^{0.33}\left(\frac{\mu}{\mu_w}\right)^{0.14}$$

Shell side

- Cross flow area (A_s)

$$A_s = \frac{(p_t - d_o) D_s l_B}{p_t}$$

where p_t = tube pitch,
d_o = tube outside diameter,
D_s = shell inside diameter, m,
l_B = baffle spacing, m.

- Shell side mass velocity and linear velocity

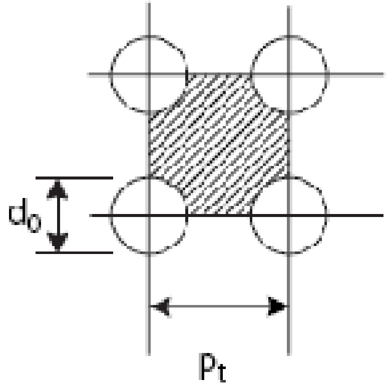
$$G_s = \frac{W_s}{A_s}$$

$$u_s = \frac{G_s}{\rho}$$

Shell side equivalent diameter

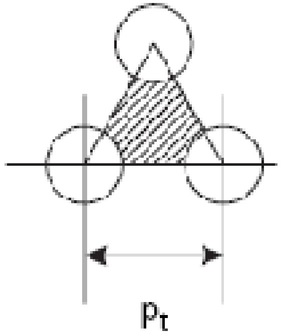
- Square pitch

$$d_e = \frac{4\left(\dfrac{p_t^2 - \pi d_o^2}{4}\right)}{\pi d_o} = \frac{1.27}{d_o}(p_t^2 - 0.785 d_o^2)$$



- Triangular pitch

$$d_e = \frac{4\left(\dfrac{p_t}{2} \times 0.87 p_t - \frac{1}{2}\pi\dfrac{d_o^2}{4}\right)}{\dfrac{\pi d_o}{2}} = \frac{1.10}{d_o}(p_t^2 - 0.917 d_o^2)$$



Shell side heat transfer coefficient

$$Re = \frac{G_s d_e}{\mu} = \frac{u_s d_e \rho}{\mu}$$

$$Nu = \frac{h_s d_e}{k_f} = j_h Re Pr^{1/3} \left(\frac{\mu}{\mu_w}\right)^{0.14}$$

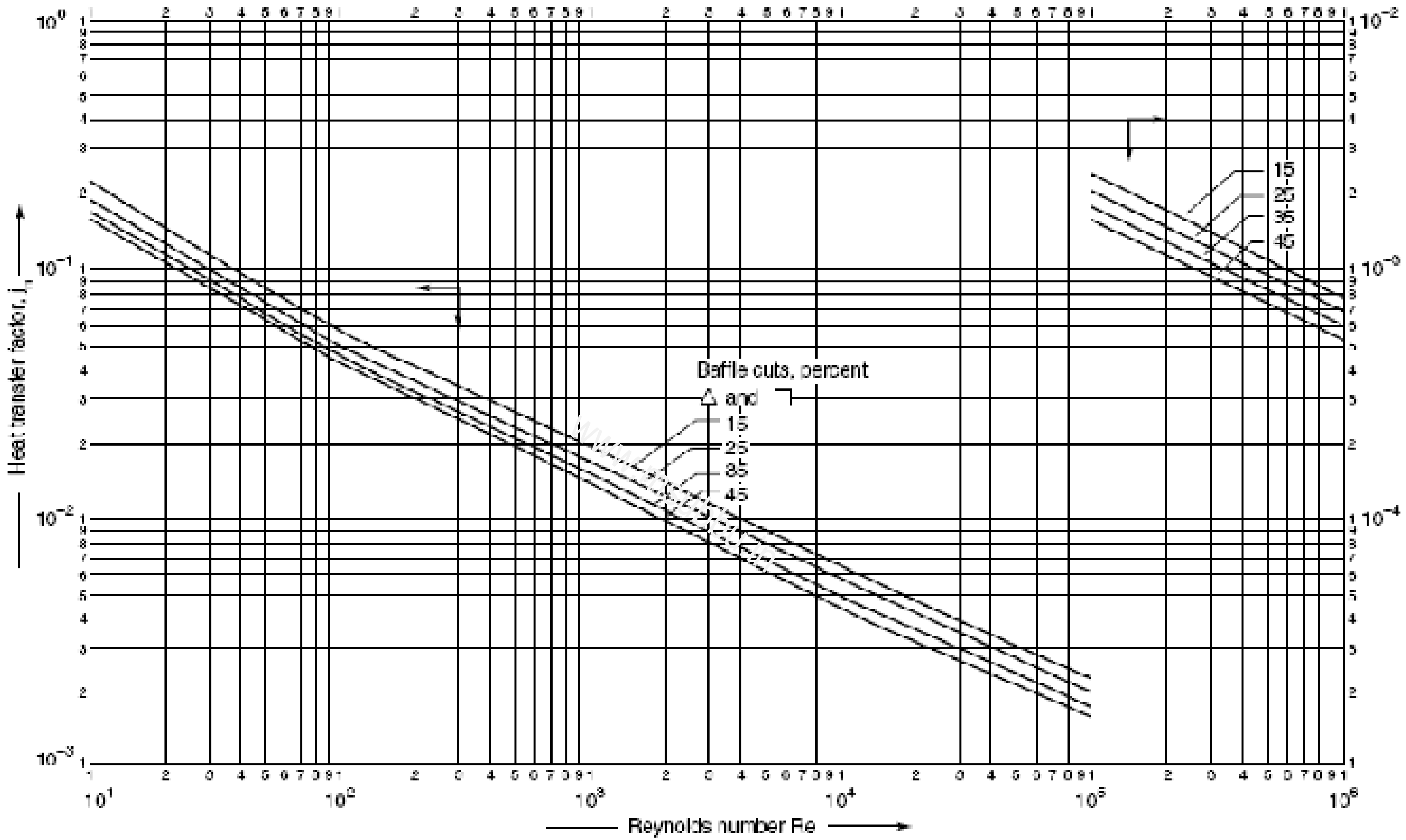


Figure 12.29. Shell-side heat-transfer factors, segmental baffles

Coulson & Richardon Vol.6 ed.4

Pressure drop calculations

$$f = 0.079Re^{-0.25}$$

- Tube side:

$$\Delta P_t = N_p \left[\frac{4fL}{D} + 2.5 \right] \frac{\rho v_t^2}{2}$$

- Shell side:

$$\Delta P_s = \left[\frac{4fL}{d_e} \frac{D_s}{l_B} \right] \frac{\rho v_s^2}{2}$$

Allowable Pressure Drop

- Liquids: 35 – 70 kN/m^2
- Gases and vapors:
  - High vacuum: 0.4 – 0.8 kN/m^2
  - Medium vacuum: 0.1 x absolute pressure
  - 1 to 2 bar: 0.5 x system gauge pressure

Design Codes

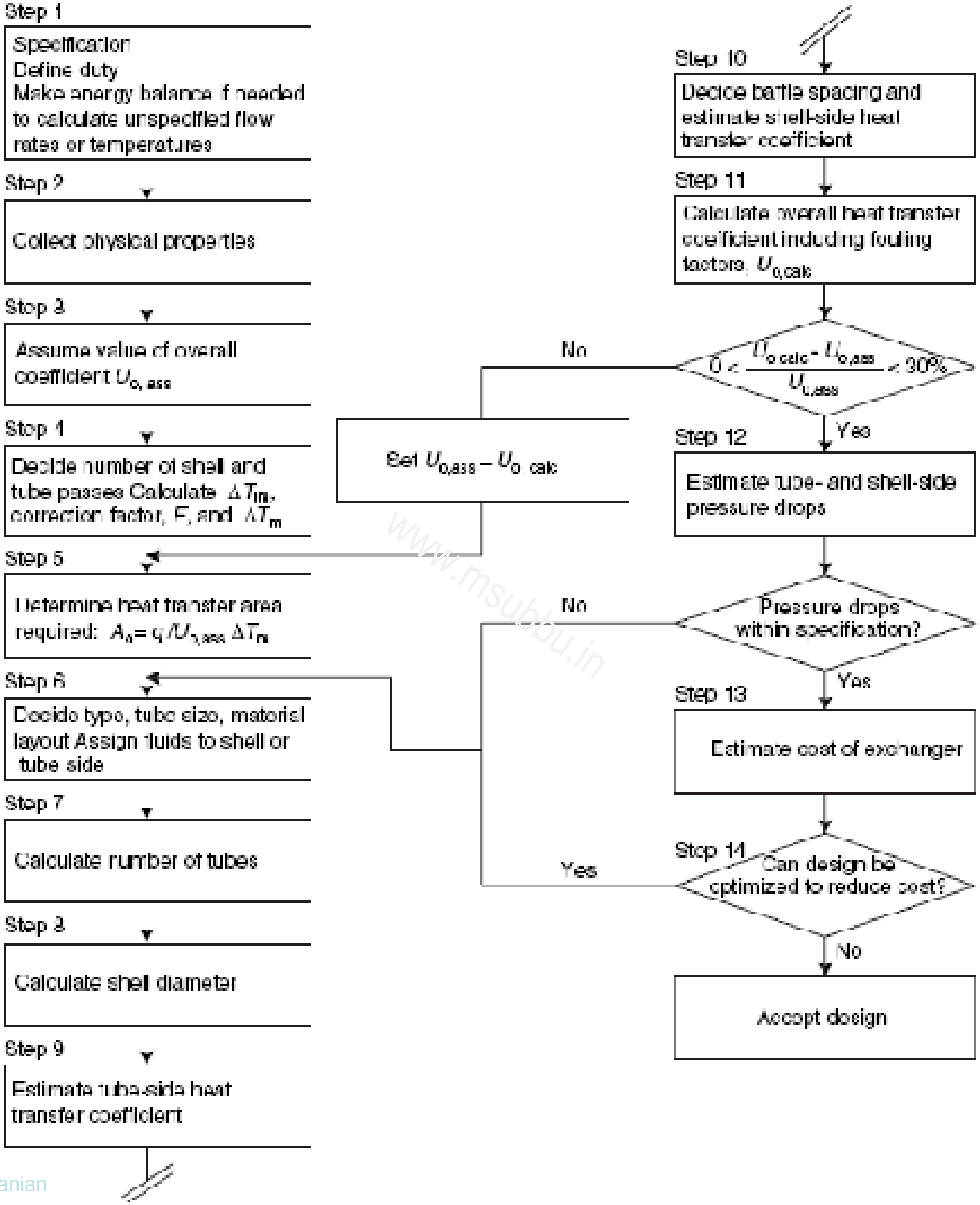
- Standards developed by Tubular Exchanger Manufacturers Association, USA (TEMA) are universally used for design of shell and tube heat exchangers.

- Equivalent Indian code is IS: 4503

- These codes specify the standard sizes of shell, tubes, etc., and also maximum allowable baffle spacing, minimum tube sheet thickness, baffle thickness, number of tie-rods required, etc.

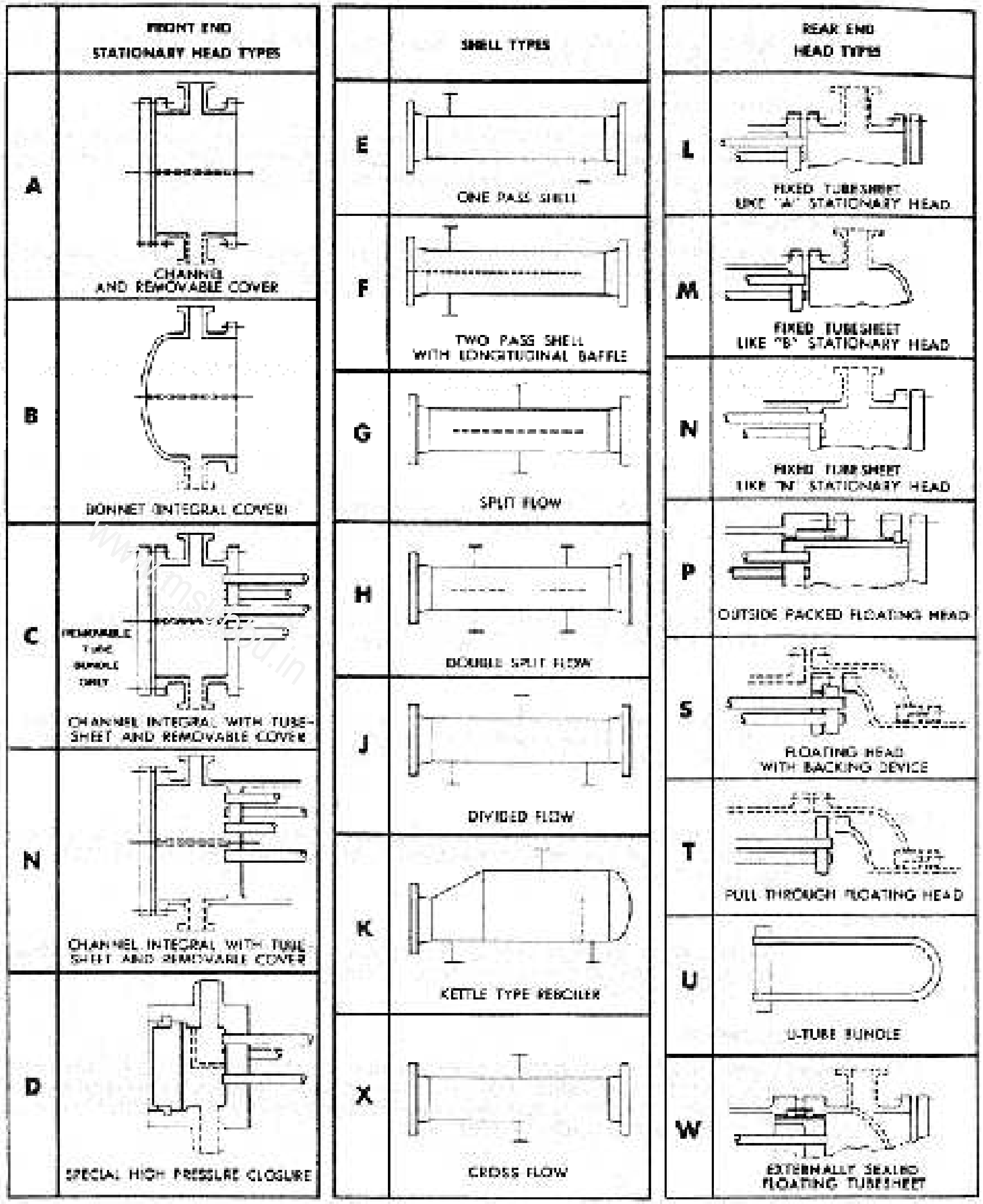
Design Procedure

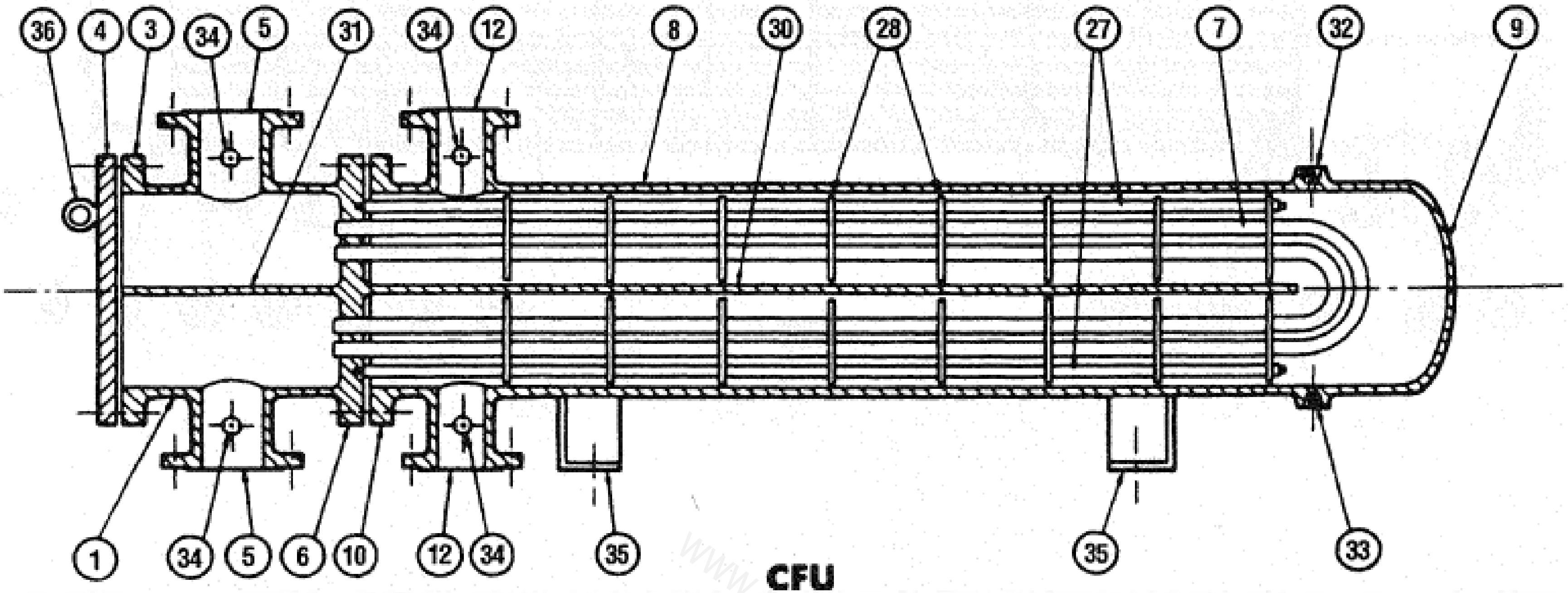
1. Define the duty: heat-transfer rate, fluid flow-rates, temperatures.
2. Collect together the fluid physical properties required: density, viscosity, thermal conductivity.
3. Decide on the type of exchanger to be used.
4. Select a trial value for the overall coefficient, U.
5. Calculate the mean temperature difference, ΔT_m.
6. Calculate the area required from equation 1.
7. Decide the exchanger layout.
8. Calculate the individual coefficients.
9. Calculate the overall coefficient and compare with the trial value. If the calculated value differs significantly from the estimated value, substitute the calculated for the estimated value and return to step 6.
10. Calculate the exchanger pressure drop; if unsatisfactory return to steps 7 or 4 or 3, in that order of preference.
11. Optimise the design: repeat steps 4 to 10, as necessary, to determine the cheapest exchanger that will satisfy the duty. Usually this will be the one with the smallest area.


Step 1
Specification
Define duty
Make energy balance if needed to calculate unspecified flow rates or temperatures
Step 2
Collect physical properties
Step 3
Assume value of overall coefficient $U_{o,ass}$
Step 4
Decide number of shell and tube passes Calculate ΔT_{lm}, correction factor, F, and ΔT_m
Step 5
Determine heat transfer area required: $A_o = q/U_{o,ass} \Delta T_m$
Step 6
Decide type, tube size, material layout Assign fluids to shell or tube side
Step 7
Calculate number of tubes
Step 8
Calculate shell diameter
Step 9
Estimate tube-side heat transfer coefficient
Step 10
Decide baffle spacing and estimate shell-side heat transfer coefficient
Step 11
Calculate overall heat transfer coefficient including fouling factors, $U_{o,calc}$
$0 < \frac{U_{o,calc} - U_{o,ass}}{U_{o,ass}} < 30\%$
No
Set $U_{o,ass} = U_{o,calc}$
Yes
Step 12
Estimate tube- and shell-side pressure drops
Pressure drops within specification?
No
Yes
Step 13
Estimate cost of exchanger
Step 14
Can design be optimized to reduce cost?
Yes
No
Accept design

Nomenclature for Heat Exchanger Components

TEMA

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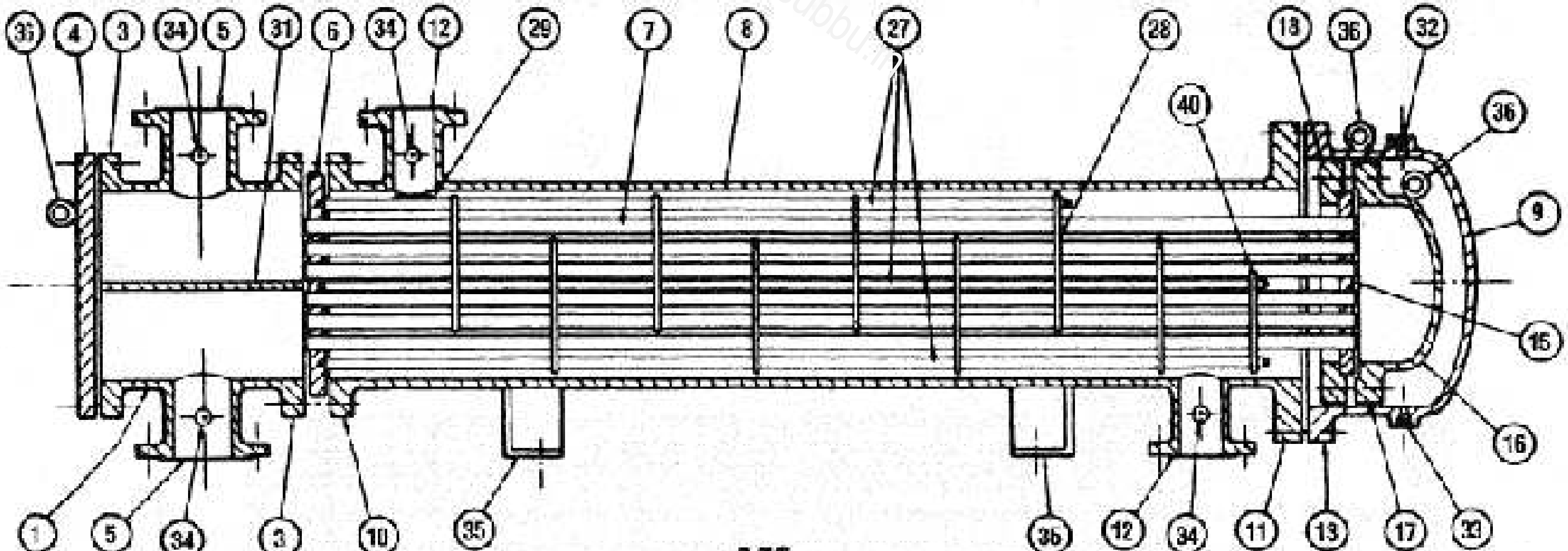
CFU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AES

Typical Parts of a Heat Exchanger

1. Stationary Head-Channel
2. Stationary Head-Bonnet
3. Stationary Head Flange-Channel or Bonnet
4. Channel Cover
5. Stationary Head Nozzle
6. Stationary Tubesheet
7. Tubes
8. Shell
9. Shell Cover
10. Shell Flange-Stationary Head End
11. Shell Flange-Rear Head End
12. Shell Nozzle
13. Shell Cover Flange
14. Expansion Joint
15. Floating Tubesheet
16. Floating Head Cover
17. Floating Head Cover Flange
18. Floating Head Backing Device
19. Split Shear Ring
20. Slip-on Backing Flange
21. Floating Head Cover-External
22. Floating Tubesheet Skirt
23. Packing Box
24. Packing
25. Packing Gland
26. Lantern Ring
27. Tierods and Spacers
28. Transverse Baffles or Support Plates
29. Impingement Plate
30. Longitudinal Baffle
31. Pass Partition
32. Vent Connection
33. Drain Connection
34. Instrument Connection
35. Support Saddle
36. Lifting Lug
37. Support Bracket
38. Weir
39. Liquid Level Connection
40. Floating Head Support

HEAT EXCHANGER SPECIFICATION SHEET

1			Job No.	
2	Customer		Reference No.	
3	Address		Proposal No.	
4	Plant Location		Date	Rev
5	Service of Unit		Item No.	
6	Size Type	(Hor/Vert)	Connected in	Parallel Series
7	Surf/Unit (Gross/Eff.)	Sq Ft Shells/Unit	Surf/Shell (Gross/Eff.)	Sq Ft
8	PERFORMANCE OF ONE UNIT			
9	Fluid Allocation		Shell Side	Tube Side
10	Fluid Name			
11	Fluid Quantity Total	Lb/Hr		
12	Vapor (In/Out)			
13	Liquid			
14	Steam			
15	Water			
16	Noncondensable			
17	Temperature (In/Out)	°F		
18	Specific Gravity			
19	Viscosity, Liquid	Cp		
20	Molecular Weight, Vapor			
21	Molecular Weight, Noncondensable			
22	Specific Heat	Btu / Lb °F		
23	Thermal Conductivity	Btu Ft / Hr Sq Ft °F		
24	Latent Heat	Btu / Lb @ °F		
25	Inlet Pressure	Psia		
26	Velocity	Ft / Sec		
27	Pressure Drop, Allow. /Calc.	Psi		
28	Fouling Resistance (Min.)	Hr Sq Ft °F / Btu		
29	Heat Exchanged		Btu / Hr; MTD (Corrected)	°F
30	Transfer Rate, Service		Clean	Btu / Hr Sq Ft °F
31	CONSTRUCTION OF ONE SHELL			Sketch (Bundle/Nozzle Orientation)
32		Shell Side	Tube Side	
33	Design / Test Pressure Psig	/	/	
34	Design Temp. Max/Min °F	/	/	
35	No. Passes per Shell			
36	Corrosion Allowance In			
37	Connections In			
38	Size & Out			
39	Rating Intermediate			
40	Tube No. OD In; Thk (Min/Avg) In; Length Ft; Pitch			In 30 60 90 45
41	Tube Type		Material	
42	Shell ID OD In		Shell Cover	(Integ.) (Remov.)
43	Channel or Bonnet		Channel Cover	
44	Tubesheet-Stationary		Tubesheet-Floating	
45	Floating Head Cover		Impingement Protection	
46	Baffles-Cross Type		%Cut (Diam/Area)	Spacing: c/c Inlet In
47	Baffles-Long		Seal Type	
48	Supports-Tube	U-Bend		Type
49	Bypass Seal Arrangement		Tube-to-Tubesheet Joint	
50	Expansion Joint		Type	
51	ρv²-Inlet Nozzle	Bundle Entrance		Bundle Exit
52	Gaskets-Shell Side		Tube Side	
53	Floating Head			
54	Code Requirements		TEMA Class	
55	Weight / Shell	Filled with Water	Bundle	Lb