Shell-and-tube Exchanger 5

Complete Design Procedure

Thermal Analysis and Calculations

As given in previous sections.

Hydraulic Calculations

- **Tube-side pressure drop**

$$\Delta P_f = \frac{f\, n_p L G^2}{7.50 \times 10^{12} D_i s \phi}$$

Units in psi

where
f = Darcy friction factor (dimensionless)
L = tube length (ft)
G = mass flux (lbm/h · ft²)
D_i = tube ID (ft)
s = fluid specific gravity (dimensionless)
ϕ = viscosity correction factor (dimensionless)
$= (\mu/\mu_w)^{0.14}$ for turbulent flow
$= (\mu/\mu_w)^{0.25}$ for laminar flow

$f = \frac{64}{Re}$ Laminar

$f = 0.4137\, Re^{-0.2585}$ turbulent Re ≥3000

Note the effect of number of tube passes, n_p

$$\Delta P_r = 1.334 \times 10^{-13} \alpha_r G^2 / s$$

α_r = number of velocity heads, See table to get it.

Number of Velocity Heads, α_r, Allocated for Minor Losses on Tube Side

Flow regime	Regular tubes	U-tubes
Turbulent	$2n_p - 1.5$	$1.6\, n_p - 1.5$
Laminar, $Re \geq 500$	$3.25\, n_p - 1.5$	$2.38\, n_p - 1.5$

- Nozzle pressure loss

No. of shells

$$\Delta P_n = 2.0 \times 10^{-13} N_s G_n^2 / s \quad \text{(turbulent flow)}$$

$$\Delta P_n = 4.0 \times 10^{-13} N_s G_n^2 / s \quad (\text{laminar flow, } Re_n \geq 100)$$

where G_n and Re_n are the mass flux and Reynolds number

- Shell-side pressure drop

$$\Delta P_f = \frac{f\,G^2\,d_s(n_b+1)}{7.50\times 10^{12}\,d_e s\phi}$$

where

f = friction factor (dimensionless)

G = mass flux = $\dot{m}/a_s$ (lbm/h · ft^2)

a_s = flow area across tube bundle (ft^2)

= $d_s C' B/(144 P_T)$

d_s = shell ID (in.)

C' = clearance (in.)

B = baffle spacing (in.)

P_T = tube pitch (in.); replaced by $P_T/\sqrt{2}$ for 45° tube layout

n_b = number of baffles

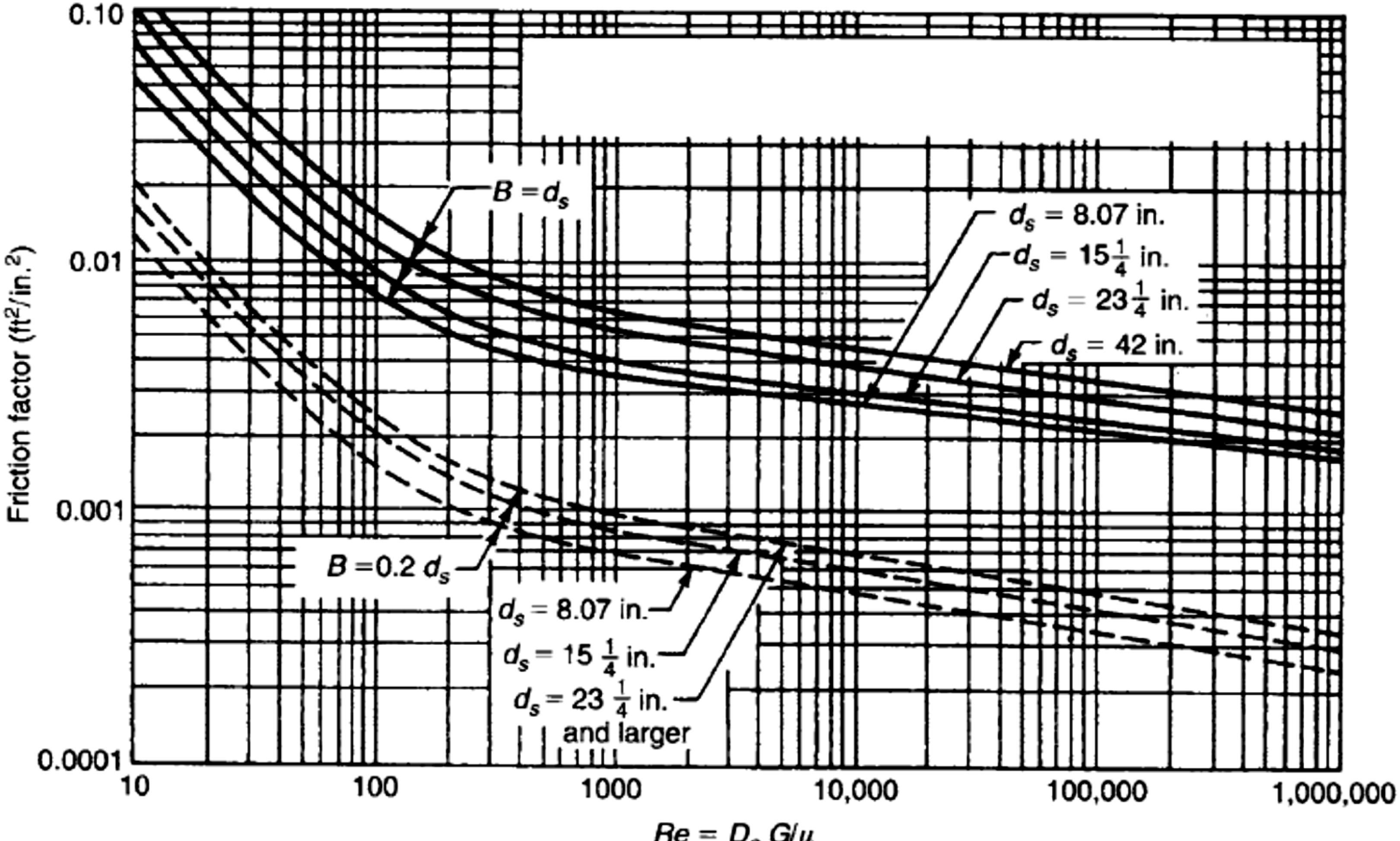
d_e = equivalent diameter from Figure 3.12 (in.)

s = fluid specific gravity

ϕ = viscosity correction factor = $(\mu/\mu_w)^{0.14}$

ΔP_f = pressure drop (psi)

For f use the following figure



Note: For use in the previous Equation, values from this figure must be multiplied by the factor 144 in.^{2}/ft ^{2}

Tube-Count Tables

Table C.1 *Tube Counts for 5/8-in. OD Tubes on 13/16-in. Square Pitch*

Shell ID (in.)	TEMA P or S				TEMA U		
	Number of passes				Number of passes		
	1	2	4	6	2	4	6
8	55	48	34	24	52	40	32
10	88	78	62	56	90	80	74
12	140	138	112	100	140	128	108
13.25	178	172	146	136	180	164	148
15.25	245	232	208	192	246	232	216
17.25	320	308	274	260	330	312	292
19.25	405	392	352	336	420	388	368
21.25	502	484	442	424	510	488	460
23.25	610	584	536	508	626	596	562
25	700	676	618	600	728	692	644
27	843	812	742	716	856	816	780
29	970	942	868	840	998	956	920
31	1127	1096	1014	984	1148	1108	1060
33	1288	1250	1178	1148	1318	1268	1222
35	1479	1438	1380	1308	1492	1436	1388
37	1647	1604	1520	1480	1684	1620	1568
39	1840	1794	1700	1664	1882	1816	1754
42	2157	2112	2004	1968	2196	2136	2068
45	2511	2458	2326	2288	2530	2464	2402
48	2865	2808	2686	2656	2908	2832	2764
54	3656	3600	3462	3404	3712	3624	3556
60	4538	4472	4310	4256	4608	4508	4426

Table C.2 *Tube Counts for 3/4-in. OD Tubes on 15/16-in. Triangular Pitch*

Shell ID (in.)	TEMA L or M				TEMA P or S				TEMA U		
	Number of passes				Number of passes				Number of passes		
	1	2	4	6	1	2	4	6	2	4	6
8	64	48	34	24	34	32	16	18	32	24	24
10	85	72	52	50	60	62	52	44	64	52	52
12	122	114	94	96	109	98	78	68	98	88	78
13.25	151	142	124	112	126	120	106	100	126	116	108
15.25	204	192	166	168	183	168	146	136	180	160	148
17.25	264	254	228	220	237	228	202	192	238	224	204
19.25	332	326	290	280	297	286	258	248	298	280	262
21.25	417	396	364	348	372	356	324	316	370	352	334
23.25	495	478	430	420	450	430	392	376	456	428	[illegible]
25	579	554	512	488	518	498	456	444	534	500	474
27	676	648	602	584	618	602	548	532	628	[illegible]	570
29	785	762	704	688	729	708	650	624	736	[illegible]	668
31	909	878	814	792	843	812	744	732	846	812	780
33	1035	1002	944	920	962	934	868	840	[illegible]	928	904
35	1164	1132	1062	1036	1090	1064	990	972	1100	1060	1008
37	1304	1270	1200	1168	1233	1196	1132	1100	1238	1200	1152
39	1460	1422	1338	1320	1365	1346	1266	1244	1390	1336	1290
42	1703	1664	1578	1552	1611	1580	1498	1464	1632	1568	1524
45	1960	1918	1830	1800	1875	1834	1736	1708	1882	1820	1770
48	2242	2196	2106	2060	2132	2100	[illegible]	1964	2152	2092	2044
54	2861	2804	2682	2660	2730	2684	2574	2536	2748	2680	2628
60	3527	3476	3360	3300	3395	3346	3228	3196	3420	3340	3286
66	4292	4228	4088	4044							
72	5116	5044	4902	4868							
78	6034	5964	5786	5740							
84	7005	6934	6766	6680							
90	8093	7998	7832	7708							
96	9203	9114	8896	8844							
108	11696	11618	11336	11268							
120	14459	14378	14080	13984							

Design Guidelines

- Fluid placement
  - as given before.
  - corrosion and fouling very important factors that affect the fluid placement. Corrosive fluids should be placed on the tube side.
  - Fluids that are heavy fouler should be placed on the tube side because it is (usually) easier to clean deposits from the interior surfaces of the tubes than from the exterior surfaces.
  - Cooling water is usually placed in the tubes due to its tendency to corrode carbon steel and to form scale, which is difficult to remove from the exterior tube surfaces.
  - See text for details.

- Tubing selection
  - ➢The most frequently used tube sizes are 3/4 and 1 in.
  - ➢ For water service, 3/4 in., 16 BWG tubes are recommended.
  - ➢For oil (liquid hydrocarbon) service, 3/4 in., 14 BWG tubes are recommended if the fluid is non-fouling, while I in., 14 BWG tubes should be used for fouling fluids.
  - ➢Tube lengths typically range from 8 to 30 ft, and sometimes longer depending on the type of construction and the tubing material.
  - ➢A good value to start with is 16 or 20 ft.

- Tube layout
  - ✓ the most commonly used tube layouts are either triangular or square, with a pitch of 1.0 in. (for 3/4-in. tubes) or 1.25 in. (for 1-in. tubes).

Design Strategy

Shell-and-tube design is an inherently iterative process, the main steps of which can be summarized as follows:

a) Obtain an initial configuration for the heat exchanger. This can be accomplished by using the preliminary design procedure as given in previous sections to estimate the required heat-transfer surface area, along with the design guidelines and tube-count tables discussed above to completely specify the configuration.
b) Rate the design to determine if it is thermally and hydraulically suitable.
c) Modify the design, if necessary, based on the results of the rating calculations.
d) Go to step (b) and iterate until an acceptable design is obtained.

The design procedure is illustrated in the following examples

See text Ch. 5 and Read these examples

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