1. Shell-and-tube Heat Exchanger

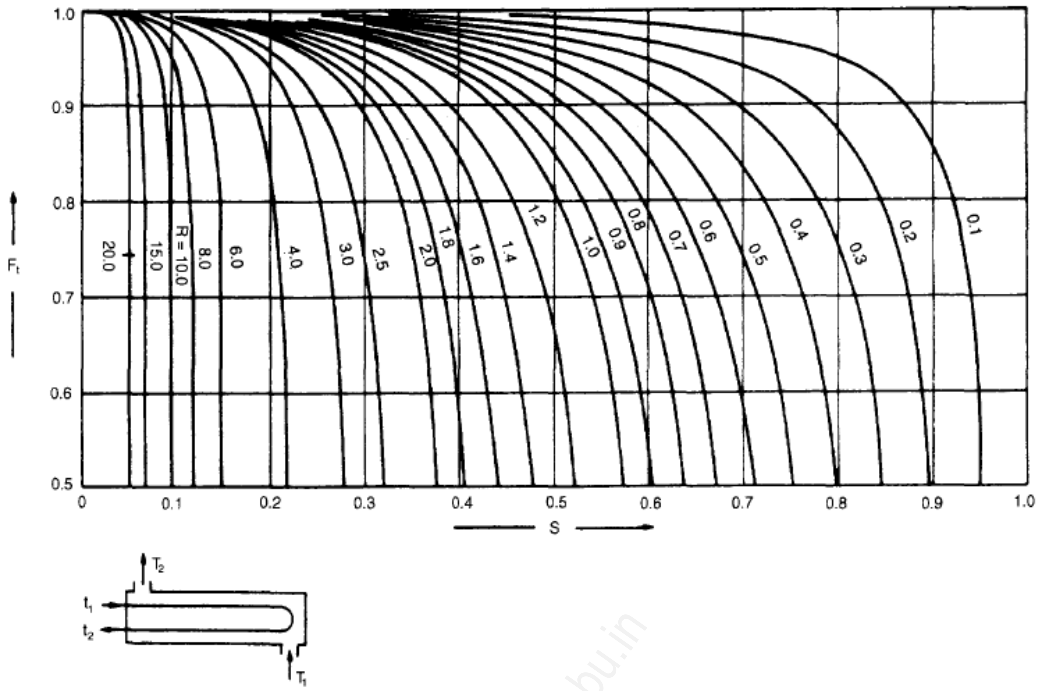

Figure 12.19. Temperature correction factor: one shell pass; two or more even tube ‘passes

F_t is a function of R and S

$$R = \frac{(T_1 - T_2)}{(t_2 - t_1)}$$

$$S = \frac{(t_2 - t_1)}{(T_1 - t_1)}$$

Tube side heat transfer coefficient:

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

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°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°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°C.

Heat transfer coefficient estimation from chart:

$$\frac{h_i d_i}{k_f} = j_h Re Pr^{0.33}\left(\frac{\mu}{\mu_w}\right)^{0.14}$$

Shell Side Calculations

Cross flow area for shell:

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

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

Calculate the shell-side mass velocity G_s and the linear velocity u_s:

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

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

where W_s = fluid flow-rate on the shell-side, kg/s,
ρ = shell-side fluid density, kg/m^3.

Shell side equivalent diameter:

Triangular pitch:

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

Reynolds number:

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

Shell side Heat Transfer coefficient:

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

Shell Diameter to Accommodate the Tubes

Relation between Tube count and Tube bundle diameter:

$$N_t = K_1 \left(\frac{D_b}{d_o}\right)^{n_1}, \qquad (12.3a)$$

$$D_b = d_o \left(\frac{N_t}{K_1}\right)^{1/n_1}, \qquad (12.3b)$$

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

Table 12.4. Constants for use in equation 12.3

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

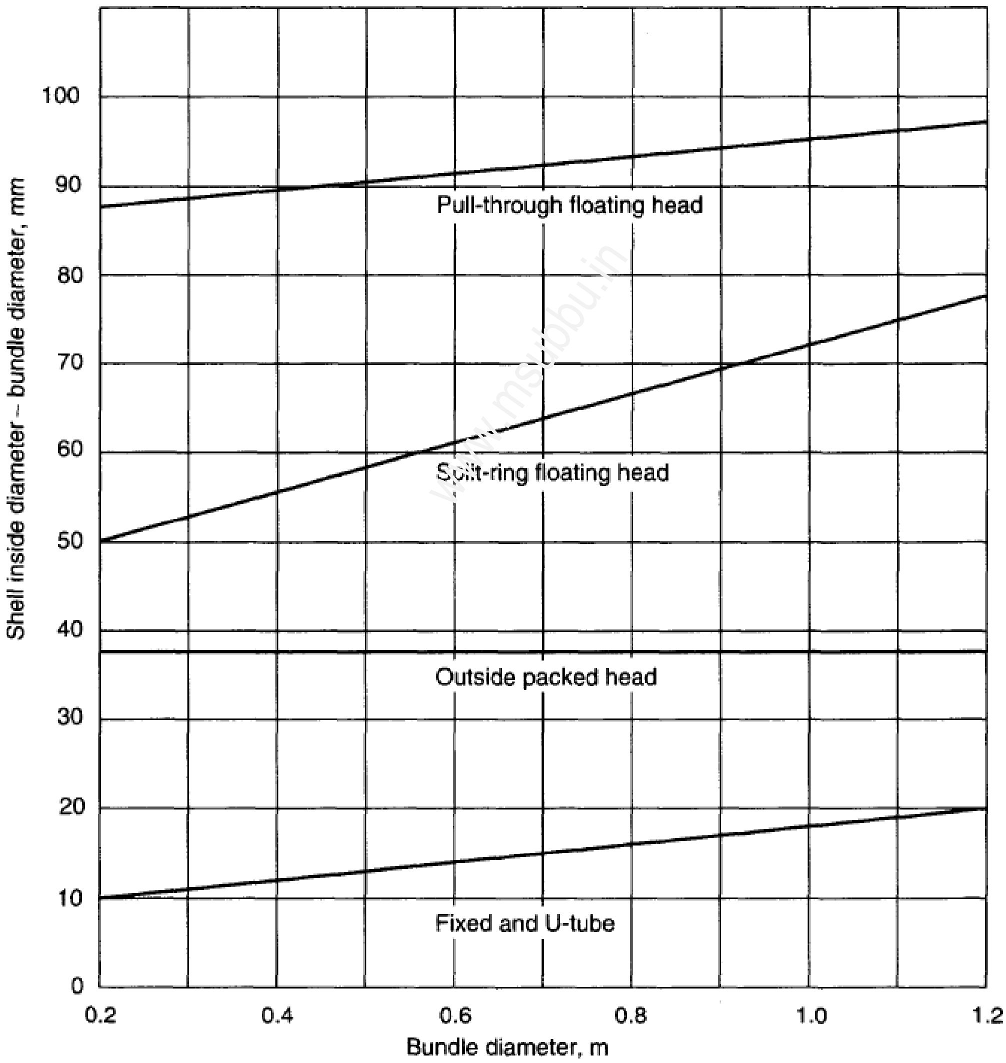

Figure 12.10. Shell-bundle clearance

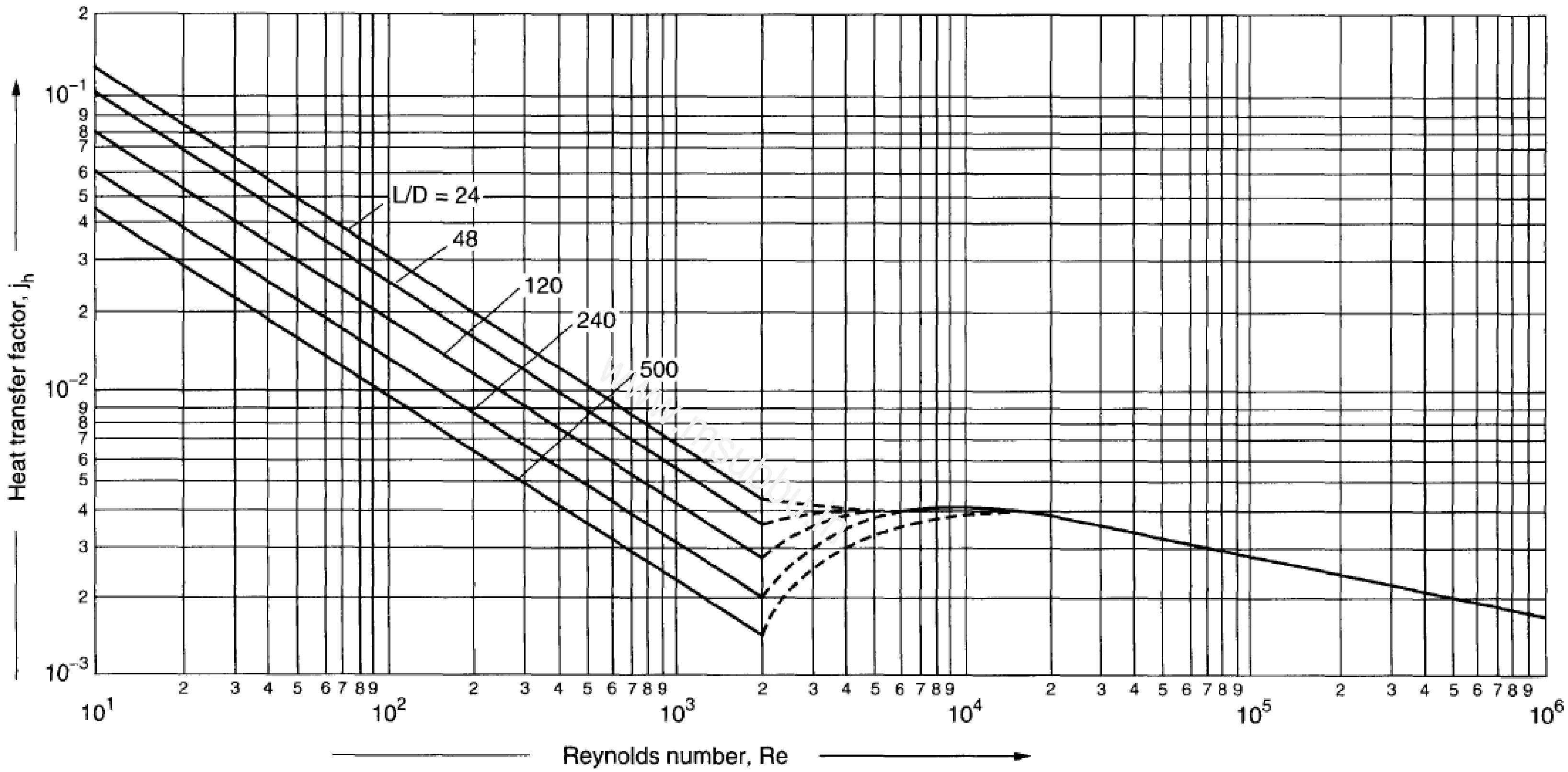

Figure 12.23. Tube-side heat-transfer factor

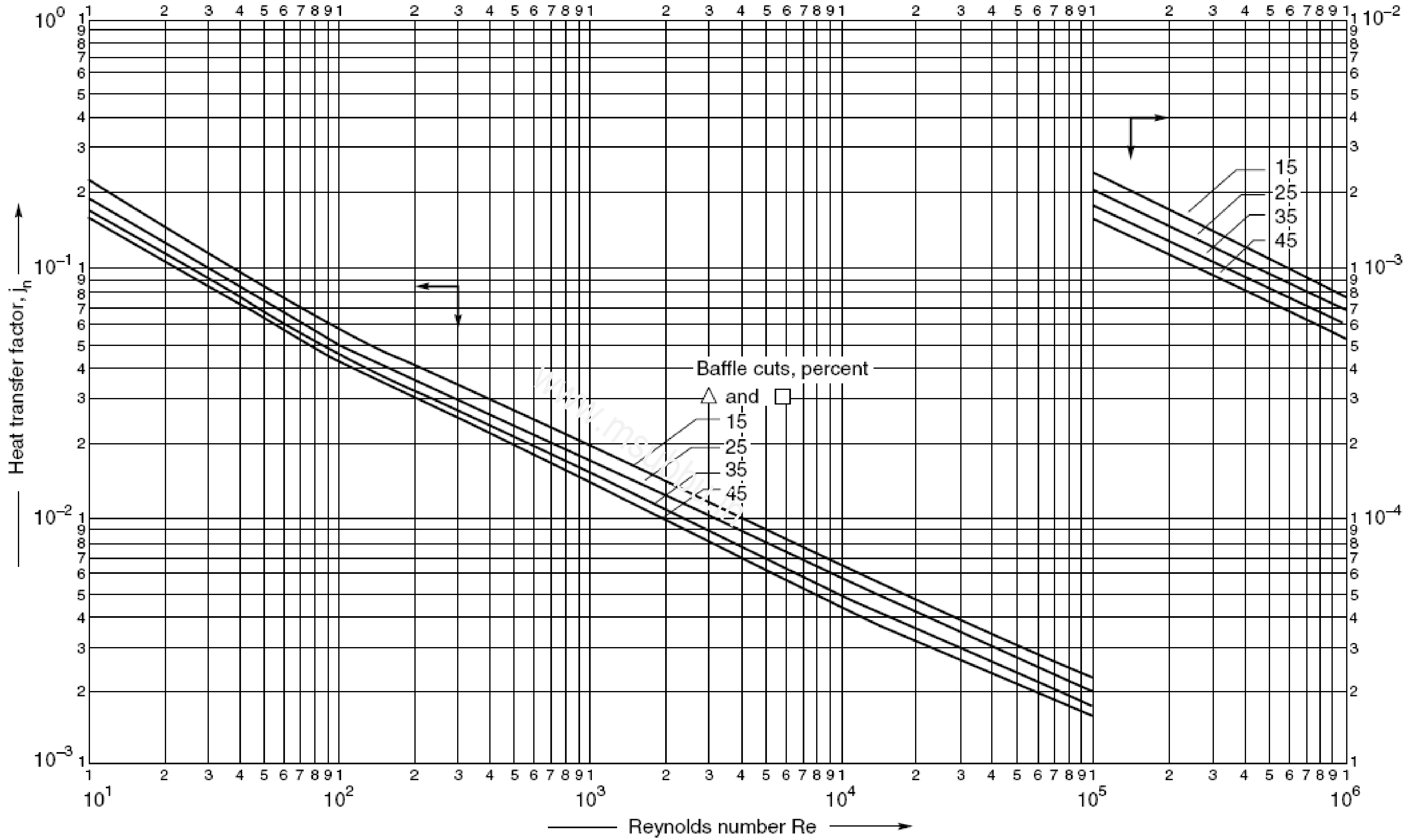

Figure 12.29. Shell-side heat-transfer factors, segmental baffles