Tutorial-4

Heat Exchanger

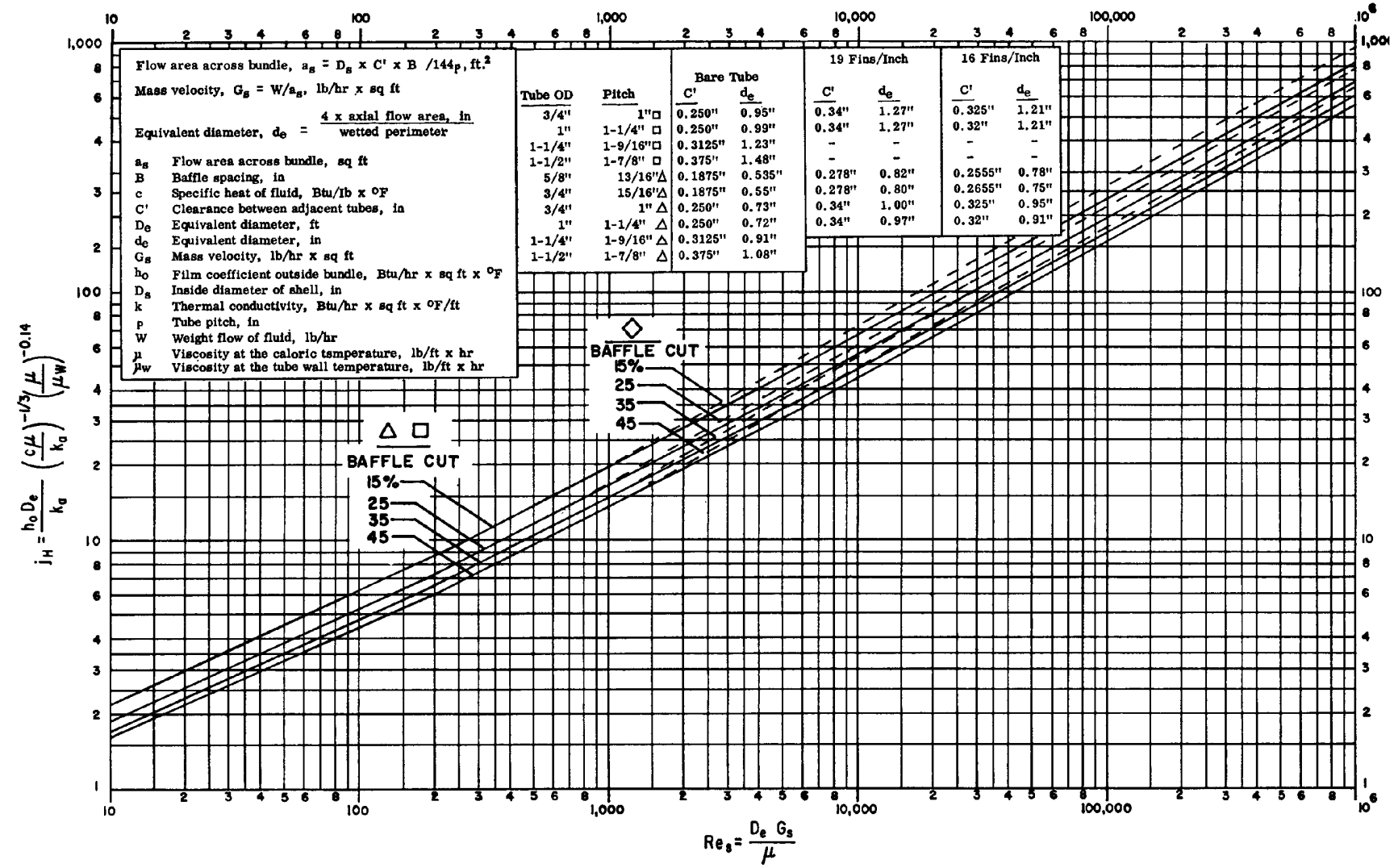
Mar 2020

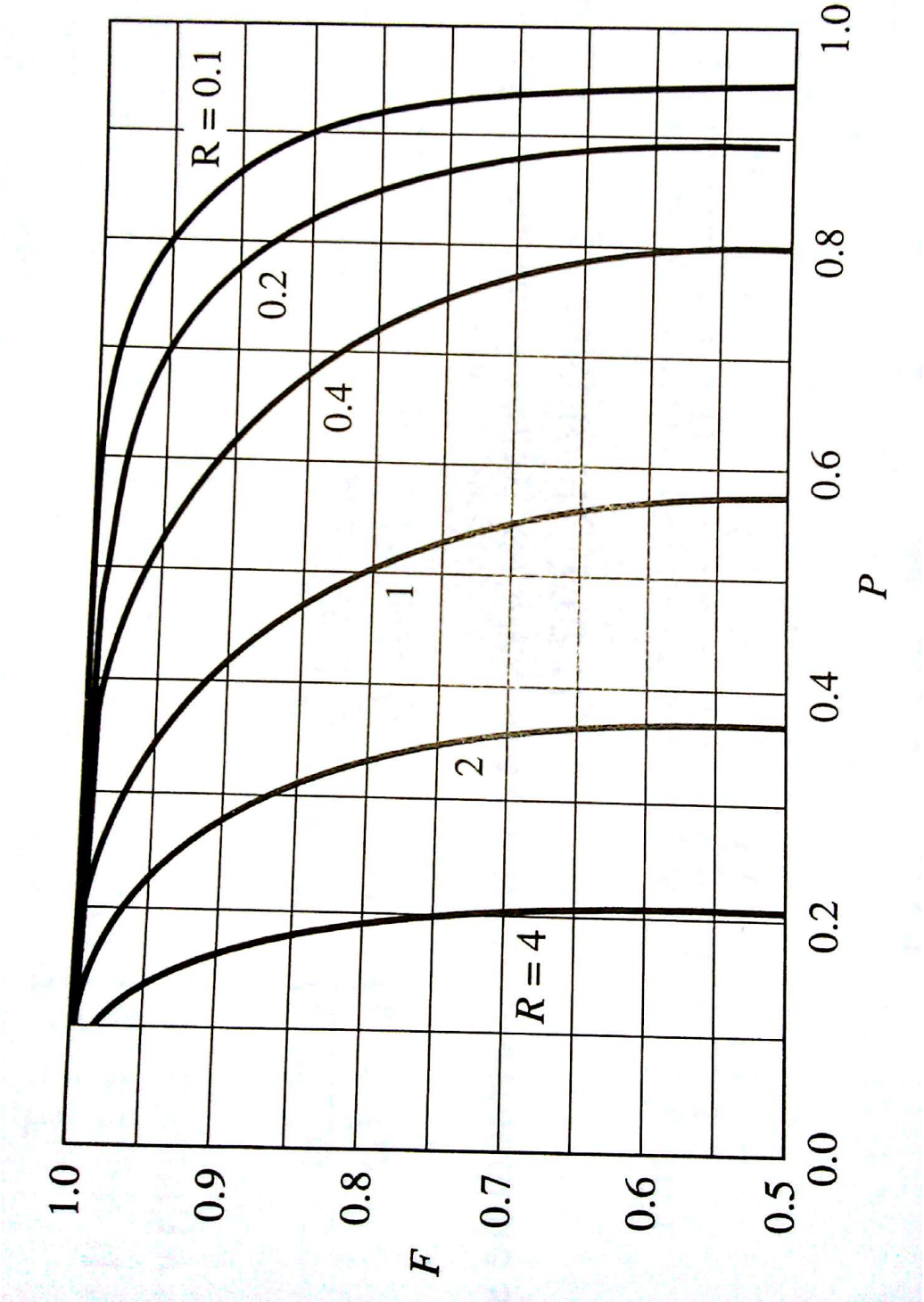
Exercise 1. Toluene is being condensed at 230 $^{\circ}F$ on outiside of a tube through which cooling water is flowing with inlet 40 $^{\circ}F$ and outlet 120 $^{\circ}F$. What is the average wall temperature? The toluene side coefficient is 2840 Btu/ft^2 h $^{\circ}$ F and the water side coefficient is 3270 Btu/ft^{2}h$^{\circ}$F.

Exercise 2. CCl_4 flowing at 19,000 Kg/h is to be cooled from 85 °C to 40 °C using 13,500 Kg/h of cold water available at 20 $^{\circ}$ C. The CCl_4 flows outside the central tube which has a film coefficient of 1700 W/m^2 °C. Inside film coefficient is 11000 W/m^2 °C. Calculate the area of a counter current exchanger. Data: c_{p,CCl_4} = 0.8 kJ/kg; c_{p,H_2O} =4.2 kJ/kg

Exercise 3. Water enters (12 kg/s) the tubes of a single-pass counter flow shell and tube heat exchanger at 20 °C. On the shell side, 7 kg/s of water enters at 60 °C. Calculate the exit temperatures of both the streams if the area of the exchanger is 12 m^2. Fouling and metal wall resistance can be neglected. Properties may be evaluated at 320 K and may be considered to be constant. The exchanger has the following tube bundle configuration: 10 inch ID shell with 74 no 1 inch OD tubes laid on 1.25 inch square pitch. Baffles are 24 inch apart with 25% cut. 1m^2 = 10.76 ft^2.

Exercise 4. 43800 lb/hr of hot Kerosene leaves the distillation column at 390 °F and will be cooled to 200 °F by 149000 lb/hr of crude from storage at 100 °F. Determine the length of an 1-2 exchanger. *Data and assumptions:* The shell side fluid is kerosene because it is more difficult to clean the shell side. The tube side coefficient is 121 Btu/hr ft^2 ^{o}F. The tubes are clean with negligible metal wall resistance. The space available can hold a maximum of 2 ft by 2 ft by 20 ft exchanger at most including the space for pulling the tube bundle. Hence, the following tube bundle configuration is prescribed: 21 inch ID shell with 158 no 1 inch OD tubes laid on 1.25 inch square pitch. Baffles are 5 inch apart with 25% cut. The outside area of the tubes are 0.344 ft^2/ft. $\hat{c_p}$ of kerosene: 0.605 Btu/lb °F; $\hat{c_p}$ of crude: 0.490 Btu/lb °F; Viscosity of kerosene: 0.97 lb/ft-hr; thermal conductivity of kerosene: 0.0765 Btu/hr ft^2 ($^{\circ}$F/ft). Viscosity correction can be neglected.


Flow area across bundle, $a_s = D_s \times C' \times B / 144p$, ft.²
Mass velocity, $G_s = W/a_s$, lb/hr x sq ft
Equivalent diameter, $d_e = \frac{4 \times \text{axial flow area, in}}{\text{wetted perimeter}}$
a_s Flow area across bundle, sq ft
B Baffle spacing, in
c Specific heat of fluid, Btu/lb x °F
C' Clearance between adjacent tubes, in
D_e Equivalent diameter, ft
d_e Equivalent diameter, in
G_s Mass velocity, lb/hr x sq ft
h_o Film coefficient outside bundle, Btu/hr x sq ft x °F
D_s Inside diameter of shell, in
k Thermal conductivity, Btu/hr x sq ft x °F/ft
p Tube pitch, in
W Weight flow of fluid, lb/hr
μ Viscosity at the caloric tsmperature, lb/ft x hr
μ_w Viscosity at the tube wall temperature, lb/ft x hr
Tube OD | Pitch | Bare Tube C' | Bare Tube d_e | 19 Fins/Inch C' | 19 Fins/Inch d_e | 16 Fins/Inch C' | 16 Fins/Inch d_e
3/4" | 1"□ | 0.250" | 0.95" | 0.34" | 1.27" | 0.325" | 1.21"
1" | 1-1/4" □ | 0.250" | 0.99" | 0.34" | 1.27" | 0.32" | 1.21"
1-1/4" | 1-9/16"□ | 0.3125" | 1.23" | - | - | - | -
1-1/2" | 1-7/8" □ | 0.375" | 1.48" | - | - | - | -
5/8" | 13/16"△ | 0.1875" | 0.535" | 0.278" | 0.82" | 0.2555" | 0.78"
3/4" | 15/16"△ | 0.1875" | 0.55" | 0.278" | 0.80" | 0.2655" | 0.75"
3/4" | 1" △ | 0.250" | 0.73" | 0.34" | 1.00" | 0.325" | 0.95"
1" | 1-1/4" △ | 0.250" | 0.72" | 0.34" | 0.97" | 0.32" | 0.91"
1-1/2" | 1-7/8" △ | 0.375" | 1.08"
△ □ BAFFLE CUT 15% 25 35 45
◇ BAFFLE CUT 15% 25 35 45
$j_H = \frac{h_o D_e}{k_a} \left(\frac{c\mu}{k_a}\right)^{-1/3} \left(\frac{\mu}{\mu_w}\right)^{-0.14}$
$Re_s = \frac{D_e G_s}{\mu}$


R = 0.1
0.2
0.4
1
2
R = 4
F
P
1.0
0.9
0.8
0.7
0.6
0.5
0.0
0.2
0.4
0.6
0.8
1.0