BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)
SUBJECT: ME579 DESIGN AND ANALYSIS OF HEAT EXCHANGERS
Time- 2 hours Marks- 50

Answer any 10 questions

1. Classify the heat exchanger in details according to process design.

5

2. What is the significance of velocity boundary layer and thermal boundary layer when fluid flows with uniform velocity and temperature (U_α and T_α) over a uniformly heated (with temperature T_b) flat plate?

5

3. A pipe of 1.27 cm outer diameter carrying high pressure condensing steam at 239˚C is exposed to the cross-flow of air at a temperature of 15˚C and a velocity of 10 m/s. what is the heat loss per meter length of pipe?

Given, $$Nu = 0.3 + \frac{0.62\,\mathrm{Re}^{1/2}\ \mathrm{Pr}^{1/3}}{\left[1+\left(0.4/\mathrm{Pr}\right)^{2/3}\right]^{1/4}}\left[1+\left(\frac{\mathrm{Re}}{28200}\right)^{5/8}\right]^{4/5}$$

Properties of air:

Density = 0.871 kg/m^3	Viscosity = 2.30 × 10^{-5} (N.s)/m^2
Conductivity = 3.38 × 10^{-2} W/(m.K)	Prandtl number (Pr) = 0.690

5

4. **a.** What are the different types of fouling in heat exchanger (names only)?

b. A double –pipe heat exchanger, consisting of a 2 cm internal diameter, 2.5 cm external diameter tube mounted in a concentric outer tube, is used to cool a hot oil. The oil flows in the inside tube and has a heat transfer coefficient of 200 W/(m^2.K) and a fouling resistance of 0.0008 (m^2.K) /W. The cooling fluid is treated cooling water that flows in the annulus between the inner and outer tube; its heat transfer coefficient is 5000 W/(m^2.K) and its fouling resistance is 0.0002 (m^2.K) /W. The tube wall thermal conductivity is 100 (W.m^2)/(K.m). Calculate the overall heat transfer coefficient for this heat exchanger.

1+4

5. Derive the expression of LMTD of counter-flow heat exchanger?

5

6. a. Why counter-flow heat exchanger is more efficient than parallel flow heat exchanger?

b. A counter current flow heat exchanger is used to cool oil from 110 to 60˚C with cooling water whose inlet temperature is 30˚C and outlet is 55˚C. what is LMTD? What is the LMTD if the heat exchanger is operated in the parallel flow rather than the counter current mode?

2+3

7. An oil cooler is used to cool lubricating oil from 70˚ to 30˚C. the cooling liquid is treated cooling water entering the exchanger at 20˚C and leaving at 30˚C. The specific heat capacities of the oil and water, respectively, are 2 and 4.2 kJ/kg.K and the oil flow rate is 4 kg/s. Calculate the water flow rate required and calculate the mean temperature difference ΔT_M for a two-pass shell-and-tube and an unmixed cross-flow configuration, respectively.

5

8. An oil-to-oil shell and tube heat exchanger has the end temperatures

$$T_{h,in} = 400^o C \qquad T_{h,\text{out}} = 62.5^o C$$

$$T_{\text{c},in} = 25^o C \qquad T_{\text{c,out}} = 193.75^o C$$

Estimate the F-correction factor for a single shell, and If the value of F is unacceptably low, increase the number of shells until an acceptable value is obtained by using Bowmen et. al. (1940) correlation.

5

9. A shell and tube heat exchanger has the following geometry:

Shell internal diameter:	D_s=0.5398 m
Tube outside diameter	D_o = 2.54 cm
Tube inside diameter	D_i = 2.0574 cm
Tube pitch (square)	P_T = 3.175 cm
Baffle spacing	L_B = 12.70 cm
Reynolds number	25,224

Use the kern method to calculate the shell-side heat transfer coefficient for the flow of a light hydrocarbon with the following specification (at bulk temperature):

Total mass flow rate	5.5188 kg/s
Density	730 kg/m^3
Thermal conductivity	0.1324 W/m.K
Specific heat capacity	2.470 kJ/kg. K
Viscosity	401 μ N.s/m^2

Assume no change in viscosity from the bulk to the wall.

Given $\text{Nu}=\dfrac{\text{h}_\text{o} D_e}{k} = 0.36\ (Re)^{0.55}\,(Pr)^{1/3}$

5

10. An oil cooler is fed with an oil that has specific heat capacitiy (c_{ph}) of 2 kJ/kg.K, flow rate (M_h) of 10 kg/s, and temperature of 90°C. The cooling stream is treated cooling water that has specific heat capacitiy (c_{pc}) of 4.2 kJ/kg.K, flow rate (M_c) of 20 kg/s, and inlet temperature of 15°C. Assuming a total heat exchanger surface area of 200 m^2 and overall heat transfer co-efficient (U) 150 W/(m^2. K).

Calculate hot and cold fluid outlet temperatures for two-pass shell-and-tube heat exchangers. Estimate the F correction factor and examine whether the correction factor is above recommended value (F>0.8).

5

11. Consider the problem:

$$\text{Minimize } f = (x_1 + 2x_2 - 7)^2 + (2x_1 + x_2 - 5)^2$$

If the base simplex is defined by the vertices

$$X_1 = \begin{Bmatrix} -2 \\ -2 \end{Bmatrix}, \quad X_2 = \begin{Bmatrix} -3 \\ 0 \end{Bmatrix}, \quad X_3 = \begin{Bmatrix} -1 \\ -1 \end{Bmatrix}$$

Find a sequence of one improved vectors using reflection, expansion, and/or contraction.

Assume reflection coefficient α=1, contraction coefficient β = 0.5, expansion coefficient γ = 2, and converge when ε ≈ 0.2.

5

*You can assume a valid parameter value which is not given above

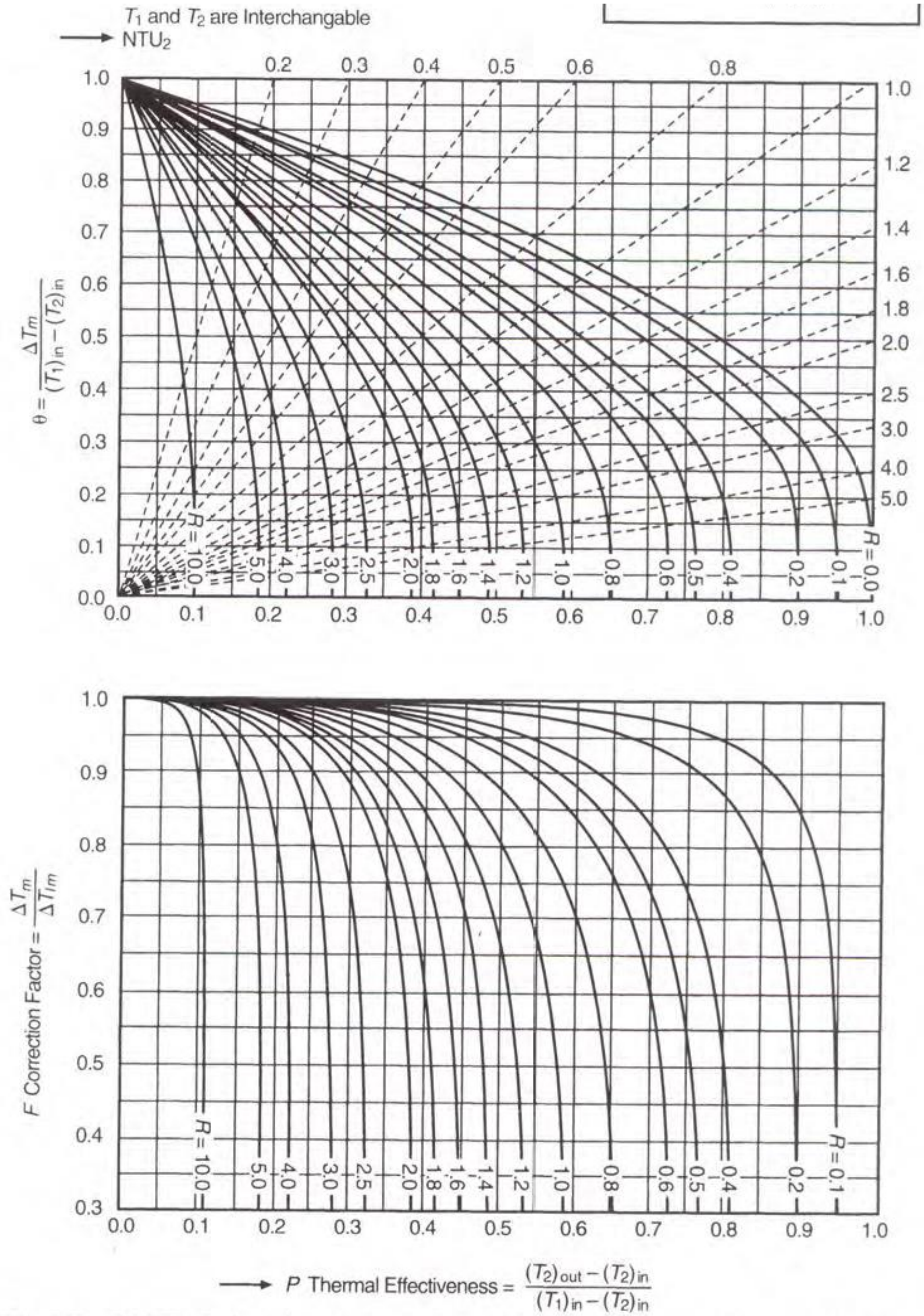

Fig. 3.22 F-θ-NTU-P chart for a two-pass shell-and-tube heat exchanger. The same chart can be used for 4, 6, 8 . . . passes. (From Taborek, 1983. With permission.)

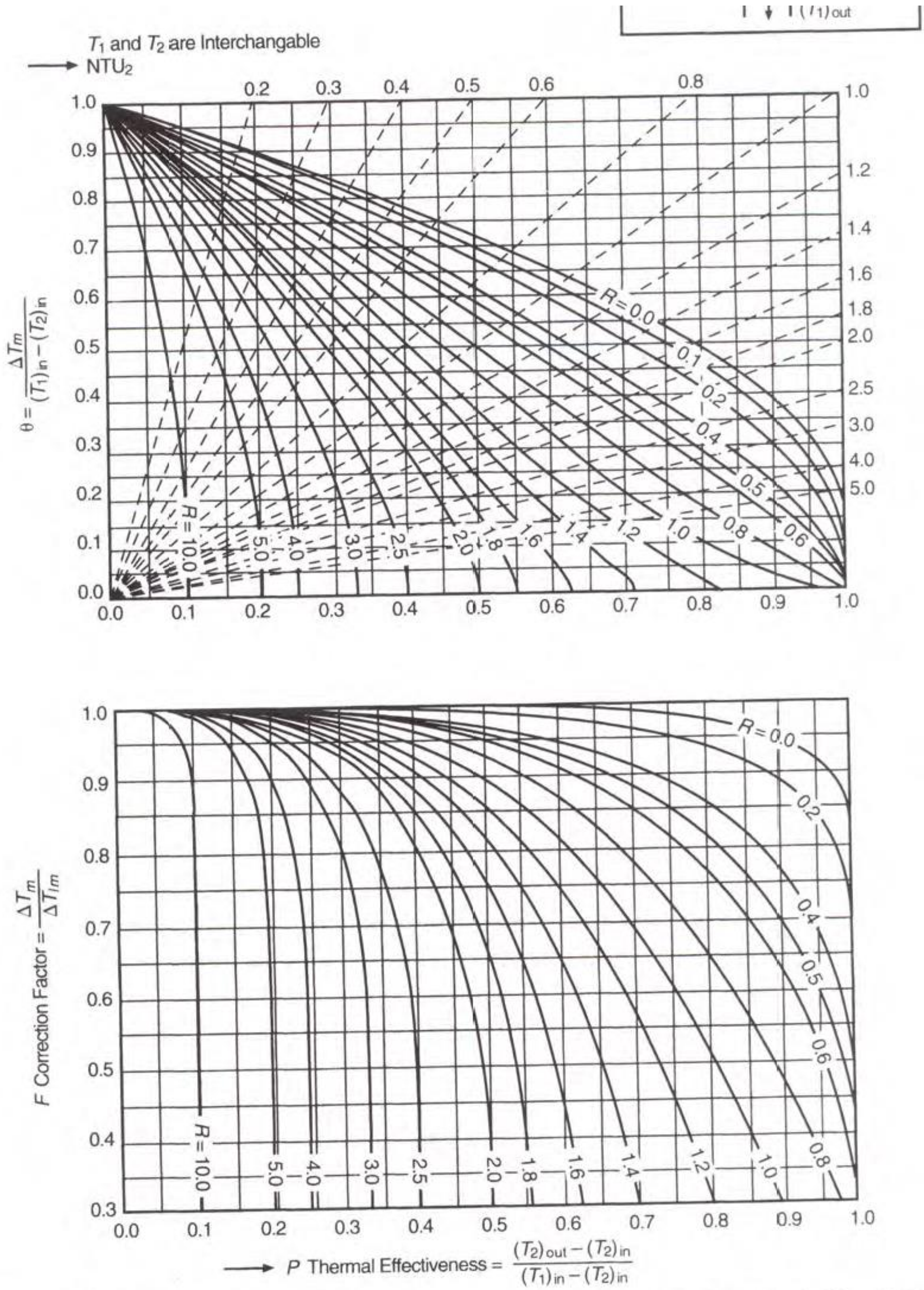

Fig. 3.23 *F-θ-NTU-P* chart for a cross-flow heat exchanger with no lateral mixing of either stream. (From Taborek, 1983. With permission.)