Master of Mechanical Engineering Examination 2018
Second Semester
HEAT EXCHANGER

Full Marks: 100 **Time: 3 hours**

Answer any *four* questions. Assume any unfurnished data suitably.

1. a) Discuss the different basis for classification of heat exchangers.
   b) Find an expression for the effectiveness of a counter-flow heat exchanger in terms of NTU and ratio of heat capacity of the fluids. Hence find the expressions for effectiveness when the ratio of heat capacity rate is equal to (a) zero and (b) unity. (25)

2. a) Explain the term 'temperature cross' in a multi-pass heat exchanger.
   b) Discuss how the following can be obtained using the *F*-*θ*-NTU-*P* chart
   i) To calculate mean temperature difference, inlet and out temperatures are known.
   ii) To calculate the outlet temperatures, total surface area, overall heat transfer coefficient, stream flow rates, specific heat capacities and inlet temperatures are given.
   c) An air blast cooler with a surface area for heat transfer of 300 m^2 and an overall heat transfer coefficient of 60 W/(m^2.K) is fed with the following streams:

$$\text{Air}: \dot{m}_c = 6 \text{ kg/s}, c_{pc} = 1050 \text{ J/(kg.K)}, T_{c,in} = 20^0 C$$

$$\text{Oil}: \dot{m}_h = 1.5 \text{ kg/s}, c_{ph} = 2000 \text{ J/(kg.K)}, T_{h,in} = 80^0 C$$

   Calculate the exit temperatures for air and oil, the *F*-value and the effectiveness for an unmixed cross-flow exchanger with the help of *F*-*θ*-NTU-*P* chart as shown in Fig.1. (25)

3. a) Compare the merits and demerits of forced draft and induced draft air-cooled heat exchangers.
   b) A plate heat exchanger has 99 plates, each 1m high and 0.25 m wide, with a gap of 5 mm between them. Cold water, initially at 15 ^0C is fed into the heat exchanger at a rate of 5 kg/s and flow through half the passages in countercurrent flow to hot water, initially at 95 ^0C, flowing at a rate of 10 kg/s. Fluid properties for both streams are given as:
   Density = 985.2 kg/m^3
   Specific heat = 4183 J/(kg.K)
   Conductivity = 0.648 W/(m.K)
   Viscosity = 5.05 X 10^{-4} (N.s)/m^2
   Prandtl number = 3.26
   An approximate expression for Nusselt number that fits in this case is given by $Nu = 0.4Re^{0.64}Pr^{0.4}$ for the hot as well as the cold streams. The expression for effectiveness for the countercurrent flow heat exchanger is given by $\varepsilon = \dfrac{\exp[(1-C_r)NTU_{min}]-1}{\exp[(1-C_r)NTU_{min}]-C_r}$, where, the symbols bear their usual meaning. Find the outlet temperatures of both the streams. (25)

4. a) Discuss the method of selection of the appropriate type of heat exchanger based on operating conditions and economic considerations.
   b) A light hydrocarbon vapour is to be condensed under saturation conditions at a temperature of 120 ^0C. It enters the condenser a saturated vapour and leaves as saturated condensate. It is flowing at a rate of 300 kg/s and has a latent heat of 200 kJ/kg. The coolant is treated cooling water entering at 20 ^0C and leaving at 50 ^0C. Assess the alternative use of shell and tube and

double pipe heat exchangers for this duty and carry out an approximate cost comparison using the C-value method to select the most economical one.
Discrete C-values are given in the following table.

Double pipe heat exchanger	$\frac{\dot{Q}}{\Delta T_M}$ (W/K)	30,000	1,00,000	1,000,000
	C-value [Re/(W/K)]	19.01	14.11	14.11
Shell and tube heat exchanger	$\frac{\dot{Q}}{\Delta T_M}$ (W/K)	30,000	1,00,000	1,000,000
	C-value [Re/(W/K)]	13.28	7.80	4.81

(25)

5. a) Consider a process plant handling three hot streams and three cold streams. The stream details are given below.

Stream Number	Hot or Cold	$\dot{m}c_p$ (W/K)	Inlet Temperatures (^0C)	Outlet Temperatures (^0C)
1	Hot	300	250	20
2	Hot	2000	80	40
3	Hot	700	160	30
4	Cold	1250	100	200
5	Cold	800	60	150
6	Cold	500	40	120

Plot the temperature intervals and composite curves on temperature-enthalpy diagram for the hot and the cold streams. Hence, compute the minimum hot and cold utilities and maximum practicable heat exchange for a pinch point temperature difference of 10 ^0C. **(25)**

6. a) Discuss the specific situations where you use parallel flow, counter flow and cross flow heat exchangers.

b) A 1-2 shell and tube heat exchanger has the following geometry:
   Shell internal diameter = 0.5398 m
   Number of tubes = 158
   Tube O.D. = 2.54 cm
   Tube I.D. = 2.0574 cm
   Tube pitch (square) = 3.175 cm
   Baffle spacing = 12.70 cm
   Shell length = 4.7868 m

Use Kern's method to calculate the shell side heat transfer coefficient for the flow of a light hydrocarbon with the following specification at mean bulk temperature on the shell side:
   Shell side fluid 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 = 401X10^{-6} (N.s/m^2)

Assume no change in viscosity from the bulk to the wall and that $Nu=0.36Re^{0.55}Pr^{0.334}$

(25)

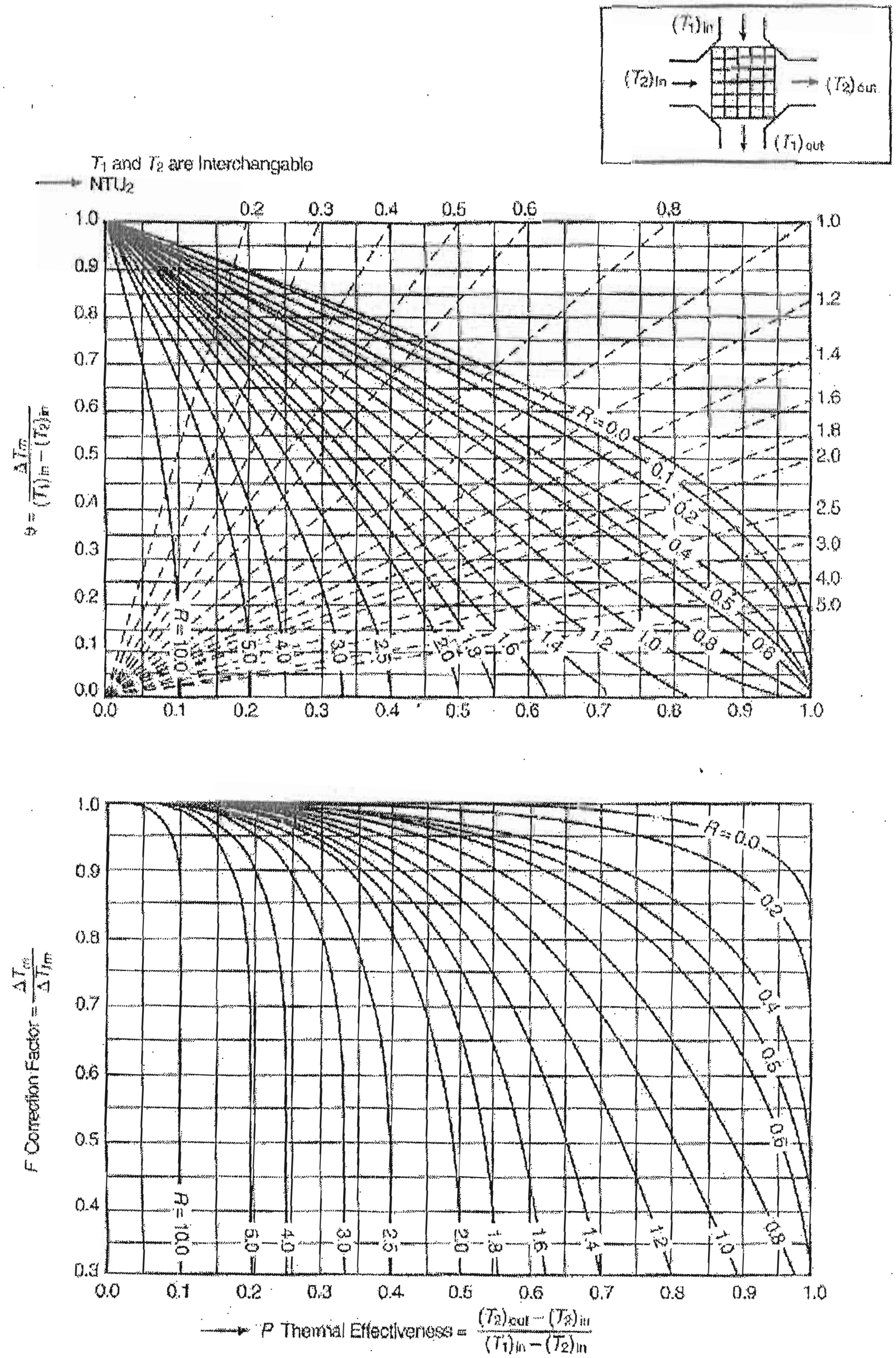

Fig.1 F-θ-NTU-P chart for an unmixed cross-flow heat exchanger