Dr Tapas Patar Roll No. 5/5/2023

National Institute of Technology Hamirpur
Department of Chemical Engineering
End Semester Examination, May 2023
Branch: Chemical Engineering **Course Code:** CH-323
Course Title: Process Equipment Design-II
Class: B. Tech. | **Semester:** VI | **Full Marks:** 50 | **Time:** 3 hours

Instructions:

- Answer all the questions. All parts (a, b, c) of any question must be answered in same place.
- Data book is to be supplied in the examination hall.
- Calculator is allowed but exchange of the same is not permitted.
- Missing data may suitably be assumed, if any.

1. It is necessary to preheat 149000 lb/h of 34 °API crude oil from 170°F to 285°F. There is a utility of 33 °API gas-oil line running near the tower at 530 °F. The temperature of the gas-oil from the exchanger should not be less than 300°F. Available on the site is a 1-6 shell and tube heat exchanger having tubes of 1" OD, 13 BWG, 16' long arranged on a 1.25" triangular pitch layout. The baffles (25% cut segmental) are spaced at 5" apart. A pumping head of 10 psi is allowable on both sides. It is preferable to pass the crude oil through the tube. (15)

   Given: Thermal conductivity of tube (steel) = 29 BTU/h.ft.°F.
   Assume overall heat transfer coefficient = 55 BTU/h.ft^2.°F.

   a) Calculate the heat duty of the exchanger.
   b) Determine Shell ID.
   c) Calculate shell-side heat transfer coefficient. Neglect the viscosity correction factor.
   d) Calculate dirt factor if the tube-side heat transfer coefficient based on outside surface area is 160 BTU/h.ft^2.°F.

2. In a distillation process, feed containing 5 mol% ethanol in water is concentrated to 50%. The concentration of alcohol in the bottom stream is reduced to less than 0.1%. Design a sieve plate column to perform this separation, for a feed rate of 10,000 kg/h at 20°C temperature. The column will operate at 1 atm. (top plate). A pressure drop of 1.25 kPa per plate is allowed. A tray spacing of 0.5 m and 80% flooding at maximum gas flow rate is suggested. Assume minimum liquid flow as 70% of the maximum rate both above and below the feed plate. Mass balance of the column gives the following data for top section. (15)

   Given: Downcomer area (both top and seal) = 10% of column cross-sectional area; Hole diameter = Plate thickness = 12 mm; Height of weir = 40 mm; Hole area = 10% of active area; Downcomer apron area = 0.0131 m^2.

Parameters	Top section
Number of plates	3
Vapour flow rate	86.0 kmol/h
Liquid flow rate	35.42 kmol/h
Density of the liquid	866.0 kg/m^3
Column top temperature	80 °C
Average Mol. wt. of vapour	36.7
Average Mol. wt. of liquid	32.0
Surface tension	40 × 10^{-3} N/m

P.T.O.

(89)

a) Calculate column diameter for the top section (take the nearest value as per IS: 2844 – 1964 for subsequent calculations).
b) Calculate the total pressure drop per plate assuming maximum weir crest is 20 mm liquid height.
c) Calculate downcomer residence time.

3. A single effect evaporator is employed to concentrate 20000 lb/h of feed from 20% to 50% aqueous solution of NaOH. The saturated steam is available at 34.7 psi and the pressure of the evaporator is 1.93 psi. The overall heat transfer coefficient is estimated to be 250 BTU/h.ft^{2}.°F. The feed temperature is 100°F. Neglect boiling point elevation. (8)
Given: Enthalpy of feed and thick liquor are 55 and 221 BTU/lb, respectively and specific heat of feed and thick liquor may be taken as 1.

a) Calculate the amount of steam consumed.
b) Estimate the steam economy.
c) Determine the heat transfer area required.

4. a) What are the advantages of floating head heat exchanger? (2)
b) What are the possible ways to decrease pressure drop in the tube side for a shell and tube heat exchanger? (2)
c) What is the role of calming zone in sieve plate distillation column? (2)
d) Explain flooding and weeping in a mass transfer column. (2)
e) Write down the energy balance equation for condensing fluid where superheated vapour is entering as feed and sub-cooled liquid is leaving as condensate. Draw a concentration profile. (2)
f) Why (1/2) factor is required for calculation of pressure drop of the boiling fluid in a reboiler? (2)

********** *All the Best* **********