Exam Date & Time: 02-May-2024 (02:30 PM - 05:30 PM)

# MANIPAL ACADEMY OF HIGHER EDUCATION

6th SEMESTER B.TECH END SEMESTER EXAMINATIONS, MAY 2024

**DESIGN AND DRAWING OF CHEMICAL PROCESS EQUIPMENT [CHE 3251]**

**Marks: 50** **Duration: 180 mins.**

**A**

**Answer all the questions.**

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) A) 4500 kg/h of ammonia vapour at 6.7 bar(a) pressure is to be cooled from 120°C to 40°C, using cooling water. The maximum supply temperature of the cooling water available is 30°C, and the outlet temperature is to be restricted to 40°C. The pressure drops over the exchanger must not exceed 0.5 bar for the ammonia stream and 1.5 bar for the cooling water. A contractor has proposed a shell and tube exchanger with the following specification for this duty. ***Shell***: E-type, shell diameter: 590 mm. Baffles: 25 per cent cut, 300 mm baffle spacing. ***Tubes***: carbon steel, 15 mm ID, 19 mm OD, 2400 mm long, number of tubes are 360, thermal conductivity: 50 W/m-°C. ***Tube arrangement:*** 8 passes, triangular tube pitch. It is proposed to put the cooling water though the tubes.

The properties of both the fluids are given below: (4)

For cooling water, at $t_{avg}$ = 35°C; $C_{Pw}$ = 4.18 kJ/kg-°C, $k_w$ = 0.61 W/m-°C, $\mu_w = 0.8 \times 10^{-3}$ kg/m-s, $\rho_w$ = 1000 kg/m$^3$.

For ammonia vapor, at $T_{avg}$ = 80°C; $C_{PG}$ = 2.418 kJ/kg-°C, $k_G$ = 0.0317 W/m-°C, $\mu_G = 1.2 \times 10^{-5}$ kg/m-s, $\rho_G$ = 4.03 kg/m$^3$.

Design the proposed shell and tube heat exchanger and evaluate the overall heat transfer coefficient for the above duty

B) Estimate the heat transfer area required and the pressure drop for the above problem. Is the calculated required area within the 30% overdesign limit in comparison with the available surface area? (4)

C) Is the proposed design suitable for the duty of above problem? If not, recommend the suitable changes for an efficient operation of heat transfer (2)

2) A) A horizontal 1-2 condenser is required for the complete condensation of 25000 kg/h saturated vapor of pure n-propanol (propyl alcohol) at 117ºC, coming from the top of the distillation column operating at 15 psi(g). Cooling water is available at 30ºC and was heated to 50ºC during condensation. Tubes of 3/4 in. OD, 16 BWG, 8 ft length on triangular pitch are available for the design. Assume the tube wall resistance is (4)

negligible. Fouling resistance value of 0.0002 can be considered for n-propanol and water. The properties are given as:

| Properties of condensate and vapor: | Properties of water at mean temperature: |
|---|---|
| Condensate conductivity, $\mathbf{k_L}$ = 0.163 W/m-°C,<br>Condensate density, $\boldsymbol{\rho_L}$ = 800 kg/m$^3$,<br>Condensate viscosity, $\boldsymbol{\mu_L}$ = 0.62 x 10$^{-3}$ kg/m-s,<br>Vapor density, $\boldsymbol{\rho_V}$ = 3.84 kg/m$^3$,<br>Vapor viscosity, $\boldsymbol{\mu_V}$ = 10$^{-5}$ kg/m-s, | Thermal conductivity, **k** = 0.13 W/m-°C,<br>Density, $\boldsymbol{\rho}$ = 1000 kg/m$^3$,<br>Specific heat, $\mathbf{C_p}$ = 4.18 kJ/kg-°C,<br>Viscosity, $\boldsymbol{\mu}$ = 0.72 x 10$^{-3}$ kg/m-s, |

Design a horizontal 1-2 condenser for the above duty and perform the shell and tube side calculations.

B) Evaluate the actual overall heat transfer coefficient value and pressure drop on both side for the above problem. (4)

C) Is the design acceptable for the above duty? if not, recommend the possible changes. (2)

3)

A) It is required to concentrate a dilute solution of NaOH from 8 wt% to 45 wt% in a forward feed triple effect evaporator. The total evaporation rate is 8000 kg water per hour. The feed is entered at 60°C and a vacuum of 0.85 bar(a) is maintained in last effect. A saturated steam is available at 5 bar(a). The overall heat transfer coefficients are 5000, 3400 and 2400 W/m$^2$°C for the first, second and third effect, respectively. The specific heat of concentrated solution in feed and all other streams can be considered as 3.5 kJ/kg°C. The latent heat data should be obtained from Steam table. Assume that the boiling point elevation is negligible. Design a triple effect evaporator and determine the area of evaporator if the areas of calandrias are equal. (5)

B) Evaluate the steam economy of the evaporator for the above problem. (3)

C) Determine the total capacity of the designed evaporator in the above problem (2)

4)

A) A saturated vapor feed mixture containing 35% benzene, 35% toluene and 30% cumene (all mole %) is to be fractionated at a rate of 100 kmol/h to recover 98% benzene in distillate and 98.5% toluene in bottom product. Constant molar flow rate and ideal solution behaviour may be assumed. The column top temperature is 80.5°C and bottom temperature is 124°C. Also, the vapor pressure (mm Hg) as a function of Temperature (K) of all three components are given as: (3)

For Benzene; [ ln P° (mmHg) = 15.9037 – 2789.01/ (220.79 + T (K)) ]

For Toluene; [ ln P° (mmHg) = 16.005 – 3090.78/ (219.14 + T (K) ]

For Cumene; [ ln P° (mmHg) = 17.9232 – 4802/T(K) ]

Estimate the composition of distillate and bottom stream

B) Determine the minimum number of stages required and minimum reflux ratio for the above problem. (4)

C) For the above problem, evaluate the number of ideal stages required and locate the feed tray for this multicomponent distillation system (3)

5) A new pressure vessel of 3 m OD and 8.5 m of effective length is to be operated at 0.06 $MN/m^2$. Flat heads are placed at both end of the vessel. Allowable stress and modulus of elasticity for material used are 90 $MN/m^2$ and 2.1 x $10^5$ $MN/m^2$, respectively.

A) Determine the required thickness of shell without stiffeners. (4)

B) Determine the standard thickness of shell if stiffeners are used (with 0.8 m spacing). (4)

C) Is the calculated thickness safe against plastic deformation in both the cases? If not, then recommend the changes. (2)

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