Exam Date & Time: 18-Jun-2024 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

VI SEMESTER B.TECH MAKE UP EXAMINATIONS, JUNE 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) It is desired to heat 9820 lb/h of a cold fluid benzene from 80 to 120ºF using hot toluene which is cooled from 160 to 100ºF. You need to design a double pipe heat exchanger if 20-ft hairpins of 2-by-$1^1/_4$ in. IPS pipe is available (inner dia. of inner pipe, D_i = 1.38 in., Outer dia. of inner pipe, D_o = 1.66 in., and inner dia. of outer pipe, D_{io} = 2.067 in.). Assume the pipe wall resistances through conduction is negligible and fouling resistance is 0.002 for both fluids. The properties of both the fluids are given below:

For cold fluid benzene, at t_{avg} = 100°F; C_P = 0.425 BTU/lb -°F, k = 0.091 BTU/h-ft-°F, μ = 1.21 lb/ft-h, ρ = 55 lb/ft^3. (4)

For hot toluene, at T_{avg} = 130°F; C_P = 0.44 BTU/lb -°F, k = 0.085 BTU/h-ft-°F, μ = 0.99 lb/ft-h, ρ = 54.3 lb/ft^3.

Evaluate the heat duty and LMTD

B) Estimate the overall heat transfer coefficient and heat transfer area for the above problem. (3)

C) Determine the number of hairpins required (3)

2)

A) A split-ring floating head type shell and tube heat exchanger is to be design to cool 100000 kg/h methanol stream from 95ºC to 40 ºC using a cooling tower water from 25 to 40 ºC. Tubes of 20 mm OD, 16 mm ID, 4.88 m-long tubes on triangular pitch are available for the design. Assume the initial value of U as 600 W/m^2-ºC and consider the tube wall resistance as negligible. Fouling resistance value of 0.0002 can be considered for methanol and water. The properties of fluids are given as: (4)

For cold water, at t_{avg} = 32.5°C; C_P = 4.18 kJ/kg-ºC, k = 0.59 W/m-ºC, μ = 0.8 x 10^{-3} kg/m-s, ρ = 1000 kg/m^3.

For hot methanol, at T_{avg} = 67.5°C; C_P = 2.84 kJ/kg-ºC, k = 0.19 W/m-ºC, μ = 0.34 x 10^{-3} kg/m-s, ρ = 750 kg/m^3.

Determine the heat transfer area, number of tubes and passes required.

B) Evaluate the actual overall heat transfer coefficient value for the above problem. (4)

C) Is the calculated value of "U" within the design limit for the above duty? if not, recommend the possible changes. (2)

3) A) 1.5 wt.% aqueous salt solution is to be concentrated to 4 wt.% in a single effect evaporator. The feed rate to the evaporator is 7500 kg/h and feed is at 85°C. The evaporator operates at 1 bar at which the corresponding saturation temperature is 100°C. Saturated steam at 170 kPa (T_{SAT} = 115°C) heats the evaporating solution. Assume BPE is negligible. Enthalpy data: enthalpy of feed stream, H_F = 356 kJ/kg; evaporated water stream, H_V = 2675 kJ/kg; and concentrated stream, H_M = 419.2 kJ/kg. For steam at 170 kPa, the latent heat of evaporation is 2215 kJ/kg. Estimate the heat load and heat transfer area required if the overall heat transfer coefficient is 2500 W/m^2-K. (4)

B) Evaluate the capacity of the designed evaporator for the above problem. (3)

C) Determine the steam economy of the evaporator in the above problem (3)

4) A) It is required to separate a saturated quaternary mixture containing propane (6 mol%), n-butane (33 mol%), n-pentane (45 mol%) and n-hexane (16 mol%) at a feed rate of 1000 kmol/h. The system pressure is assumed constant at 1 atm. The reflux ratio is 3. It is desired to recover 99% of butane (LK) in distillate and 99.5% of pentane (HK) in bottom. Estimate the flow rates and composition of distillate and bottom stream (3)

B) For the above problem, using Fenske and Underwood equations, determine the minimum number of stages required and minimum reflux ratio. (4)

C) For the above problem, using Gilliland equation, evaluate the number of ideal stages required at a reflux ratio, R = 3, for the above problem. (3)

5) A) An absorption tower of OD 5.2 m with an effective length of the tower is 10.33 m. The tower is to be designed for full vacuum i.e. p = 0.1 MN/m^2 at 400°C. The material of construction is carbon steel having allowable stress value of 100 MN/m^2 and E = 2 x 10^5 MN/m^2. Determine the required thickness of shell without stiffeners. (4)

B) Determine the standard thickness of shell if stiffeners are used (with 1 m spacing). (4)

C) In which case the calculated thickness is less and why? (2)

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