Exam Date & Time: 05-Jul-2023 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

VI B.TECH Make Up EXAMINATIONS, June-July 2023

DESIGN AND DRAWING OF CHEMICAL PROCESS EQUIPMENT [CHE 3251]

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

A

Answer all the questions. Section Duration: 180 mins

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

1) A) A pressure vessel having outer diameter 1.3 m and height 4 m is subjected to an internal pressure of 12 kg_f/cm^2. Allowable stress of the material = 1020 kg_f/cm^2. Corrosion allowance is 1 mm. If the vessel is fabricated as class B vessel joint efficiency is 85%; if the vessel is fabricated as class C vessel, with welded joint efficiency is 50%; if the vessel is provided with a strip along the longitudinal joint, joint efficiency is 100%. Calculate the vessel thickness under these different conditions. Compare and discuss the answers. (5)

B) A vacuum distillation column is to operate under a pressure of 350 mmHg. The column diameter is 1 m and the plate spacing 0.5 m. The material of construction is carbon steel and the maximum operating temperature 95 °C. If the vessel thickness is 15 mm, check if this is sufficient or not. (5)

2) A) A vessel is designed for an internal pressure 200 kg_f/cm^2. A spiral wound metal, fiber stainless steel gasket with inside diameter 40 cm and width 4 cm is used. Gasket factor is 4, while gasket seating stress is 750 kg_f/cm^2. Permissible stress for bolt material at atmospheric and operating condition is 1400 kgf/cm2. Check whether the gasket width is sufficient to keep it away from crushing out? (5)

B) Explain the various methods of altering internal and external heat transfer coefficients during the process design of shell and tube heat exchanger. (5)

3) A) 1-2 STHE is used to cool methanol (k:0.197 W/m K; viscosity: 0.325 cP; C_p : 2.72 kJ/kg K; density : 750 kg/m^3) from 95 to 40 °C. Flow rate of methanol is 100,000 kg/h. Brackish water (k:0.623 W/m K; viscosity: 0.8 cP; C_p : 4.184 kJ/kg K; density: 995 kg/m^3) will be used as a solvent with a temperature rise from 25 to 40°C. Assume methanol passes through the shell side and brackish water passes through the tube side (tube OD: 3/4"; tube ID: 0.62"; Number of tubes: 1124). If shell side heat transfer coefficient is 1400 W/m2 K, determine the overall heat transfer coefficient. Use, $Nu = 0.023\, Re^{0.8} Pr^{0.4}$ (5)

B) 1-1 STHE is used to heat an organic liquid (50 m^3/h) from 10°C to 28°C, which passes through the tubes (40 steel tubes; 5cm ID; 5mm thick) of the exchanger. The density, viscosity, heat capacity and the thermal conductivity of the organic liquid are the same (5) as water (1 g/cc; 1cP; 4.2 kJ/kg K and 0.54 W/ m K respectively). The shell-side fluid is water that enters with flow rate $4x10^4$ kg/h and temperature 60°C. Determine the tube side heat transfer coefficient.

4)

A) It is proposed to use an existing distillation column, which is fitted with reflux condenser which has 400 vertical, 70 mm ID tubes, for separating benzene from a mixture of chlorobenzenes. The top product will be 4000 kg/h benzene and the column will operate with a reflux ratio of 4. Check whether flooding occurs or not. The condenser pressure will be 1 bar. Densities at benzene boiling point are Density(L): 900 kg/m^3, Density(v): 3 kg/m^3. (5)

$$\left[u_v^{1/2}\rho_v^{1/4} + u_L^{1/2}\rho_L^{1/4}\right] < 0.6\left[g d_i(\rho_L - \rho_v)\right]^{1/4}$$

B) A water-cooled, 1-1 shell-and-tube freon condenser with in-tube condensation of R-22 @37°C (C_{pL} = 1.31 kJ/kg K; $v_L = 8.4 \times 10^{-4}$ m^3/kg; v_g = 0.02 m^3/kg; viscosity(L) = $1.86x10^{-4}$ Pa.s; viscosity(g) = $1.39x10^{-5}$ Pa.s; k_L = 0.082 W/m K; latent heat = 170 kJ/kg; Pr = 3) has to be designed. City water (Inlet and outlet temperatures are 18°C & 26°C respectively) is used as coolant. Determine the tube side heat transfer coefficient using Shaw theory. (5)

Design parameters:
Design cooling load: 250 kW; One tube pass; Pitch: 1" Square; Shell dia: 17"; Baffle Spacing: 35 cm; Number of Tubes: 200; Size of tubes: 0.75" OD & 0.68" ID; Vapor quality = 75%.

5)

A) A forward-feed evaporator (triple effect) is used to evaporate a solution. Saturated steam at 9 atm abs is being used. The feed rate enters at 16 °C.
Assume,
Del T1 = 30 K, Del T2 = 25 K and Del T3 = 40 K.
Determine enthalpy of steam, vapor and liquid streams of each evaporator: (5)

B) A forward-feed evaporator (triple effect) is being used to evaporate a solution containing 10 wt% solids to a concentrated solution of 50 wt%. The feed rate is 25000 kg/h. Using the following enthalpy values, calculate the steam and liquid flow rates of each evaporator.

(5)

Enthalpies of each stream		
Steam Enthalpies, kJ/kg	**Vapor Enthalpies, kJ/kg**	**Liquid Enthalpies, kJ/kg**
		@T_F, $h_F = 212$
@T_{s1}, $\lambda_{s1} = 2300$	@T_1, $H_1 = 2784$	@T_1, $h_{L1} = 540$
@T_1, $\lambda_{s2} = 2343$	@T_2, $H_2 = 2755$	@T_2, $h_{L2} = 464$
@T_2, $\lambda_{s3} = 2390$	@T_3, $H_3 = 2701$	@T_3, $h_{L3} = 330$

Useful Energy Balance Equations:

- $F (h_F - H_1) + S\lambda_{s1} = L_1 (h_{L1} - H_1)$
- $L_1 (h_{L1} - \lambda_{s2} - H_2) + F\lambda_{s2} = L_2 (h_{L2} - H_2)$
- $L_2 (h_{L2} - \lambda_{s3} - H_3) + L_1 \lambda_{s3} = L_3 (h_{L3} - H_3)$

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