Exam Date & Time: 14-May-2022 (10:00 AM - 01:00 PM)

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

VI SEMESTER B.TECH END SEMESTER EXAMINATIONS, MAY 2022

DESIGN AND DRAWING OF CHEMICAL PROCESS EQUIPMENT [CHE 3251]

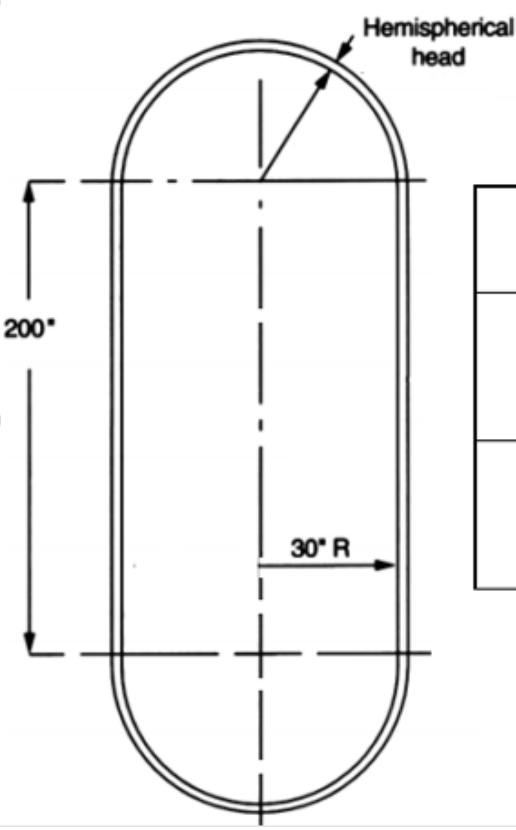
Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

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

1) A) Determine the minimum wall thickness of the shell of 200" length(Grade 70) and head of 30" radius (Grade I) from the figure to withstand a pressure of 640 psi (absolute). The reactants are at a temperature of 640°F. Assume that full radiography is done for the welded joints. (Take, 1 psi = 6.9 x 10^{-3} N/mm^2) (5)



Material	Temperature limit (°F)	Allowable stress (psi)
Grade 70	640 704 800	17500 16600 14500
Grade I	640 704 800	18400 16600 12000

B) A vacuum distillation column is to operate under a pressure of 50 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 50 °C. If the vessel thickness is 10 mm, check if this is sufficient or not. If it is insufficient find out the required thickness. (5)

2) A) A vessel is designed for an internal pressure 100 kg_f/cm^2. A spiral wound metal, fibre stainless steel gasket with inside diameter 36 cm and width 2.0 cm is used. Gasket factor is 3.0, while gasket seating stress is 675 kg_f/cm^2. Permissible stress for bolt material at atmospheric and operating condition is 1300 kg_f/cm^2. Check whether the gasket width is sufficient to keep it away from crushing out? (5)

B) Detail the ways to modify the internal heat transfer coefficient in the process design of a shell and (5) tube heat exchanger:

3) A) 1-1 STHE is used to heat an organic liquid, which passes through the tubes (30 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 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 the maximum linear shell-side fluid velocity of 0.15 m/s. Determine the shell side heat transfer coefficient. (5)
Use, $Nu = 0.26\ Re_{max}^{0.6} Pr^{0.33}$; $G_{max} = (v_{max} * \rho)$
In the above equation, take Diameter = OD of tubes

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 (30 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 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 $3x10^4$ kg/h and temperature 60°C. (5)

- Determine the tube side heat transfer coefficient.
- If the overall heat transfer coefficient is 500 W/m^2K, determine the length of the tubes.

4) A) A water-cooled, 1-1 shell-and-tube freon condenser with in-tube condensation of R-22 @37°C has to be designed. City water (Inlet and outlet temperatures are 18°C & 26°C respectively) is used as coolant. The physical properties at the average temperature of the coolant are: c_{pL} = 4.181 kJ/kg K; $\mu_L = 959x10^{-6}$ Pa.s; k_L = 0.606 W/m K; Pr = 6.61. Fouling resistance: $1.76x10^{-4}\ m^2$ K/W for both inside and outside. Determine the

- Shell side heat transfer coefficient (5)
- Overall heat transfer coefficient if the tube side heat transfer coefficient is 300 W/ m^2K.

<u>Design parameters:</u>
Design cooling load: 100 kW; One tube pass; Pitch: 1" Square; Shell dia: 15.25"; Baffle Spacing: 35 cm; Number of Tubes: 137; Size of tubes: 0.75" OD & 0.68" ID; Vapor quality = 50%.

B) A water-cooled, 1-1 shell-and-tube freon condenser with in-tube condensation of R-22 @37°C (c_{pL} = 1.305 kJ/kg K; $v_L = 8.3734 \times 10^{-4}\ m^3/kg$; $v_g = 0.01643\ m^3/kg$; $\mu_L = 1.86x10^{-4}$ Pa.s; $\mu_g = 1.39x10^{-5}$ Pa.s; k_L = 0.082 W/m K; latent heat = 169 kJ/kg; Pr = 2.96) 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 *Cavallini and Zecchin* theory. (5)
- Length of the condenser if the overall heat transfer coefficient is 201 W/ m^2K.

<u>Design parameters:</u>
Design cooling load: 100 kW; One tube pass; Pitch: 1" Square; Shell dia: 15.25"; Baffle Spacing: 35 cm; Number of Tubes: 137; Size of tubes: 0.75" OD & 0.68" ID; Vapor quality = 50%.

5) A) A forward-feed evaporator (triple effect) is used to evaporate a solution. Saturated steam at 205.5kPa abs is being used. The feed enters at 26.7 °C.

Take
$\Delta T_1 = 16$ K, $\Delta T_2 = 18$ K and $\Delta T_3 = 32$ K. (5)

Determine enthalpy of steam, vapor and liquid streams of each evaporator:

B) A forward-feed evaporator (triple effect) is being used to evaporate a solution containing 5 wt% solids to a concentrated solution of 50 wt%. The feed rate is $2x10^5$ kg/h at 16°C. Using the (5) following enthalpy values, calculate the steam and liquid flow rates of each evaporator.

Enthalpies of each stream		
Steam Enthalpies, kJ/kg	**Vapor Enthalpies, kJ/kg**	**Liquid Enthalpies, kJ/kg**
		@T_F, $h_F = 67.1$
@T_{s1}, $\lambda_{s1} = 2038$	@T_1, $H_1 = 2741$	@T_1, $h_{L1} = 615$
@T_1, $\lambda_{s2} = 2125$	@T_2, $H_2 = 2708$	@T_2, $h_{L2} = 512$
@T_2, $\lambda_{s3} = 2196$	@T_3, $H_3 = 2644$	@T_3, $h_{L3} = 335$

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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