Exam Date & Time: 25-Jul-2022 (09:00 AM - 12:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

VI SEMESTER B.TECH MAKE UP EXAMINATIONS, JULY 2022

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 cylindrical pressure vessel 1.8 m outer diameter and 5 m in height is subjected to an internal pressure of 8 kg_f/cm^2. Corrosion allowance is 2 mm. What will be the minimum thickness of the vessel if the vessel is fabricated as Class A vessel (J = 1), Class B vessel (J = 0.85), Class C vessel (J = 0.5 & J = 0.7). Take allowable stress of the material = 1400 kg_f/cm^2. (5)

B) The pressure inside an evaporator (1.2 m ID & 46 m height) is 200mmHg. The design temperature is 250°C. Your boss proposes that the wall thickness of this evaporator be 12mm. Check whether this is sufficient or not. (5)

2)

A) A pressure vessel has inside diameter 1470 mm and a plate thickness of 5mm. Inside diameter of flange is 1482 mm. A gasket is provided over the flange face. Gasket factor is 2.0 and the gasket seating stress is 120 kg_f/cm^2. Inside diameter of gasket is 1485 mm. Pressure inside the vessel is 2.5 kg_f/cm^2. Permissible stress of flange material is 1060 kg_f/cm^2. Permissible stress in bolts under atmospheric condition is 600 kg_f/cm^2. Permissible stress in bolts at operating conditions is 550 kg_f/cm^2. Diameter of bolt is 20 mm. Check whether the gasket width is sufficient to keep it away from crushing out. (5)

B) While doing thermal design of a 1-2 STHE you end up with the following results: Length of tubes = 5m; No. of tubes = 400; Shell ID = 600 mm; $\Delta P_t = 65$ kN/m^2 & $\Delta P_s = 10$ kN/m^2; Available $U_{OD} = 500$ W/m^2K; Required $U_{OD} = 2000$ W/m^2K. Do you feel that this design is satisfactory? If not, what are the strategies will you incorporate to satisfy the design criteria? (5)

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)

Shell side: (Take Diameter = OD of tubes): $Nu = 0.26\ Re_{max}^{0.6} Pr^{0.33}$; $G_{max} = (v_{max} * \rho)$

B) 1-1 STHE is used to heat an organic liquid ($50 m^3/h$) from 10°C to 28°C, which passes (5) 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.

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; $viscosity_{(L)}$ = $959x10^{-6}$ Pa.s; k_L = 0.606 W/m K; Pr = 6.61.
Determine the

- Shell side heat transfer coefficient (5)
- Overall heat transfer coefficient if the tube side heat transfer coefficient is 157 W/ m^2K.

Design parameters:
Design cooling load: 125 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 x 10^{-4} m^3/kg; v_g = 0.01643 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 = 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 Shaw theory. (5)
- Length of the condenser if the overall heat transfer coefficient is 142 W/ m^2K.

Design parameters:
Design cooling load: 125 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 8.5 atm abs is being used. The feed rate enters at 16°C.
Take
delT_1 = 28 K, **del**T_2 = 23 K and **del**T_3 = 42 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 10 wt% solids to a concentrated solution of 50 wt%. The feed rate is 22680 kg/h at 26.7°C. 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, $h_F = 111.95$
@T_{s1}, $\lambda_{s1} = 2199.35$	@T_1, $H_1 = 2684$	@T_1, $h_{L1} = 440.21$
@T_1, $\lambda_{s2} = 2243.18$	@T_2, $H_2 = 2654.62$	@T_2, $h_{L2} = 364.35$
@T_2, $\lambda_{s3} = 2290.27$	@T_3, $H_3 = 2600.9$	@T_3, $h_{L3} = 230.24$

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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