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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL

A Constituent Institution of Manipal University

VII SEMESTER B.TECH. END SEMESTER EXAMINATIONS DEC 2020/ JAN 2021

SUBJECT: DESIGN AND DRAWING OF CHEMICAL EQUIPMENT [CHE 4102]

REVISED CREDIT SYSTEM

Date of Exam: 26/12/2020 **Time of Exam: 2 – 5 pm**

Time: 3 Hours **Max. Marks: 50**

Instructions to Candidates:

- Answer ALL the questions & missing data may be suitably assumed
- Use of code book/data book/formula sheet are permitted

1A	A jacketed vessel is to be used as a reactor. The vessel has an internal diameter of 2 m and is fitted with a jacket over a straight section 1.5 m long. Both the vessel and jacket walls are 25 mm thick. The spacing between the vessel and jacket is 75 mm. The vessel and jacket are made of carbon steel. The vessel will operate at atmospheric pressure and the jacket will be supplied with steam at 20 bar. Check if the thickness of the vessel and the jacket is adequate for this duty. Take the allowable design stress as 100 N/mm^2 at the design temperature of 400 °C.	5
1B	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; 5 cm ID; 5 mm 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. If the maximum linear shell-side fluid velocity is estimated as 0.15 m/s, determine the i. Shell side heat transfer coefficient ii. Tube side heat transfer coefficient iii. Length of the tubes **Useful Formula: Tube Side:** $a_t = (\pi/4\ d_i^2)\ N/n$; $Nu = 0.023\ Re^{0.8}Pr^{0.4}$ **Shell side:** (Take Diameter = OD): $Nu = 0.26\ Re_{max}^{0.6}Pr^{0.33}$; $G_{max} = (v_{max} * \rho)$	2+2+1
2A	Detail the ways to modify the individual heat transfer coefficients in the process design of a shell and tube heat exchanger.	5
2B	A ring type flange with a plain face for a heat exchanger shell has to be designed to the following specifications: Design pressure = 150 psi; Design temp = 300° F Flange: ASTM A-201, Grade B (Allowable stress = 15 $x10^3$ psi) Bolts: ASTM A-193 ,Grade B7 (Allowable stress = $20x10^3$ psi); 19 mm Bolts Shell thickness = 3/8 " ; Shell ID = 30 ¼ " Gasket material = Asbestos composition (m = 2.75; y = 37 N/mm^2) For initial guess, assume gasket inner diameter = shell OD + 10 mm Determine the following: • Bolt loads • Actual bolt area and the thickness of the flange	5

3 Distilled water (c_p:4.1785 kJ/kg K; ρ:995.7 kg/m^3; μ:0.000797 kg/m s; k:0.614 W/m K) with a mass flow rate of 80,000 kg/h enters the shell side of an exchanger at 35 °C and leaves at 25 °C. The heat will be transferred to 140,000 kg/h of raw water (c_p: 4.179 kJ/kg K; ρ: 997 kg/m^3; μ:0.00095 kg/m s; k: 0.6065 W/m K) coming from a supply at 20 °C. The baffles will be spaced 12" apart. A single shell and single tube pass is preferable. The tubes (81nos.) are 18 BWG tubes with a 1" outside diameter (OD = 0.0254 m, ID = 0.0229 m) and laid out in square pitch. Shell diameter is 15.25". A pitch size of 1.25" and a clearance of 0.25" are selected. **3+3+3+**

- Determine the shell side heat transfer coefficient
- Determine the tube side heat transfer coefficient
- Calculate the length of the heat exchanger and the pressure drop for each stream.
- If the shell-side allowable maximum pressure drop is 200 kPa, will this heat exchanger be suitable?

Useful Formula: Tube Side: $a_t = (\pi/4\ d_i^2)\ N/n$; $Nu_t = 0.027\ Re_t^{0.8}\ Pr_t^{0.33}$
Shell side: $a_s = D_s\ C\ B / P_T$; $Nu_s = 0.36\ Re_s^{0.55}\ Pr_s^{0.33}$;
$D_{eq} = 4\{[0.44\ P_T^2 - (\pi d_o^2/8)] / [\pi d_o/2]\}$

4 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; μ_L = 1.86x10^{-4} Pa.s; μ_g = 1.39x10^{-5} Pa.s; k_L = 0.082 W/m K; λ= 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 solvent. The physical properties at the average temperature of the coolant are: c_{pL} = 4.181 kJ/kg K; μ_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. **4+4+2**

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%.

i. Determine the shell side heat transfer coefficient.
ii. By using *Shaw* theory, calculate the tube side heat transfer coefficient. Take vapor quality = 50%
iii. Calculate the length of the condenser.

Useful Formula: Tube side: $a_t = (\pi/4\ d_i^2)\ N/n$

$$h_{TP} = h_l\left[1 + \frac{3.8}{Z^{0.95}}\right]; \quad Z = \left[\frac{1-x}{x}\right]^{0.8} Pr^{0.4};$$

$$h_l = 0.023\left[\frac{G(1-x)d}{\mu_l}\right]^{0.8} \frac{Pr^{0.4}k}{d}$$

Shell side: $a_s = D_s\ C\ B / P_T$; $D_{eq} = 4\{[P_T^2 - (\pi d_o^2/4)] / [\pi d_o]\}$;
$Nu = 0.36\ Re^{0.55} Pr^{0.33}$

5 A 5 % aqueous solution of a high molecular weight solute has to be concentrated to 40 % in a forward-feed double effect evaporator at 8000 kg/h. The feed temperature is 40 °C. Saturated steam at 4.5 kg$_f$/cm^2 (abs) is available for heating. A vacuum of 160 mmHg (abs) is maintained in the second effect. The overall heat transfer coefficients are 550 and 370 kcal/h m^2°C in the first and the last effect respectively. The specific heat of the liquor is 0.87 kcal/kg °C. Determine, **5+3+2**

i. the amount of concentrated liquor leaving each evaporator
ii. the surface area of the evaporator and
iii. the steam economy