B. Tech.
(SEM. VIII) EXAMINATION, 2006-07
PROCESS EQUIPMENT DESIGN

Time : 3 Hours [Total Marks : 100]

Notes:
(1) Attempt all questions.
(2) Be precise in your answers.
(3) Reasonable assumptions can be made for any missing data.
(4) Calculators and steam tables can be used.

1. Attempt any two parts of the following: 10x2=20
   (a) Boiling water, saturated-steam and high-pressure steam are available for heating in a heat exchanger. Which one will be preferred? Give reasons.
   (b) What is flooding? A condenser has been designed which has 200 vertical, 50 mm i.d. tubes for separating benzene from a mixture. The condenser is fitted at the top of a distillation column. The top product will be 2500 kg/h and the column will operate with a reflux ratio of 3. If the condenser premises is 1 bar check if the fluid will flood the tubes. Given: Liquid density – 840 kg/m³, vapor density – 0.39 kg/m³. For no flooding:
   \[ UV^{1/2} PV^{1/4} + U_L^{1/2} P_L^{1/4} < 0.6 \left[ gd_i \left( P_L - P_v \right) \right]^{1/4} \]

V-9143] 1 [Contd...
(c) For a distillation column a condenser has to be selected. The top product has a composition of 70% ethanol and remaining water. Under the following conditions which type of heat exchanger would be preferred? Give reasons
(i) distillate product is saturated vapour,
(ii) distillate product is superheated.

2. Attempt any two parts of the following: 10 x 2 = 20
(a) A tank of 100,000 liter capacity containing fermented broth having properties of water is heated by natural convection from submerged horizontal steam pipes. The pipes are schedule 40 J in steel. If the available steam is at 1 atm pressure and the broth temperature is 25°C, what is the rate of heat transfer to the broth?
(b) Explain the design and working of (i) short tube evaporators, (ii) Falling – film evaporators and (iii) Forced circulation evaporators
(c) A continuous sterilization system with continuous steam injections is required to be designed to sterilize 50,000 kg (25°C) of fermentation medium in 30 min. The pipe used is 155 m i.d. and holding section 40 m long. It may be assumed that dry steam (a bar gauge) which is injected elevates the temperature of the raw medium instantly. The initial contamination level is \(2 \times 10^5\) ml\(^{-1}\) and the desired sterility level is \(10^{-3}\). If the medium properties at the sterility level are
\[C_p = 4.18 \text{ kJ/} (\text{kg K}), \quad \rho = 10^3 \text{ kg/m}^3\]
and \(\mu = 3.6 \text{ kg/m.h}\). Calculate:
(i) Sterilization temperature
(ii) Steam consumption rate
3. Attempt any two parts of the following: 10×2=20
   (a) What is the scale-up procedure in designing an agitated vessel? What shape factors have to be considered?
   (b) A six bladed turbine impeller is used to agitate an aqueous solution (sp. Gravity = 0.98, viscosity = 1.01 cp) in a tank of 0.5 m diameter and 0.5 m height. Impeller diameter is 1/3 of tank diameter. The tank is fitted four longitudinal baffles (width of each is 0.1 D_t) and filled to 90% of its volume with the solution. The turbine is mounted at one impeller dia. above the vessel floor (i) Determine the power consumption if the impeller is operating at 300 rpm. Given H_t = 6.3 under these conditions.
   (c) What are different types of packings? Write briefly the designs aspects of packed bed column for distillation.

4. Attempt any two parts of the following: 10×2=20
   (a) Give major design features of solid-liquid extractors.
   (b) Briefly discuss the design aspects of liquid – liquid extractors.
   (c) Water-Nicotine solution containing 1.5% nicotine has to be extracted with kerosene at 25°C. Kerosene is basically insoluble in water.
      (i) Determine the present extraction of nicotine if 100 kg of feed is extracted once with 150 kg of kerosene
      (ii) Repeat for three extractions using 50 kg of kerosene each; Given: At equilibrium 
           \( Y^* = 0.9 \, X \) where \( Y^* \) is mass of nicotine

V-9143] 3 [Contd...
per unit mass of kerosene and $X$ is mass of nicotine per unit mass of water at equilibrium.

5. Attempt any two parts of the following: $10 \times 2 = 20$
   (a) Discuss briefly the design features of rectifying and exhaust sections in a multistage distillation column.
   (b) A methanol-water solution containing 0.40 mole fraction methanol is distilled at 1 atm pressure with the rate of 10,000 kg/h to provide a distillate containing 0.80 mole fraction methanol and residue of 0.02 mole fraction methanol. The feed enters at its boiling point. The distillate is totally condensed and the reflux returned at its bubble point. A reflux ratio of 1.5 times the minimum reflux will be used. Determine:
      (i) Quantities of top and bottom products
      (ii) Number of trays for the specified reflux ratio.
      Given:

\[
\begin{array}{|c|c|c|c|c|c|}
\hline
x & 0.20 & 0.30 & 0.40 & 0.70 & 0.90 \\
\hline
y^* & 0.580 & 0.665 & 0.73 & 0.87 & 0.96 \\
\hline
\end{array}
\]

where $x$, $y^*$ are equilibrium values of liquid and vapor

(c) Discuss the design parameters for (i) How rates of liquid and vapor in a bubble plate column. (ii) Height and wind velocity of a vertical column and (iii) to minimize flooding in a multistage column and axial mixing in a packed column.

V–9143] 4 [ 100 ]