Dr Sabhagil Mahamdav 17/11/2023 (20)

NATIONAL INSTITUTE OF TECHNOLOGY HAMIRPUR
(An Institute of National Importance under Ministry of HRD)
Department of Chemical Engineering

CH-411 PROCESS PLANT DESIGN AND ECONOMICS
END-SEMESTER EXAMINATION

Maximum Marks: 50 | Time: 3 hours

Instructions:

- Make suitable assumptions, if necessary, by clearly stating them.
- Marks will be deducted for omitting steps.
- Draw the figure wherever needed.
- **Answer against each question must be written in sequence and at the same place in the answer booklet.**
- Exchange of calculator, pen, pencil etc. are strictly not allowed.

Q1. (10 Marks) [CO1, CO3]

A concern has a total income of $1 million/yr and all expenses except depreciation amount to $600000/yr. At the start of the first year of the concern's operation, a composite amount of all depreciable items shows a value of $850000 and overall service life is estimated to be 20 years. The total salvage value at the end of the service life is estimated to be $50000. Thirty % of all profits before taxes must be paid out at income taxes. Determine the reduction in income tax charges for the first year of operation if the sum-of-the-years digits method were used for depreciation accounting instead of SLM.

Q2. (10 Marks) [CO1, CO2, CO3, CO4]

In a peanut processing plant 10 ton/h of miscella (15 wt% peanut oil in hexane) leaves at 35°C. As a process engineer you are asked to propose a processing scheme which can separate the hexane from the oil so that the final oil contains less than 0.01% hexane and such that the temperature never exceeds 80°C. Begin with what seems to be the most economical process 'distillation', start answering the following questions in sequence and come out with your proposal for processing scheme:

a) What makes you so confident that distillation is plausible?
b) The vapor pressure of hexane in a solution containing 0.01% hexane in peanut oil at 80°C is only 0.6 mm Hg. Normally, even vacuum distillation towers do not operate at pressure less than 100 mm Hg. How will you operate the distillation column at this lower pressure?
c) How are you going to choose the tower pressure? Justify.
d) For the sake of argument, fix the still pressure at 200 mm Hg and assume that the still can be designed. Will you face any other problem?
e) Indeed this one of the plausible alternatives. Vapor liquid equilibrium calculations reveal that a flash of the hexane-peanut oil solution at 75°C and 1 atm will remove 85% of the hexane, and at 75°C and 300 mm Hg 98% of the hexane will be removed. Can you suggest some modification in the existing alternative to reduce the load on the distillation. Draw the flowsheet.

Additional Information

Mol. wt. of: Peanut Oil = 885.02, Hexane = 86.18, Vapor pressure of peanut oil is 0 mm Hg at 20°C, Dew point of hexane is 87°C at 151 mm Hg of pressure. Cooling water is available at 25°C.

Q3. (10 Marks) [CO1, CO2, CO3]

a) In the given reaction system, assume the second reaction is reversible. The main product is 2-butanol which produces MEK as a by-product. The reactions are as follows:

Step 1: 2-butene + H_2O $\longrightarrow$ 2-butanol
Step 2: 2-butanol $\rightleftharpoons$ MEK + H_2

Discuss the decision for recycling or recovering the byproduct (i.e. MEK).

b) Cyclohexane is produced by the following reaction.

$$C_6H_6 + 3H_2 \Leftrightarrow C_6H_{12}$$

Discuss the design guidelines with respect to decision making at level-3 corresponding to the use of excess amount of reactant.

Q4. (10 Marks) [CO1, CO2, CO3, CO4]

Consider a condensation process for recovering acetone from air-acetone stream (acetone = 10.3 mol/h and air = 687 mol/h). The air-acetone stream is available at ambient conditions (77°F and 1 atm). Two alternatives of condensation process are given below:

Alternative-1

The condensation process operates at 15 psia to recover 99.5% of acetone.

Alternative-2

The condensation process operates at 113°F to recover 99.5% of acetone.

a) Propose a flowsheet for the acetone recovery process (for both alternatives).
b) What temperature would be maintained in Alternative-1?
c) What pressure would be required in Alternative-2?
d) Describe the economic trade-offs involved in the design of the condensation process for both alternatives.

The coefficient values for acetone used in appropriate equation are A = 16.6513, B = 2940.46, C = -35.93 (when vapor pressure and temperature are given in **mm Hg** and **K**, respectively).

Q5. (10 Marks) [CO2, CO3]

For the problem given with ΔT_{min} = 10 °C, depending upon the units in a given problem, carry out the Energy Integration Analysis (Heat Exchanger Network Synthesis) using Pinch Technology by determining the following:

a) Shifted temperature scales diagram with net heat in respective intervals.
b) Cascade Diagram.
c) Pinch Temperatures.
d) T-H diagram.
e) How does increase in approach temperature affects the utility requirement? Justify your answer using the T-H diagram.

Stream No.	Condition	FC_p (kW/°C)	Source Temperature (°C)	Target Temperature (°C)
1	Hot	30	300	80
2	Hot	45	200	40
3	Cold	40	40	180
4	Cold	60	140	280

**********ALL THE BEST**********