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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.
- Exchange of calculator, pen, pencil etc. are strictly not allowed.

Q1. (15 Marks)

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.

Q2. (10 Marks)

Cyclohexane is produced by the following reaction

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

The reaction takes place at 392°F and 370 psia. Benzene used in the feed is pure, but the hydrogen stream contains 5% methane. The desired production rate of cyclohexane is 100 mol/h.

a) Draw the input-output structure.

b) Derive an expression for Economic Potential (EP-2) in terms of design variables and determine EP-2 for one set of parametric value of purge composition.

Additional Information

Cost of: C_6H_6 = 270 INR/mol, H_2 = 60 INR/mol, C_6H_{12} = 480 INR/mol, Fuel = 160 INR/10^6 Btu

Heat value of: $CH_4 = 0.383 \times 10^6$ Btu/mol, $H_2 = 0.123 \times 10^6$ Btu/mol.

Q3. (10 Marks)

A rule of thumb commonly used in design is that the approach temperature in a heat exchanger should be 10°F in the range from ambient to the boiling point of organics. Consider a simple system shown in Fig. 1, where we are attempting to recover some heat from a waste stream by producing steam in the first heat exchanger. Some more heat is recovered by cooling water in the second heat exchanger. Calculate the bounds of approach temperature (i.e. T_1 - T_s) for the above case where,

F	= Mass flow rate of waste stream	= 51,000 lb/hr
C_{pw}	= Heat capacity of water	= 1.0 Btu/(lb.°F)
U_C	= Overall heat transfer coefficient of coolant	= 30 Btu/(hr.ft^2. °F)
U_S	= Overall heat transfer coefficient of steam	= 20 Btu/(hr.ft^2. °F)
C_A	= Annual cost of heat exchanger per unit area	= \$11.38/(yr.ft^2)
C_W	= Annual cost for cooling water	= \$0.07388/[(lb/hr).yr]
C_S	= Value of steam produced	= \$21.22/[(lb/hr).yr]
ΔH_S	= Latent heat vaporization for steam	= 933.7 Btu/lb
T_S	= Temperature of steam	= 267°F
T_{in}	= Inlet temperature of waste stream	= 366°F
T_1	= Temperature of outlet stream from 1st heat exchanger (in °F)	
W_S	= Mass flow rate of steam (lb/hr)	
W_C	= Mass flow rate of cooling water (lb/hr)	

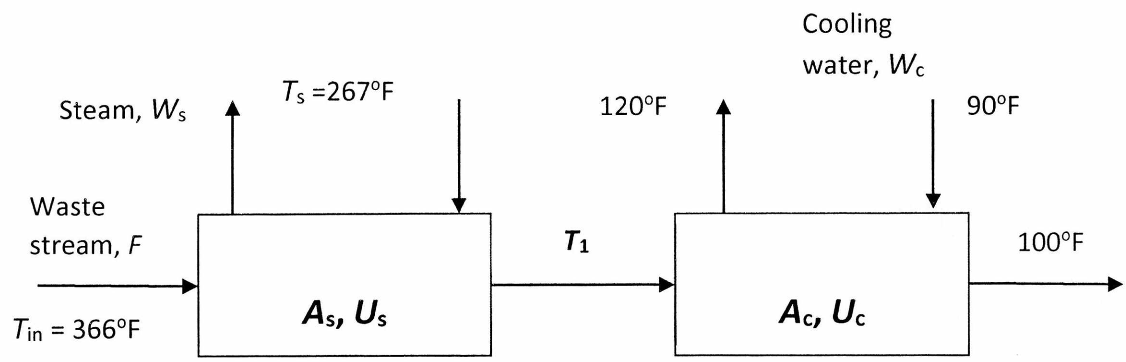

Fig. 1

Q4. (15 Marks)

Assuming ΔT_{min} = 10 °C, and heat transfer coefficient for both hot and cold utilities as 0.5 kW/m^2 °C, determine the following using the process stream data given below:

Stream No.	Condition	h (kW/m^2 °C)	FC_p (kW/°C)	Source Temperature (°C)	Target Temperature (°C)
1.	Hot	0.35	30	300	80
2.	Hot	0.40	45	200	40
3.	Cold	0.45	40	40	180
4.	Cold	0.55	60	140	280

a) Net amount of heat available in the streams based on Ist law.
b) Shifted temperature scales diagram with net heat in respective intervals. ***(graph paper to be used)***
c) Construction of cascade diagram.
d) Minimum hot and cold utilities requirement
e) Pinch temperature
f) Heat Exchanger Network for the Maximum Energy Recovery (MER)
g) Number of loop/s crossing the pinch and identification of loop/s.
h) Number of independent loop/s with justification.

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