DEPARTMENT OF CHEMICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

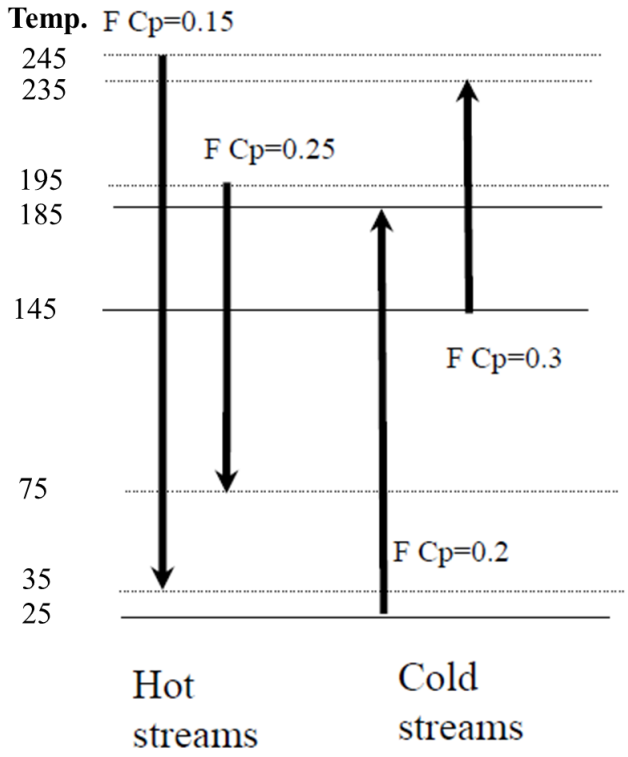
CH42010 - Process Plant Operation & Safety (LTP: 3-0-0, CRD: 3)

Mid Sem [30 Marks]

1. **Solution of Pinch Analysis** [Marks distribution: Shifted Temp – 2, Calculation of CP – 2, Correct First Table – 1, Correct 2nd Table – 2, Correct Pinch point – 1, Hot & Cold Utility - 2]

Stream	Type	Supply T (°C)	Target T (°C)	ΔH (MW)	F*Cp (MW °C^{-1})
Reactor 1 feed	Cold	20	180	32.0	0.2
Reactor 1 product	Hot	250	40	-31.5	0.15
Reactor 2 feed	Cold	140	230	27.0	0.3
Reactor 2 product	Hot	200	80	-30.0	0.25

ΔT_{min}=10 °C



$\Delta T_{interval}$	$\Delta H_{interval}$
10	-1.5
40	+6.0
10	-1.0
40	+4.0
70	-14.0
40	+2.0
10	+2.0

Shifted Temperature (˚C)	ΔH (MW)	Heat Cascade at stage 1 (MW)	Heat Cascade at stage 2 (MW)
245		0	7.5 **(Hot Utility)**
	-1.5		
235		1.5	9.0
	6.0		
195		-4.5	3.0
	-1.0		
185		-3.5	4.0
	4.0		
145		-7.5	0 **(Pinch Point)**
	-14.0		
75		6.5	14.0
	2.0		
35		4.5	12.0
	2.0		
25		2.5	10.0 **(Cold Utility)**

Hot Pinch = 145+5 = 150 ˚C, Cold Pinch = 145-5 = 140 ˚C

2. **Solution of Mass Balance** [Marks distribution: Calculation of weight of B – 1, Calculation of EtOH % – 1, H_2O % – 1, EtOH Kg - 2]

Solution

Steps 1, 2, and 3 See Fig. E2.11.
Step 4 Select as the basis the given feed

Basis: 1000 kg of feed

Step 3 (Continued) We are given that P is $\frac{1}{10}$ of F, so that

$$P = 0.1(1000) = 100 \text{ kg}$$

Steps 7, 8, and 9 Calculate B by direct subtraction using the total mass balance

$$B = 1000 - 100 = 900 \text{ kg}$$

Steps 5, 6, 7, 8, and 9 The unknown quantities are the bottoms compositions. We can make two component mass balances, or one sum of masses or mass fractions of the components in B plus one component mass balance, so that the problem has a unique solution.

The solution can be computed directly by subtraction.

	kg feed in	− *kg distillate out*	= *kg bottoms out*	*percent*
EtOH balance:	0.10(1000)	− 0.60(100)	= 40	4.4
H_2O balance:	0.90(1000)	− 0.40(100)	= 860	95.6
			900	100.0

If we use the total balance to calculate B, all we need to do is make one component balance because

$$\text{mass } H_2O \text{ in } B = 900 - 40 = 860 \text{ kg}$$

Step 10 *Check:* 900 kg B + 100 kg P = 1000 kg F.

3. **Solution to FTA** [Marks distribution: 1 mark each for first three steps and 2 marks for reporting $P(T0)$ = 169/1024 or 0.165 or 16.5 %]

$$P(T_3) = P(A) + P(B) - P(A) \cdot P(B) = 1/4 + 1/4 - 1/16 = 7/16$$

$$P(T_2) = P(C) \cdot P(D) = 1/4 \cdot 1/4 = 1/16$$

$$P(T_1) = P(T_3) \cdot P(E) = 7/16 \cdot 1/4 = 7/64$$

$$P(T_0) = P(T_1) + P(T_2) - P(T_1) \cdot P(T_2)$$

$$= 7/64 + 1/16 - 7/64 \cdot 1/16 = 169/1024$$

$\therefore$ Probability of occurrence of top event = 169/1024

Question 4:

No of employees = 1000

Working hours = 30 hours per week

No of fatalities over one- year period= 2

No of injuries = 2

(a) Worker-based fatal injury rate = (2*100000)/1000 = 200
(b) Hour-based fatal injury rate = (2*200*100000*30*50)/ (1000*30*50) = 200
(c) Recordable incidence rate = (2*100*30*50)/ (1000*30*50) = 0.2

Question 5:

(a) No of reports of unsafe activities in a plant = Lagging
(b) Money spent on insurance claims = Lagging
(c) No of visit to the plant first aid facility = Leading
(d) No of process alarm there were managed without incident = Leading

Question 6:

(a) Emergency shut-off valves = Preventive
(b) Emergency fire water system = Mitigative
(c) Emergency cooling system = Preventive
(d) Emergency houses = Mitigative
(e) Mitigative
(f) Inhibitor-Preventive