DEPARTMENT OF CHEMICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

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

Class Test [20 Marks]

1. Solution of Pinch Analysis

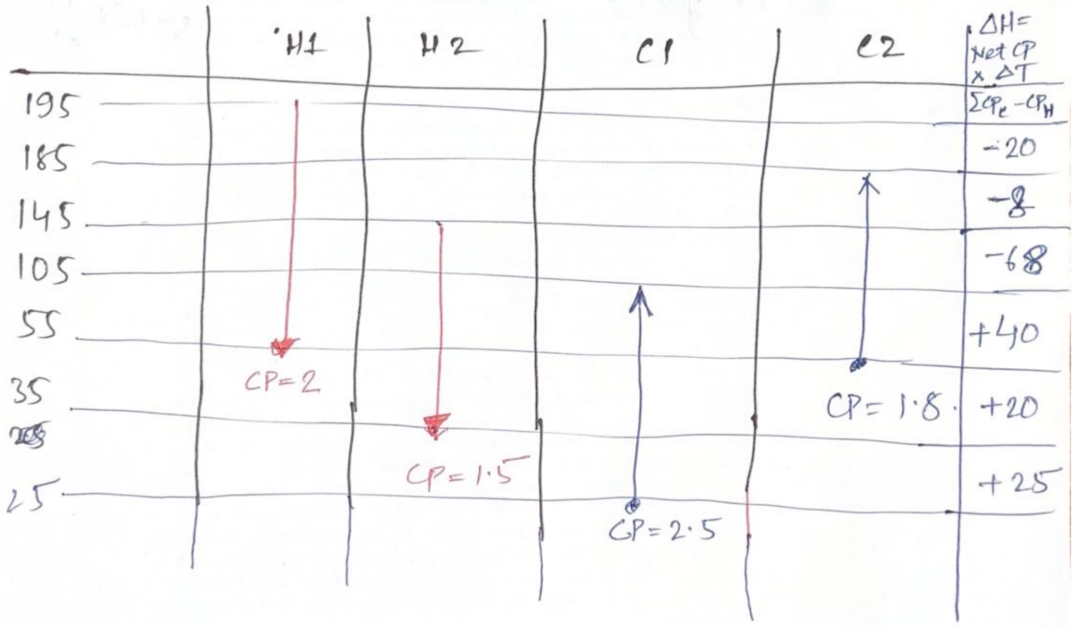
1. Shifted temperature:

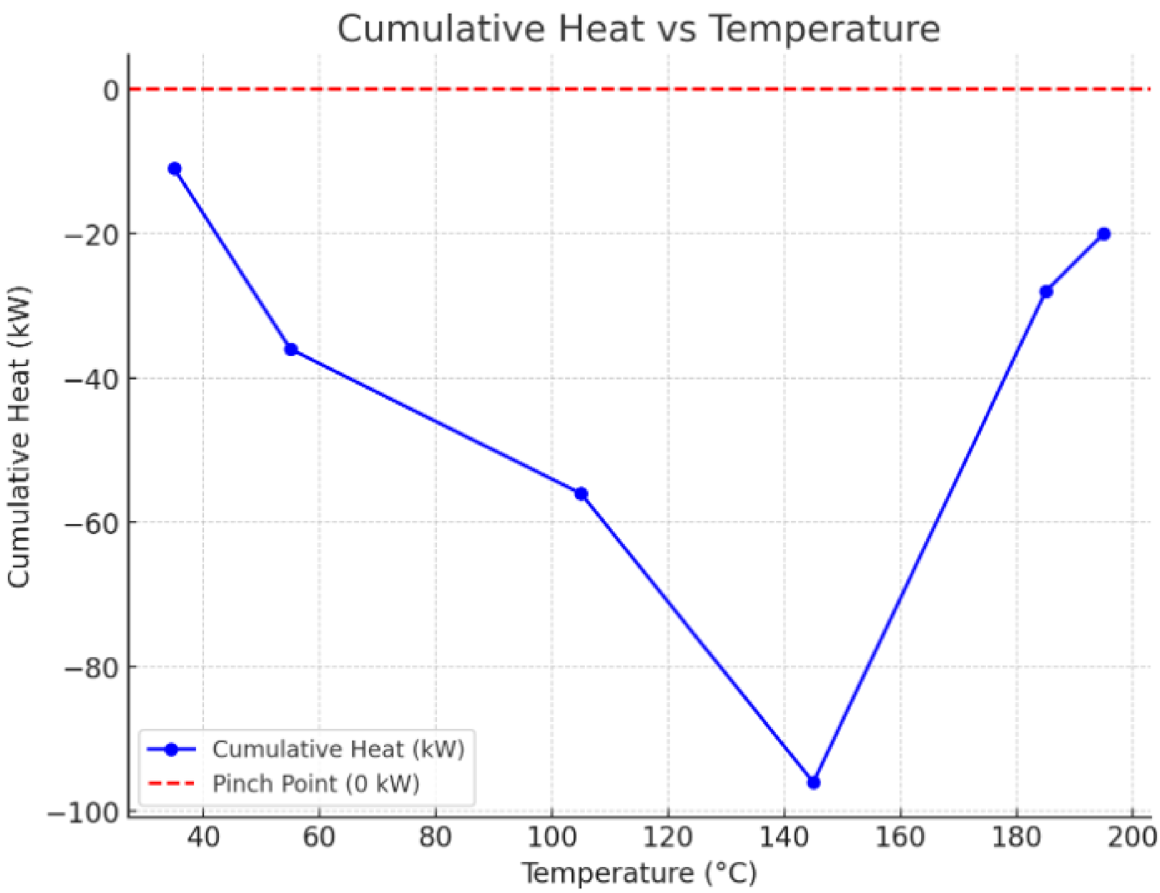
$$\left[T_{shifted}\right]_{hot} = T - \frac{\Delta T_{min}}{2}$$

$$\left[T_{shifted}\right]_{cold} = T + \frac{\Delta T_{min}}{2}$$

	Actual S	Actual T	Shifted S	Shifted T
H1	200	60	195	55
H2	150	40	145	35
C1	20	100	25	105
C2	50	180	55	185

Temp. intervals: 25, 35, 55, 105, 145, 185, 195





Here is the plot of the cumulative heat versus temperature. The red dashed line represents the "pinch point" at 0 kW. As you can see, the cumulative heat balance does not cross this line, indicating that **there is no pinch point in this system**. The heat is consistently either being supplied or removed, but without a zero-heat balance.

A pinch point occurs when the temperature gradient of heat exchange between two streams becomes zero or approaches zero, typically leading to an infeasible heat exchange scenario. To find the pinch point, you need to look for a temperature at which the heat demand of the cold stream matches the heat available from the hot stream.

In this case, there are both negative and positive heat values, which indicate that heat is being transferred from the system (negative values) and being supplied to the system (positive values). The fact that you have intervals with positive heat flows and negative heat flows without any obvious point where the heat balance becomes zero suggests that there is no "pinch point" in the system — meaning the temperature and heat exchanges do not lead to an operational constraint.

To confirm, you'd typically plot the cumulative heat balances for hot and cold streams to check for a pinch point, where the two curves would converge or touch. If they do not, it indicates no pinch point, and the heat recovery process can continue smoothly without this limiting factor.

2. Solution to the FTA:

Writing equations for each gate of the tree

$$\mathrm{T} = \mathrm{P1} + \mathrm{G1} \tag{9}$$
$$\mathrm{G1} = \mathrm{P2} + \mathrm{P3} + \mathrm{G2} + \mathrm{G3} \tag{10}$$
$$\mathrm{G2} = \mathrm{P4} + \mathrm{S1} \tag{11}$$
$$\mathrm{G3} = \mathrm{G4} + \mathrm{P5} \tag{12}$$
$$\mathrm{G4} = \mathrm{C1} \cdot \mathrm{G5} \tag{13}$$
$$\mathrm{G5} = \mathrm{P6} + \mathrm{P7} \tag{14}$$

Using the **top-down** approach we get by substitution

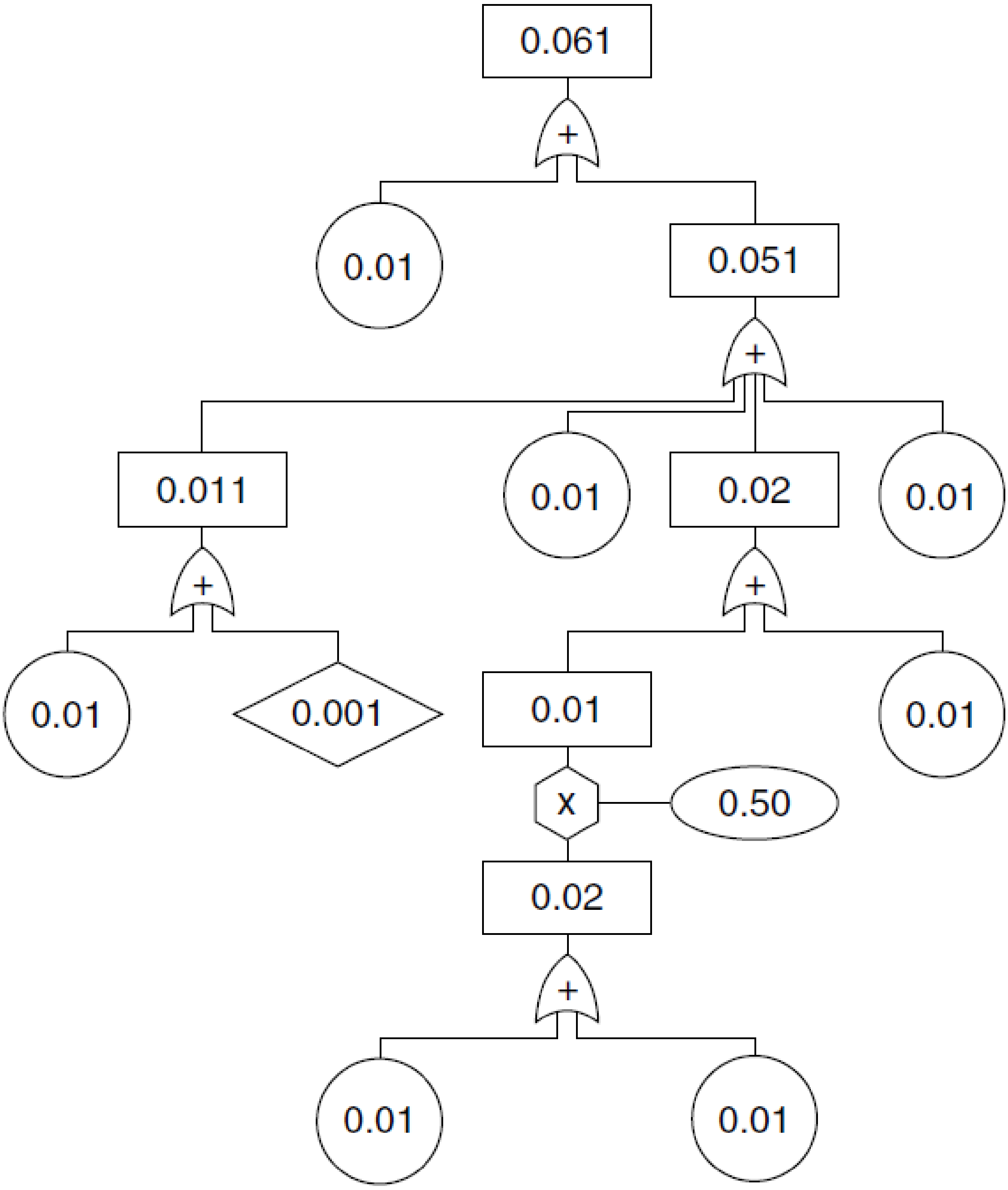
$$\mathrm{T} = \mathrm{P1} + \mathrm{G1} \tag{15}$$
$$= \mathrm{P1} + \mathrm{P2} + \mathrm{P3} + \mathrm{G2} + \mathrm{G3} \tag{15.1}$$
$$= \mathrm{P1} + \mathrm{P2} + \mathrm{P3} + \mathrm{P4} + \mathrm{S1} + \mathrm{G3} \tag{15.2}$$
$$= \mathrm{P1} + \mathrm{P2} + \mathrm{P3} + \mathrm{P4} + \mathrm{S1} + \mathrm{G4} + \mathrm{P5} \tag{15.3}$$
$$= \mathrm{P1} + \mathrm{P2} + \mathrm{P3} + \mathrm{P4} + \mathrm{S1} + (\mathrm{C1} \cdot \mathrm{G5}) + \mathrm{P5} \tag{15.4}$$
$$= \mathrm{P1} + \mathrm{P2} + \mathrm{P3} + \mathrm{P4} + \mathrm{S1} + \mathrm{P5} + \mathrm{C1} \cdot (\mathrm{P6} + \mathrm{P7}) \tag{15.5}$$
$$= \mathrm{P1} + \mathrm{P2} + \mathrm{P3} + \mathrm{P4} + \mathrm{S1} + \mathrm{P5} + (\mathrm{C1} \cdot \mathrm{P6}) + (\mathrm{C1} \cdot \mathrm{P7}) \tag{15.6}$$

The top event, therefore, contains 6 single component minimum cut sets and 2 double component minimum cut sets.

Event	Description	Probability
P1	Defect in motor	0.01
P2	Wire failure (open)	0.01
P3	Power supply failure	0.01
P4	Switch fails open	0.01
P5	Fuse failure under normal conditions (open)	0.01
P6	Wire failure (shorted)	0.01
P7	Power failure (surge)	0.01
S1	Switch opened erroneously	0.001
C1	Fuse fails open	0.50

The probability of **intermediate** events can be evaluated using the fault tree. The probability of the top event is given by the union of the minimum cut sets determined before as

$$\mathrm{T} = \mathrm{P1} + \mathrm{P2} + \mathrm{P3} + \mathrm{P4} + \mathrm{S1} + \mathrm{P5} + (\mathrm{C1} \cdot \mathrm{P6}) + (\mathrm{C1} \cdot \mathrm{P7}) \tag{16}$$
$$= 0.01 + 0.01 + 0.01 + 0.01 + 0.001 + 0.01 + (0.50)(0.01) + (0.50)(0.01) \tag{16.1}$$
$$= 0.061 \tag{16.2}$$


0.061
+
0.01
0.051
+
0.011
0.01
0.02
0.01
+
+
0.01
0.001
0.01
0.01
X
0.50
0.02
+
0.01
0.01