TUTORIAL-02: PROBLEM TABLE ANALYSIS

Based on Lecture-11: **PROBLEM TABLE ALGORITHM-1st Part**

Problem 1: The stream data for a typical process plant is given in Table 1 for which ΔT_{min} = 10°C. Calculate the hot and cold utility and pinch point for this process.

Table 1: Stream data for typical process plant

Stream Name	Stream Type	T_S (^{0}C)	T_T (^{0}C)	CP (kW/ ^{0}C)
1	Cold(C1)	10	45	120
2	Hot(H1)	45	15	110
3	Cold(C2)	50	85	5
4	Hot(H2)	85	15	5
5	Cold(C3)	10	75	25
6	Cold(C4)	45	80	20
7	Hot(H3)	40	10	120

Solution to Problem-1:

The first step to calculate hot and cold utilities is to find out the shifted temperatures for the hot and cold streams as shown below:

$$T_{H(shifted)} = T_{H(actual)} - \Delta T_{min}/2 \qquad (1)$$

$$T_{C(shifted)} = T_{C(actual)} + \Delta T_{min}/2 \qquad (2)$$

Values of shifted temperatures of hot and cold streams are shown in Table 2.

Table 2: Shifted temperature data for stream data of Table 1

Stream type	Actual temperature (^{0}C)		Shifted temperature (^{0}C)	
	Supply Temperature	Target Temperature	Supply Temperature	Target Temperature
H1	45	15	40	10
H2	85	15	80	10
H3	40	10	35	5
C1	10	45	15	50
C2	50	85	55	90
C3	10	75	15	80
C4	45	80	50	85

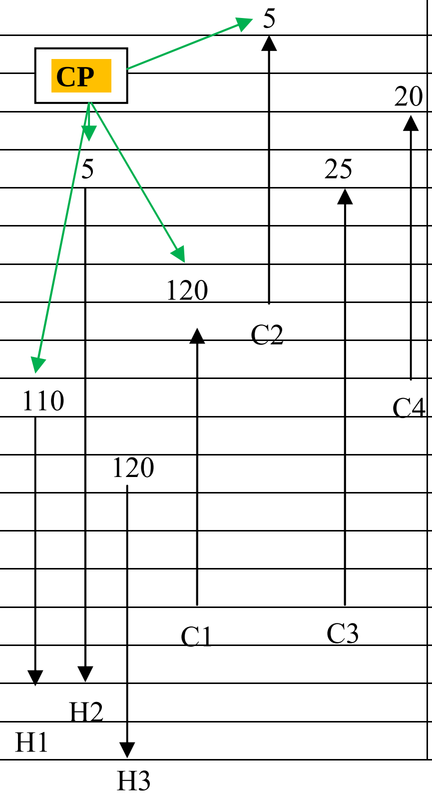
The shifted temperatures are arranged in decreasing order where the temperature, which appears more than one, should be written only once. It gives temperature intervals as shown in column no. 1 of Table 3.

Enthalpy balances can easily be calculated for each temperature interval using Eq. 3:

$$\Delta H_i = [\sum CP_C - \sum CP_H]_i \Delta T_i = (T_i - T_{i+1}) * [\sum CP_C - \sum CP_H]_i \tag{3}$$

This equation is valid for any temperature interval i. The computed heat balance in all the temperature intervals are shown in the Table 3. The last column of this table indicates whether the interval is in heat surplus or heat deficit.

Table 3: Temperature interval and heat balance in each interval

Shifted temperature (°C)	Stream population	$T_I - T_{I+1}$	$\sum CP_C - \sum CP_H$	ΔH(kW)	surplus or deficit
90					
		5	5	25	Deficit
85					
		5	25	125	Deficit
80					
		25	45	1125	Deficit
55					
		5	40	200	Deficit
50					
		10	140	1400	Deficit
40					
		5	30	150	Deficit
35					
		20	-90	-1800	Surplus
15					
		5	-235	-1175	Surplus
10					
		5	-120	-600	Surplus
5					

After constructing the Problem table and defining intervals with surplus and deficit of heat, the next step is to develop a heat cascade based on key feature of problem table that any heat available in interval i is hot enough to supply its duty in interval i+1. The cascading is shown in column no. 3 of Table 4. Further, the column shows negative values of heat in a interval, which is infeasible. To make the problem feasible most negative value of heat, which is 3025 kW (column 3 in Table 4), is cascaded from top and considered as hot utility. The cascading is shown in last column of Table 4.

Table 4: Problem table cascade

3025kW

Shifted temperature (^{o}C)	ΔH (kW)	Heat cascade at stage 1, ΔH (kW)	Heat cascade at stage 2, ΔH (kW)
90		0	3025
	25		
85		-25	3000
	125		
80		-150	2875
	1125		
55		-1275	1750
	200		
50		-1475	1550
	1400		
40		-2875	150
	150		
35		-3025	0
	-1800		
15		-1225	1800
	-1175		
10		-50	2975
	-600		
5		550	3575

Pinch point

Hot utility

3025-25 = 3000

3000-125 = 2875

2857-1125=1750

Add to the TOP temp. level with sign change (i.e. 3025 kW) and then cascade down satisfying the heat demand and supply

Cold utility

From the problem table cascade shown in Table 4 following information are extracted:

Amount of minimum hot utility required: 3025 kW

Amount of minimum cold utility required: 3575 kW

Pinch point: 35 ^{0}C

Hot pinch : 40 ^{0}C

Cold pinch : 30 ^{0}C

PROBLEM 2 – The stream data for the process is given in Table 5. For this process compute the amount of hot and cold utility required considering ΔT_{min} as 10°C.

Table: 5: Stream data for problem 2

Stream	T_s(°C)	T_T (°C)	Heat Capacity Flow rate (MW.$^oC^{-1}$)
Hot	415	40	0.22
Hot	50	35	1.2
Cold	25	380	0.18
Cold	30	370	0.06
Cold	115	120	25

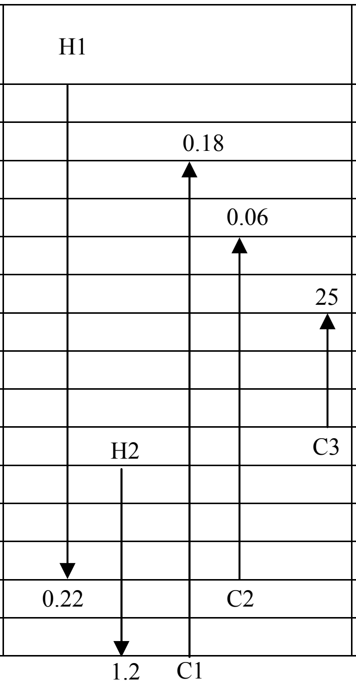
Solution to Problem-2: The shifted temperature data can be calculated using Eq. 1 and 2 and their values are shown in Table 6.

Table: 6: Shifted temperature data for stream data of problem -2

Stream	Actual temperature (^{0}C)		Shifted temperature (^{0}C)	
	Supply Temperature	Target Temperature	Supply Temperature	Target Temperature
H1	415	40	410	35
H2	50	35	45	30
C1	25	380	30	385
C2	30	370	35	375
C3	115	120	120	125

Enthalpy balances for each temperature interval are calculated using Eq.3. The computed heat balance in all the temperature intervals are shown in the Table 7. The last column of the table shows whether the interval is in heat surplus or heat deficit.

Table 7: Table for temperature interval heat balance

Shifted temperature (^oC)		$T_I - T_{I+1}$ (^oC)	$\sum CP_C - \sum CP_H$ ($MW.^oC^{-1}$)	ΔH (MW)	Surplus or deficit
410					
		25	-0.22	-5.5	Surplus
385					
		10	-0.04	-0.4	Deficit
375					
		250	0.02	5	Deficit
125					
		5	25.02	125.1	Deficit
120					
		75	0.02	1.5	Deficit
45					
		10	-1.18	-11.8	Surplus
35					
		5	-1.02	-5.1	Surplus
30					

After defining intervals with surplus and deficit of heat, heat cascade is done as carried out for Problem -1. It is shown in Table 8.

Table 8: Problem table cascade

Shifted temperature (°C)	ΔH (MW)	Heat cascade at stage 1, ΔH (kW)	Heat cascade at stage 2, ΔH (kW)
410		0	125.7
	-5.5		
385		5.5	131.2
	-0.4		
375		5.9	131.6
	5		
125		0.9	126.6
	125.1		
120		-124.2	1.5
	1.5		
45		-125.7	0
	-11.8		
35		-113.9	11.8
	-5.1		
30		-108.8	16.9

Hot utility

Pinch point

Cold utility

From the problem table cascade shown in Table 13.8 following observations are drawn:

Amount of hot utility required: 125.7 MW

Amount of cold utility required: 16.9 MW

Pinch point: 45 °C

Hot pinch point: 50 °C

Cold pinch point: 40 °C