EXERCISE 6 – SOLUTIONS

1 LP Transshipment model

a)

First we look at the hot streams including the hot utility. We find all the starting points (inlet temperatures). We find the corresponding points for the cold composite curve by extracting *HRAT* from the temperatures:

T_{start}	$T_{start} - HRAT$
220	210
180	170
140	130

And similar for the cold streams including the cold utility, by adding *HRAT* to the starting points:

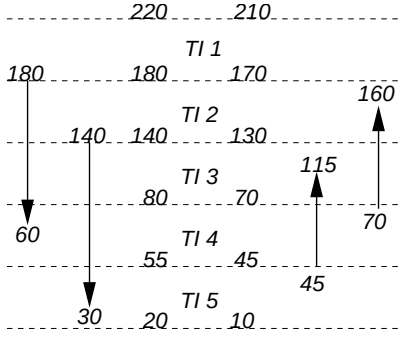
T_{start}	$T_{start} + HRAT$
45	55
70	80
10	20

Sorting the two tables we end up with the final partitioning:

Hot	*Cold*
220	210
180	170
140	130
80	70
55	45
20	10

b)

The calculation is easier if we draw the streams together with the temperature intervals:



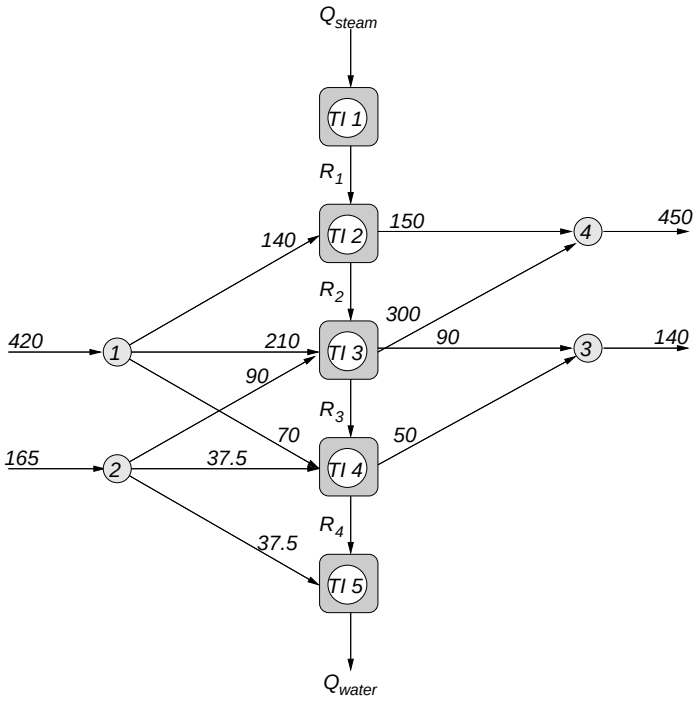
The heat content for the hot streams is calculated from $\dot{m} \cdot cp(T_{start} - T_{target})$ and $\dot{m} \cdot cp(T_{target} - T_{start})$ for the cold streams..[1]

[1] Note that the streams target temperatures might be different from the interval temperatures!

Interval	*Stream 1*	*Stream 2*	*Stream 3*	*Stream 4*
TR-1	0.0	0.0	0.0	0.0
TR-2	140.0	0.0	0.0	150.0
TR-3	210.0	90.0	90.0	300.0
TR-4	70.0	37.5	50.0	0.0
TR-5	0.0	37.5	0.0	0.0
total	420.0	165.0	140.0	450.0

c)

The formulation will be a lot easier if we draw the cascade including the heat content of each stream:



Simple energy balance calculations over each interval yields:

$$Q_{steam} = R_1 \Leftrightarrow Q_{steam} - R_1 = 0 \tag{1}$$
$$R_1 + 140 = R_2 + 150 \Leftrightarrow R_1 - R_2 = 10 \tag{2}$$
$$R_2 + 210 + 90 = R_3 + 300 + 90 \Leftrightarrow R_2 - R_3 = 90 \tag{3}$$
$$R_3 + 70 + 37.5 = R_4 + 50 \Leftrightarrow R_3 - R_4 = -57.5 \tag{4}$$
$$R_4 + 37.5 = Q_{water} \Leftrightarrow R_4 - Q_{water} = -37.5 \tag{5}$$

The final LP-formulation is then:

$$\min\ Q_{steam} + Q_{water} \tag{6}$$
$$\text{subject to} \tag{7}$$
$$Q_{steam} - R_1 = 0 \tag{8}$$
$$R_1 - R_2 = 10 \tag{9}$$
$$R_2 - R_3 = 90 \tag{10}$$
$$R_3 - R_4 = -57.5 \tag{11}$$
$$R_4 - Q_{water} = -37.5 \tag{12}$$
$$Q_{steam}, Q_{water}, R_1, R_2, R_3, R_4 \geq 0 \tag{13}$$

d)

Solving the model using Excel gives:

z	195
Q_{steam}	100
Q_{water}	95
R_1	100
R_2	90
R_3	0
R_4	57.5