The amount of cold utility consumption in 3 last figures are wrong. Should be 95 kW, now 110 kW.

EEN-E3007 - Process Integration and Energy Optimization L

Espoo 2021

EXERCISE 5 – SOLUTIONS

1 Problem table algorithm

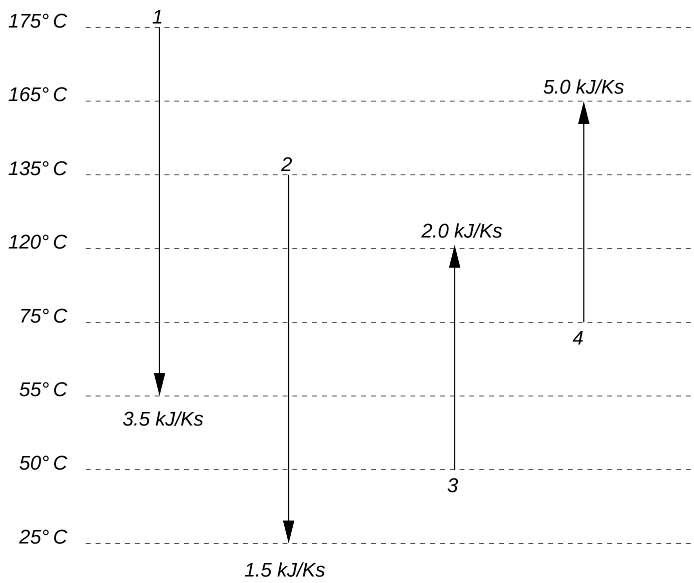
a)

First we must adjust the start and target temperatures. This is done by subtracting ?$\frac{1}{2}\Delta T_{min}$ from the hot streams' temperatures and adding $\frac{1}{2}\Delta T_{min}$ to the cold streams' temperatures.

					ΔT_{min} *adjusted*	
stream #	*type*	$cp \cdot \dot{m}$	T_{start} $[^\circ C]$	T_{target} $[^\circ C]$	T_{start} $[^\circ C]$	T_{target} $[^\circ C]$
1	hot	3.5	180	60	175	55
2	hot	1.5	140	30	135	25
3	cold	2.0	45	115	50	120
4	cold	5.0	70	160	75	165

b)

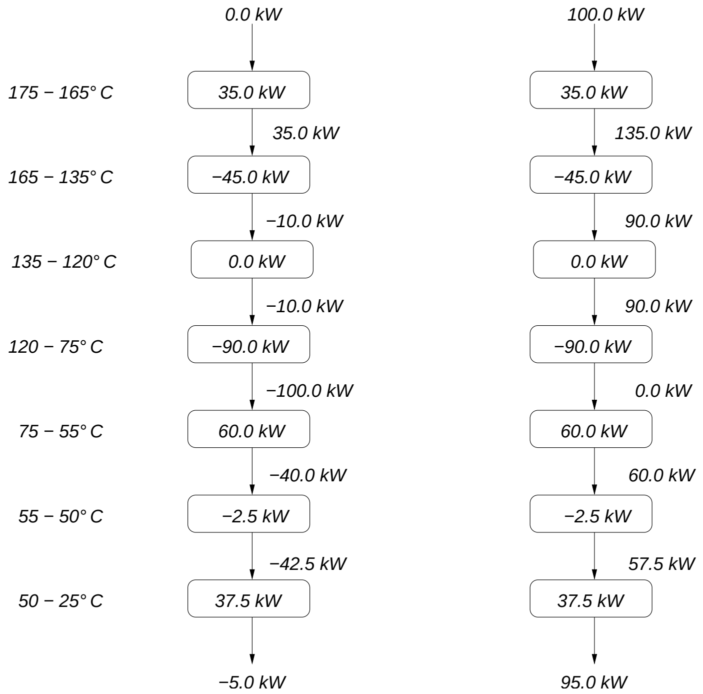
We can then draw the streams and identify the intervals:



interval $[^\circ C]$	$\sum_{hot} cp \cdot m - \sum_{cold} cp \cdot m$	*surplus/deficit* $[kW]$
175–165	3.5	35.0
165–135	$3.5 - 5.0 = -1.5$	-45.0
135–120	$3.5 + 1.5 - 5.0 = 0.0$	0.0
120– 75	$3.5 + 1.5 - 5.0 - 2.0 = -2.0$	-90.0
75– 55	$3.5 + 1.5 - 2.0 = 3.0$	60.0
55– 50	$1.5 - 2.0 = -0.5$	-2.5
50– 25	1.5	37.5

c)

Based on this information we can draw a heat cascade diagram.

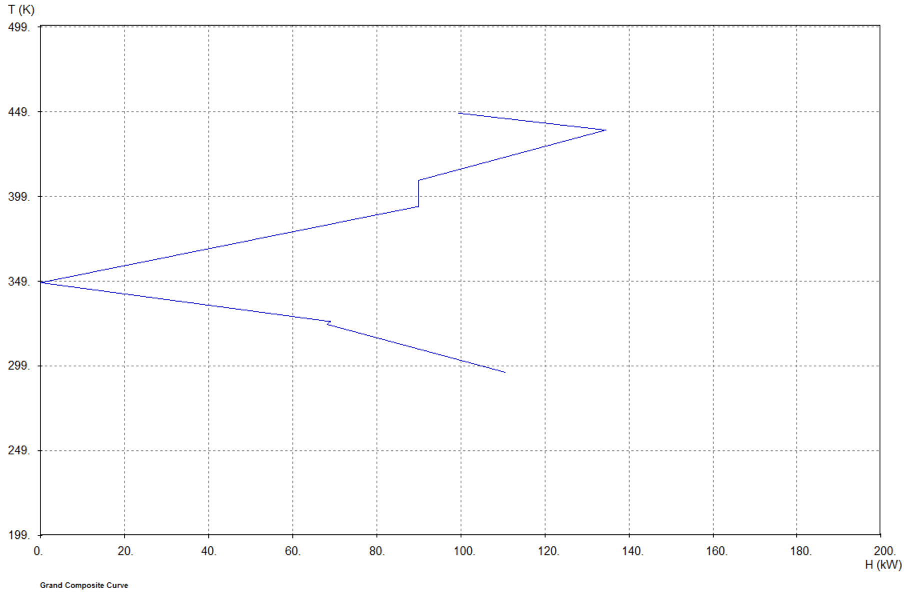


Heat can be transfered from a higher temperature to a lower, but not vice versa. A negative heat flow is not feasible since it would mean a heat transfer from a low temperature to a high. Looking at the cascade we can identify the largest thermodynamic in-feasibility, which in this case is $100\ kW$. We can make it thermodynamically feasible by adding this amount of heat to the top of the cascade.

The minimum utility consumptions and the pinch temperature can be directly read from this cascade. In this case the minimum hot- and cold utility consumption is $100\ kW$ and $95\ kW$ respectively and the pinch temperature is $75\ °C$. The pinch temperature is found where no heat is cascaded.

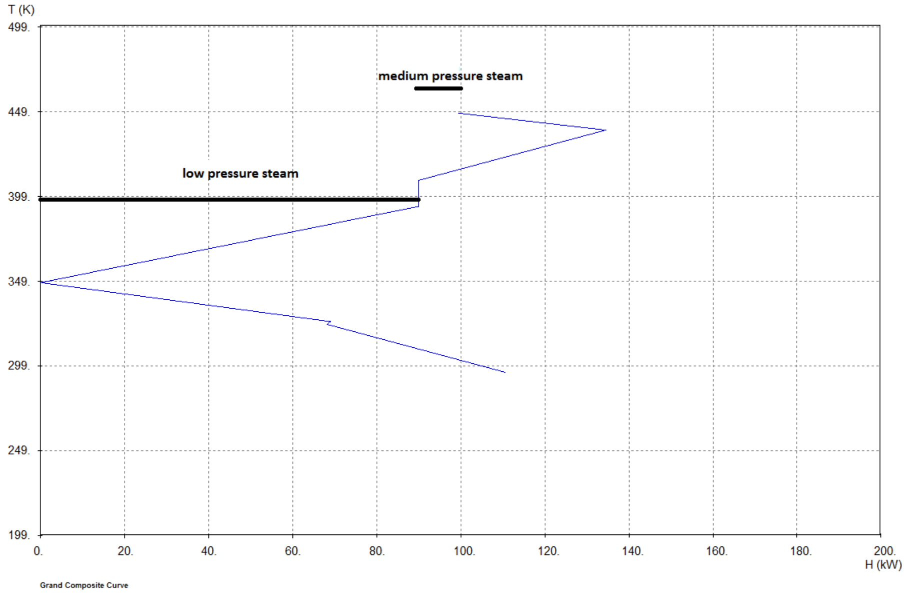
2 HINT

a)



b)

First we must remember to adjust for ΔT_{min}, which means that the high- and low pressure steams adjusted temperatures are $185\ °C$ and $125\ °C$ respectively. The total minimum hot utility consumption is $100\ kW$. We are able use $90\ kW$ low pressure steam. This leaves $10\ kW$ for high pressure steam. The grand composite curve is shown in the figure below.



3 Heat pump

a)

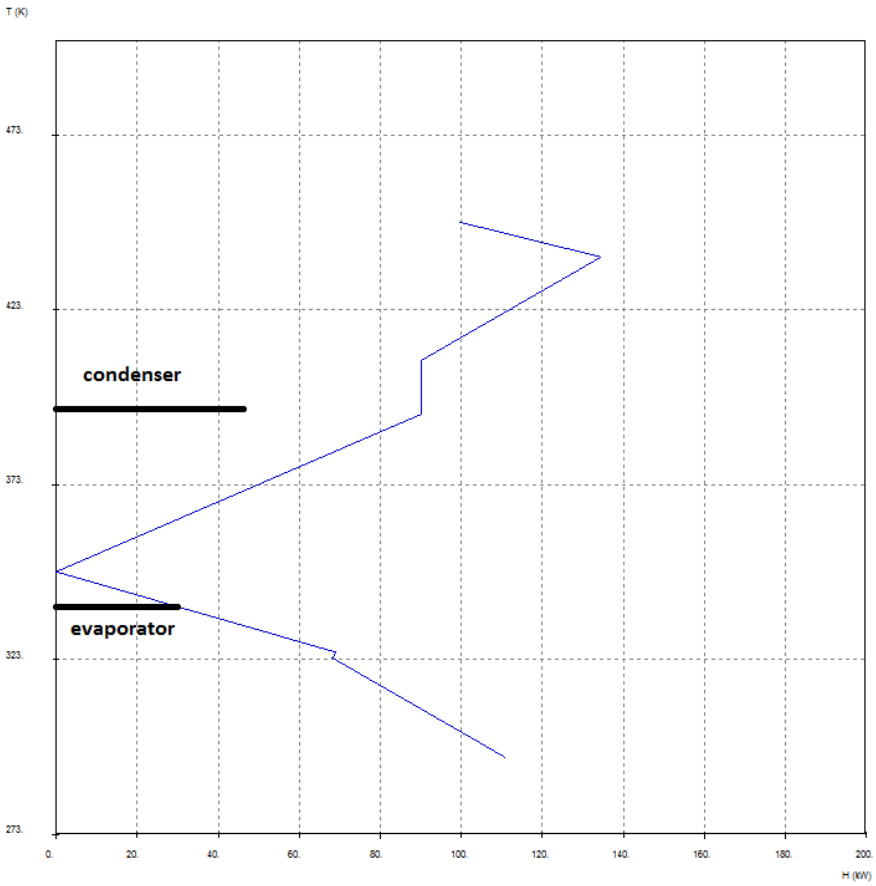
First we must adjust the temperatures for ΔT_{min}. Then we check how much heat that is available for the evaporator (at 65 $°C$). We can get approximately 30 kW for the evaporator. This corresponds to 45 kW heat from the condenser;

$$COP \approx \frac{Q_C}{Q_C - Q_E} \Rightarrow Q_C = \frac{COP}{COP - 1} \cdot Q_E$$

$$Q_C = \frac{3}{3-1} \cdot 30 = 45$$

This means that with help of the heat pump we can reduce the low pressure steam consumption with 45 kW and the cooling water consumption with 30 kW. The electricity consumption for the heat pump is 15 kW.

b)



Grand Composite Curve