CHE 526: PINCH TECHNOLOGY

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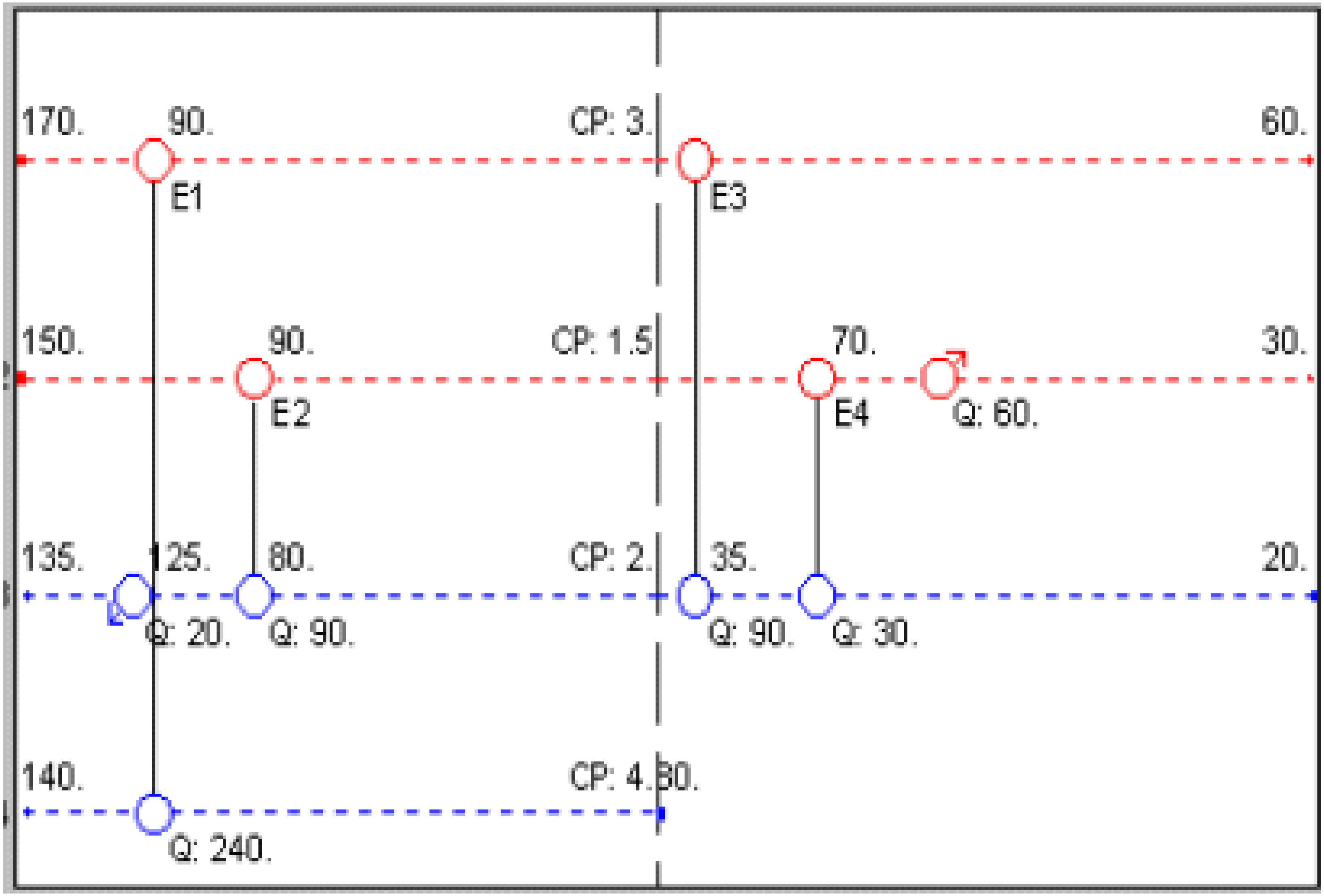
Designing Stream Networks

- Stream network is a grid diagram showing the streams and the corresponding heat exchange units (HEN).
- The design of HEN incorporates two fundamentally important features:
  - it recognizes that the pinch region is the most constrained part of the problem (consequently it starts the design at the pinch and develops by moving away) and,
  - it allows the designer to choose between match options.
- Network design examines which "hot" streams can be matched to "cold" streams via heat recovery. This can be achieved by employing "tick off" heuristics to identify the heat loads on the pinch exchanger.
- Every match brings one stream to its target temperature.
- The pinch divides the heat exchange system into two thermally independent regions, HENs for both above and below pinch regions are designed separately.
- When the heat recovery is maximized the remaining thermal needs must be supplied by hot utility. The graphical method of representing flow streams and heat recovery matches is called a 'grid diagram'.



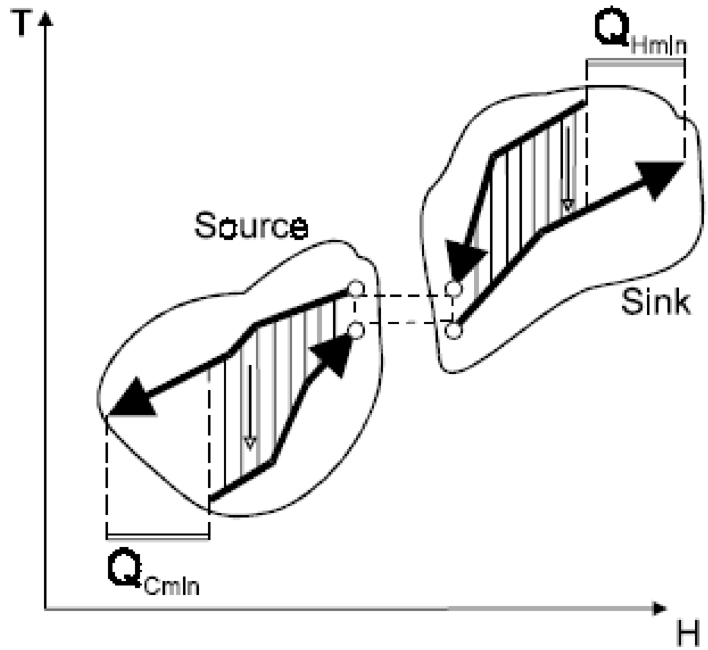
Typical grid diagram

Describing the Heat Exchange Networks

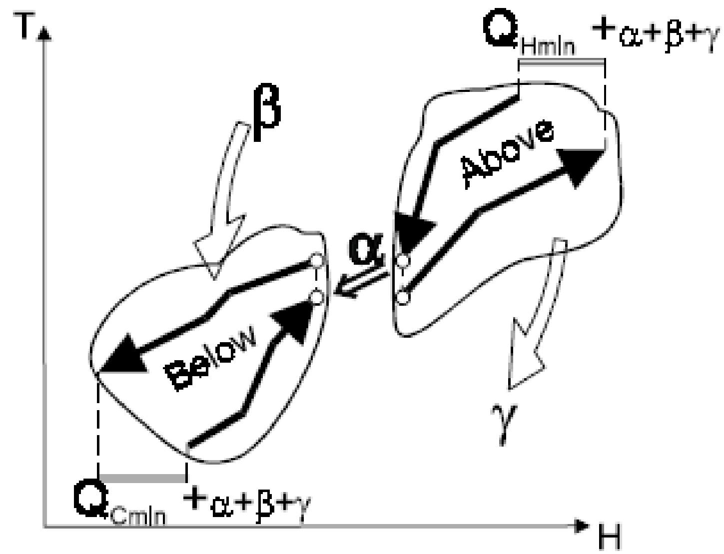
- All the cold and hot streams are represented by horizontal lines.
- The entrance and exit temperatures are shown at either end.
- The vertical line in the middle represents the pinch temperature.
- The circles represent heat exchangers. Unconnected circles represent exchangers using utility heating and cooling.
- The design of a network is based on certain guidelines like the "C_P Inequality Rule", "Stream Splitting", "Driving Force Plot" and "Remaining Problem Analysis".
- Having made all the possible matches, the two designs above and below the pinch are then brought together and usually refined to further minimize the capital cost.
- After the network has been designed according to the pinch rules, it can be further subjected to energy optimization.
- Optimizing the network involves both topological and parametric changes of the initial design in order to minimize the total cost.

Steps Involved in Designing Heat Exchange Networks

1. Construct the curves for the temperature – enthalpy load (t – H) graph from which the Pinch conditions and the minimum external heating and cooling duties can be found.
2. Use the Pinch temperature to design the heat recovery network that will satisfy the targets for minimum external duties. Rules that must be observed in the design of the optimum heat recovery scheme;
   - No heat transfer across the Pinch
   - No external cooling above the Pinch
   - No external heating below the Pinch
3. Construct a design chart where the streams are represented as horizontal lines drawn between their respective temperature limits and broken by vertical lines representing the Pinch.
4. Next, link the hot streams with the cold streams by heat exchangers, bearing in mind the rules for optimum heat recovery. In addition, to link a hot and cold stream immediately adjacent to the pinch, the following rules should be followed:
   - $CP_H \leq CP_C$; above the Pinch
   - $CP_H \geq CP_C$; below the Pinch.



The Pinch Divides the Problem into Source and Sink
(a)



By violating the three golden rules Q_{Hmin} and Q_{Cmin} are each increased by $\alpha+\beta+\gamma$.

(b)

Designing Stream Networks

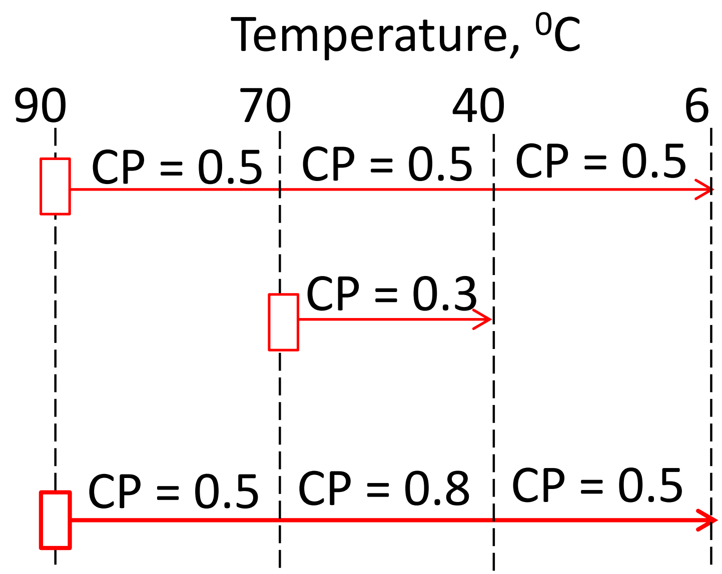
- Stream network is a grid diagram showing the streams and the corresponding heat exchange units (HEN).
- Steps involved in designing networks.

1. Construct the curves for the temperature – enthalpy load (t – H) graph from which the Pinch conditions and the minimum external heating and cooling duties can be found.

Hot stream composite

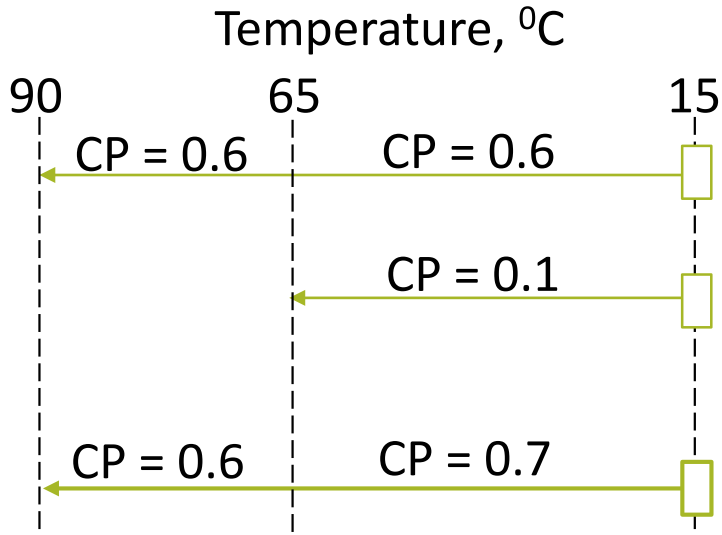
Stream number	CP, kW/K
1	0.5
2	0.3

Hot composite stream

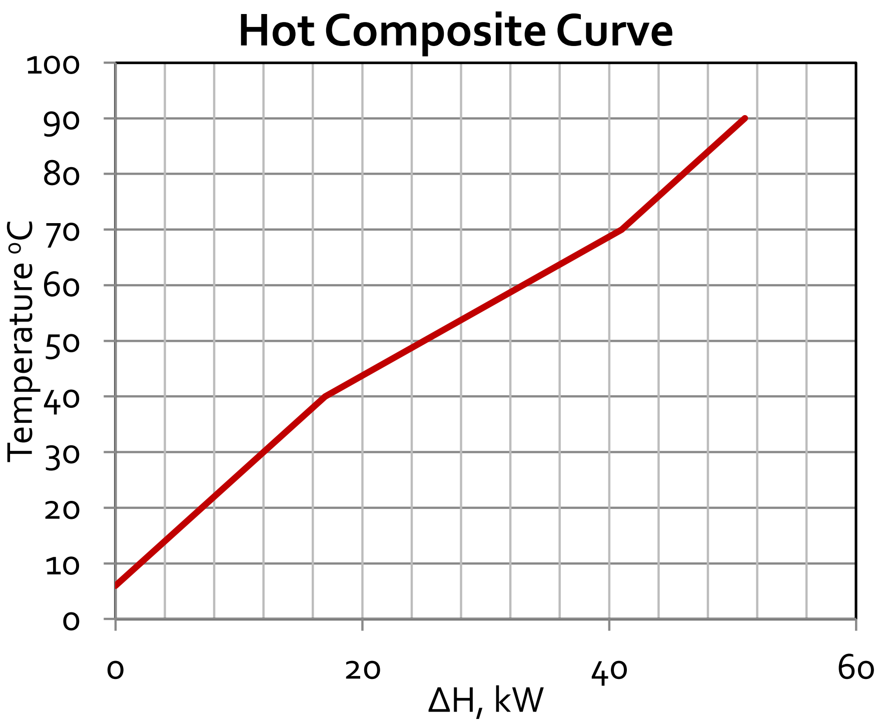


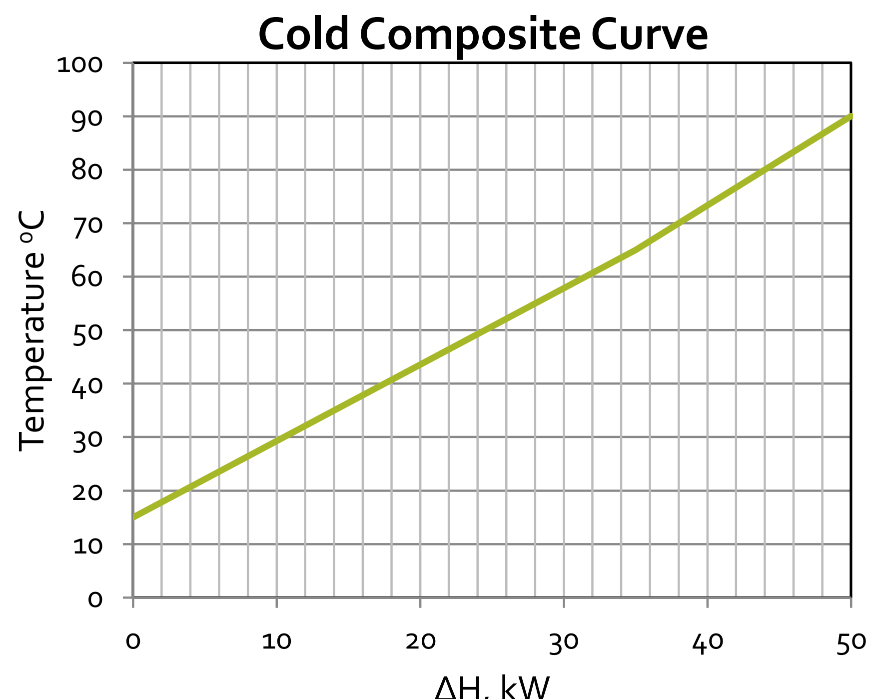
Cold stream composite

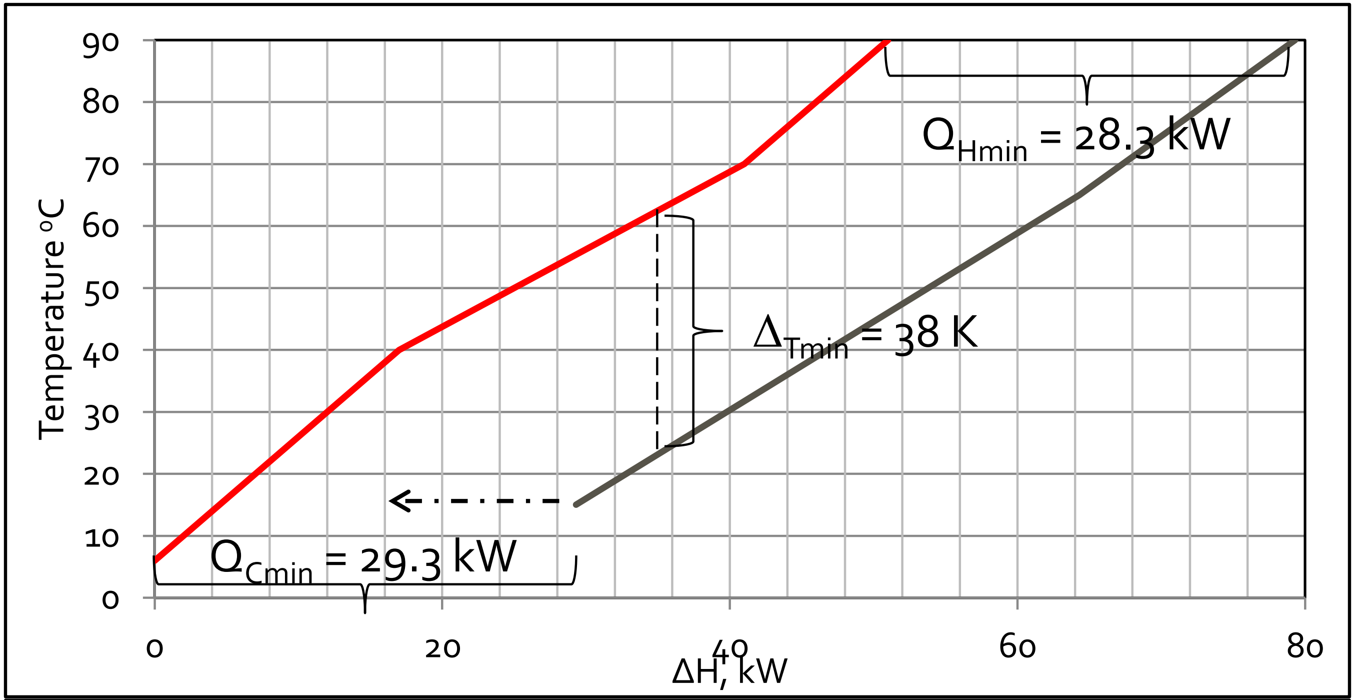
Stream number	CP, kW/K
3	0.6
4	0.1

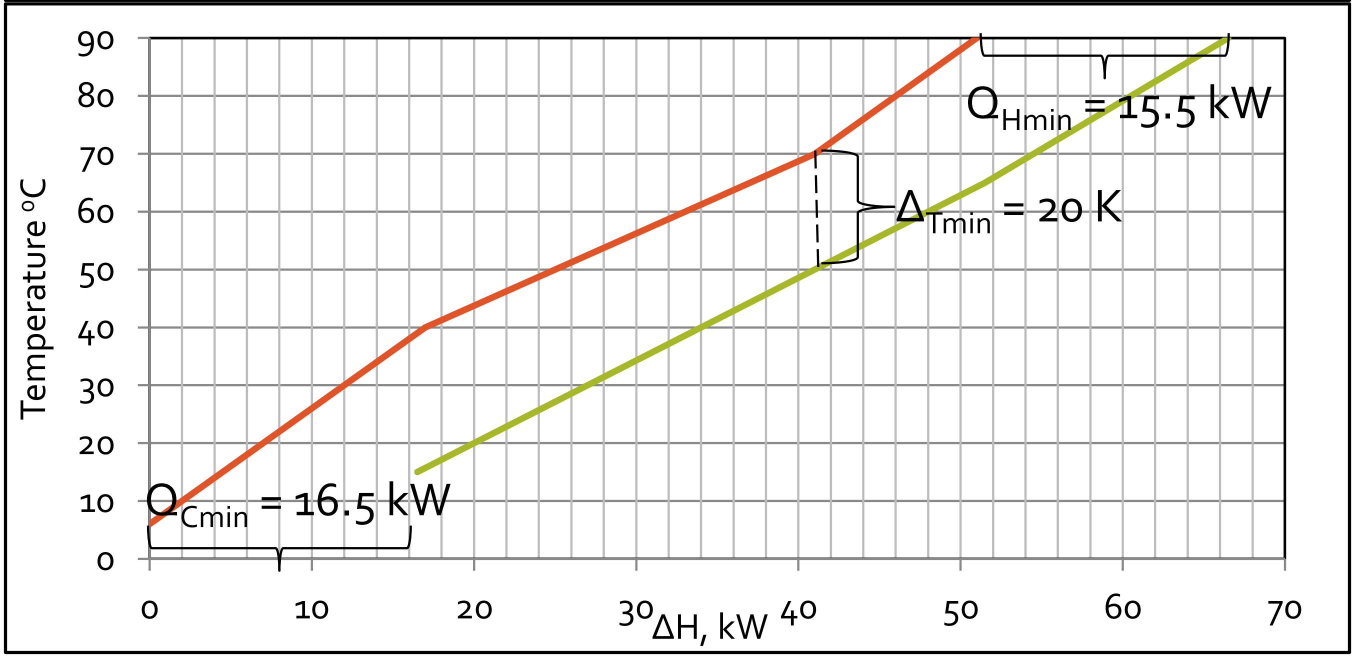


Cold composite stream







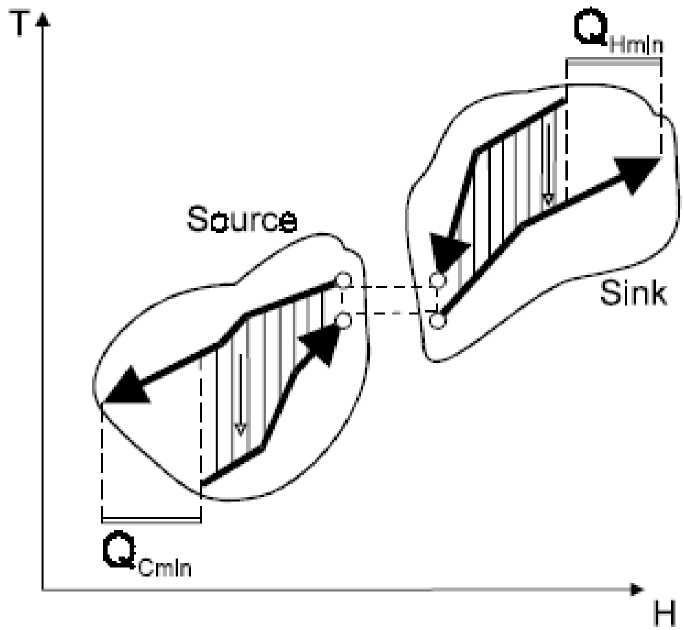


From the graph,

- T_{Hot} at Pinch = 70°C
- T_{cold} at Pinch = 50°C
- Q_{Hmin} = 15.5 kW
- Q_{Cmin} = 16.5 kW
- the cooling load exceeds the heating load by 1 kW

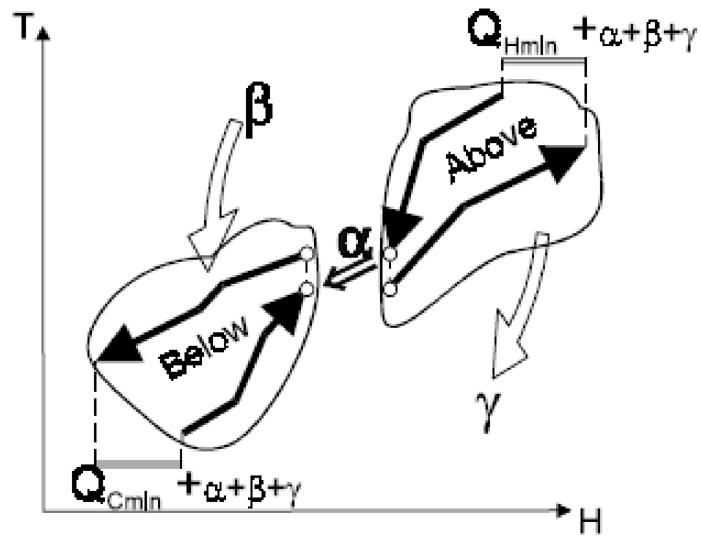
2. Use the Pinch temperature to design the heat recovery network that will satisfy the targets for minimum external duties.

- Rules that must be observed in the design of the optimum heat recovery scheme;
  - No heat transfer across the Pinch
  - No external cooling above the Pinch
  - No external heating below the Pinch



The Pinch Divides the Problem into Source and Sink

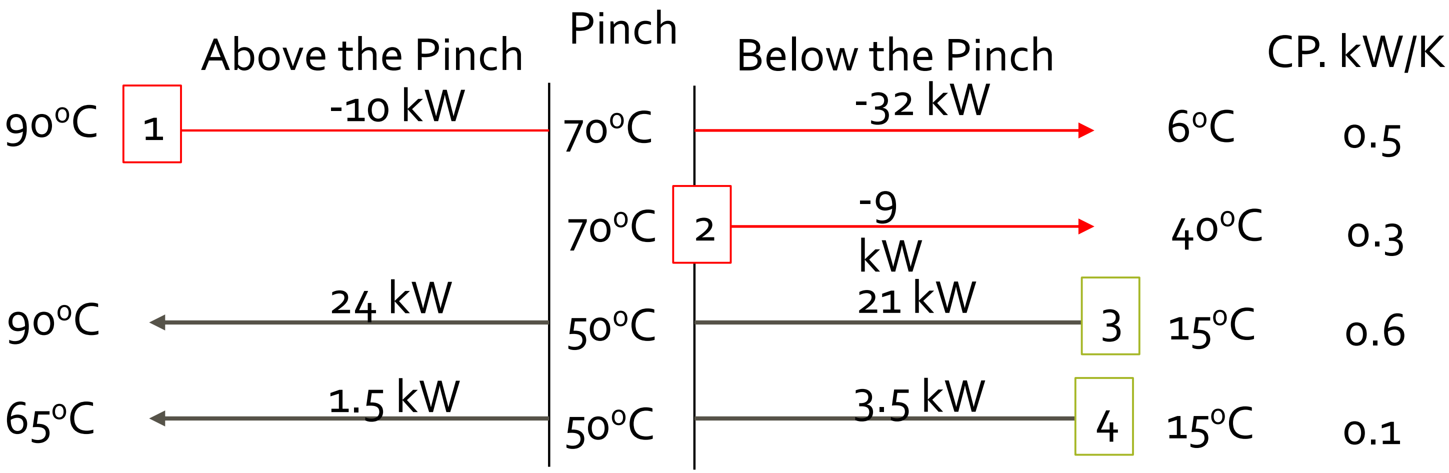
(a)



By violating the three golden rules Q_{Hmin} and Q_{Cmin} are each increased by $\alpha+\beta+\gamma$.

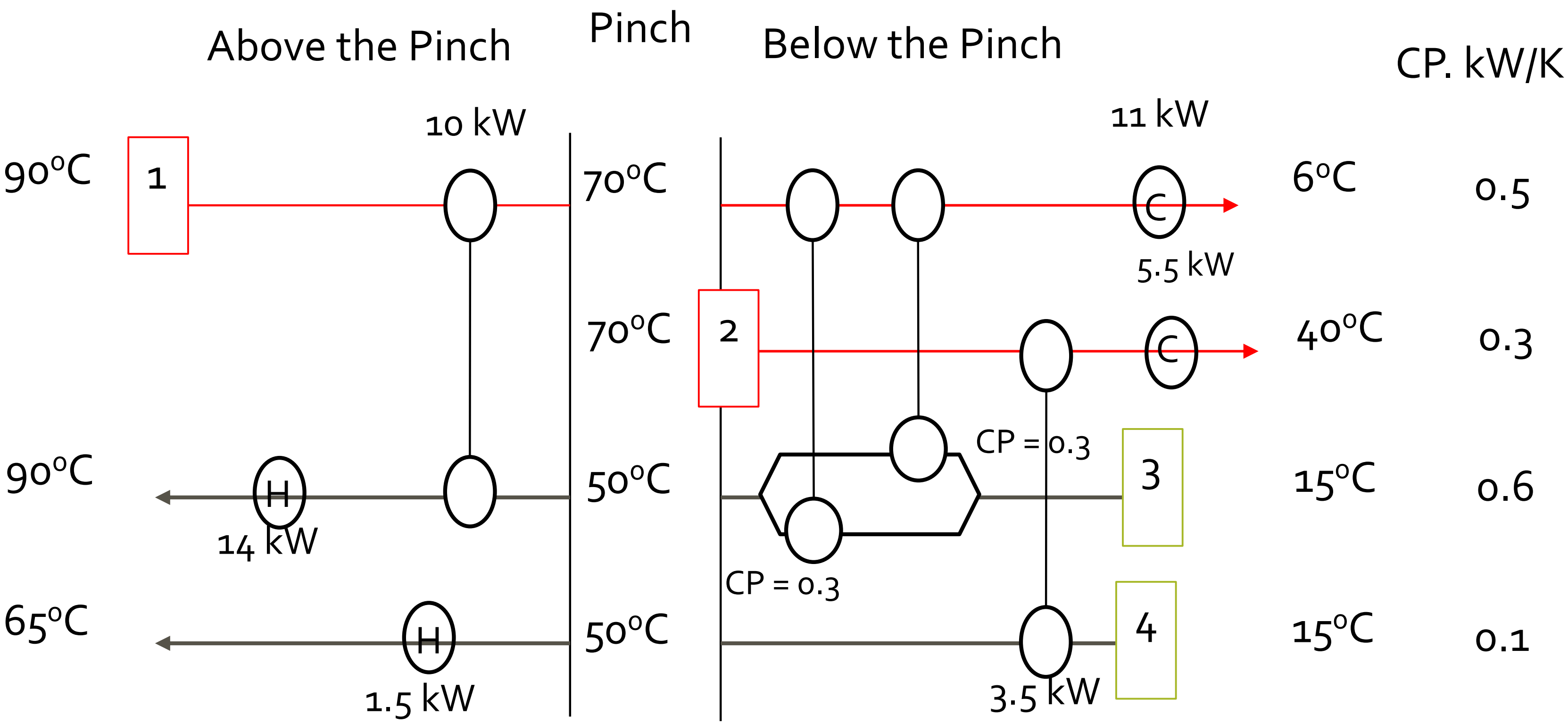
(b)

a) Construct a design chart where the streams are represented as horizontal lines drawn between their respective temperature limits and broken by vertical lines representing the Pinch as shown below:



b) Next, we link the hot streams with the cold streams by heat exchangers, bearing in mind the rules for optimum heat recovery. In addition, to link a hot and cold stream immediately adjacent to the pinch, the following rules should be followed:

- $CP_H \leq CP_C$; above the Pinch
- $CP_H \geq CP_C$; below the Pinch.


Above the Pinch
Pinch
Below the Pinch
CP. kW/K
10 kW
11 kW
90°C
1
70°C
6°C
0.5
5.5 kW
70°C
2
40°C
0.3
CP = 0.3
3
90°C
50°C
15°C
0.6
14 kW
CP = 0.3
65°C
50°C
4
15°C
0.1
1.5 kW
3.5 kW
H
H
C
C

Design Considerations

- Some design rules to optimize utility consumption:
  - Do not pass heat through the pinch point
  - Do not use cooling utilities at temperatures above the pinch point
  - Do not use heating utilities at temperatures below the pinch point

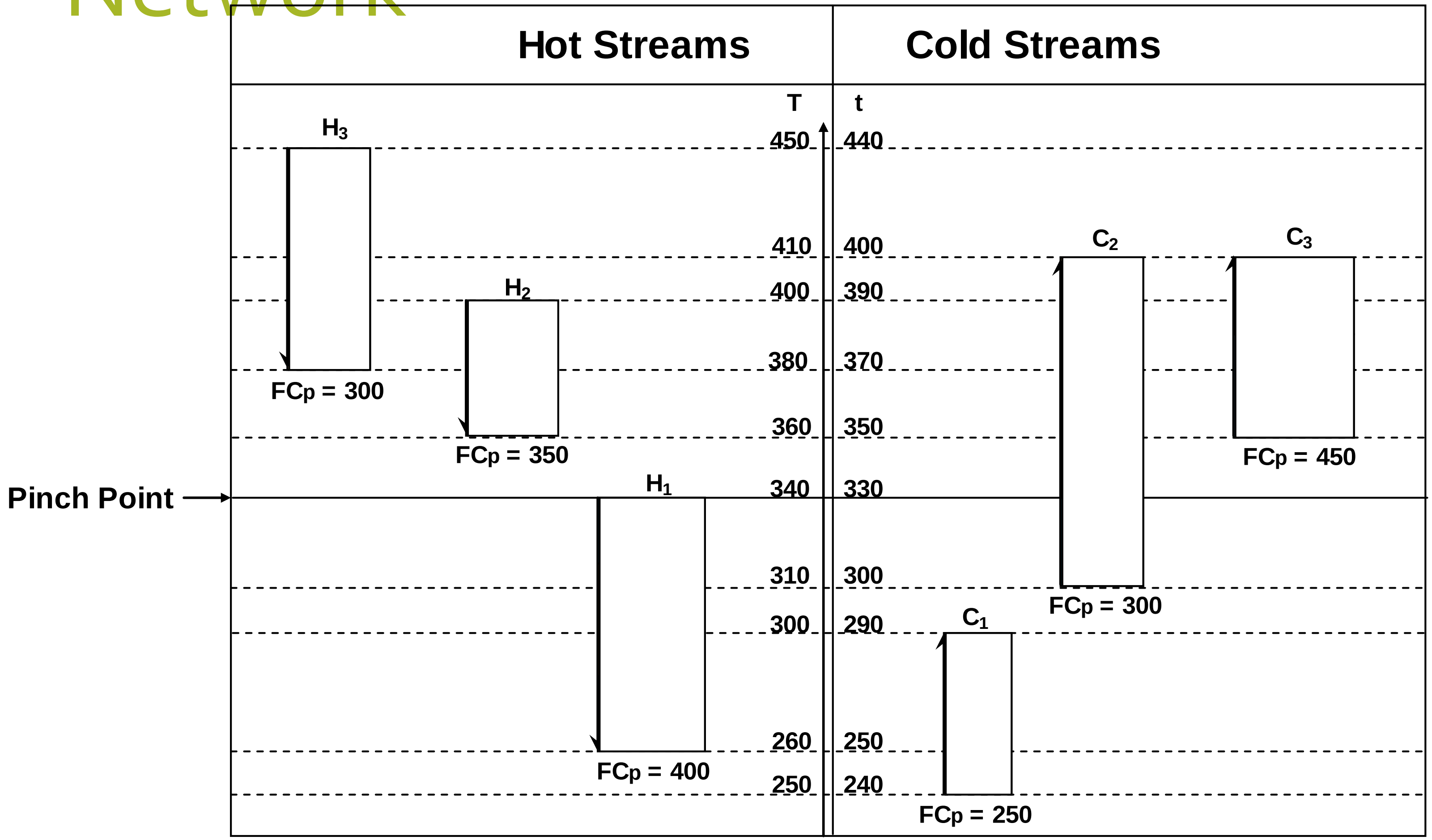
Constructing the Heat Exchange Network

- Now that the pinch analysis has been performed, the heat exchange network can be constructed
- It is a good idea to perform the pinch analysis first because it sets the performance goal of an optimized heat exchange network
- There is no quick method of reliably determining the minimum number of heat exchangers, but the following method should help to construct the network

Constructing the Heat Exchange Network

- With $Q_{C,min}$ and $Q_{H,min}$ known, construct a plot similar to the temperature interval diagram, except instead of arrows, use boxes that have a width representing FCp
- The area of these boxes corresponds to the heat exchanged by the stream
- Draw a horizontal line across at the pinch point – remember, no heat is to be passed across this point

Constructing the Heat Exchange Network



Constructing the Heat Exchange Network

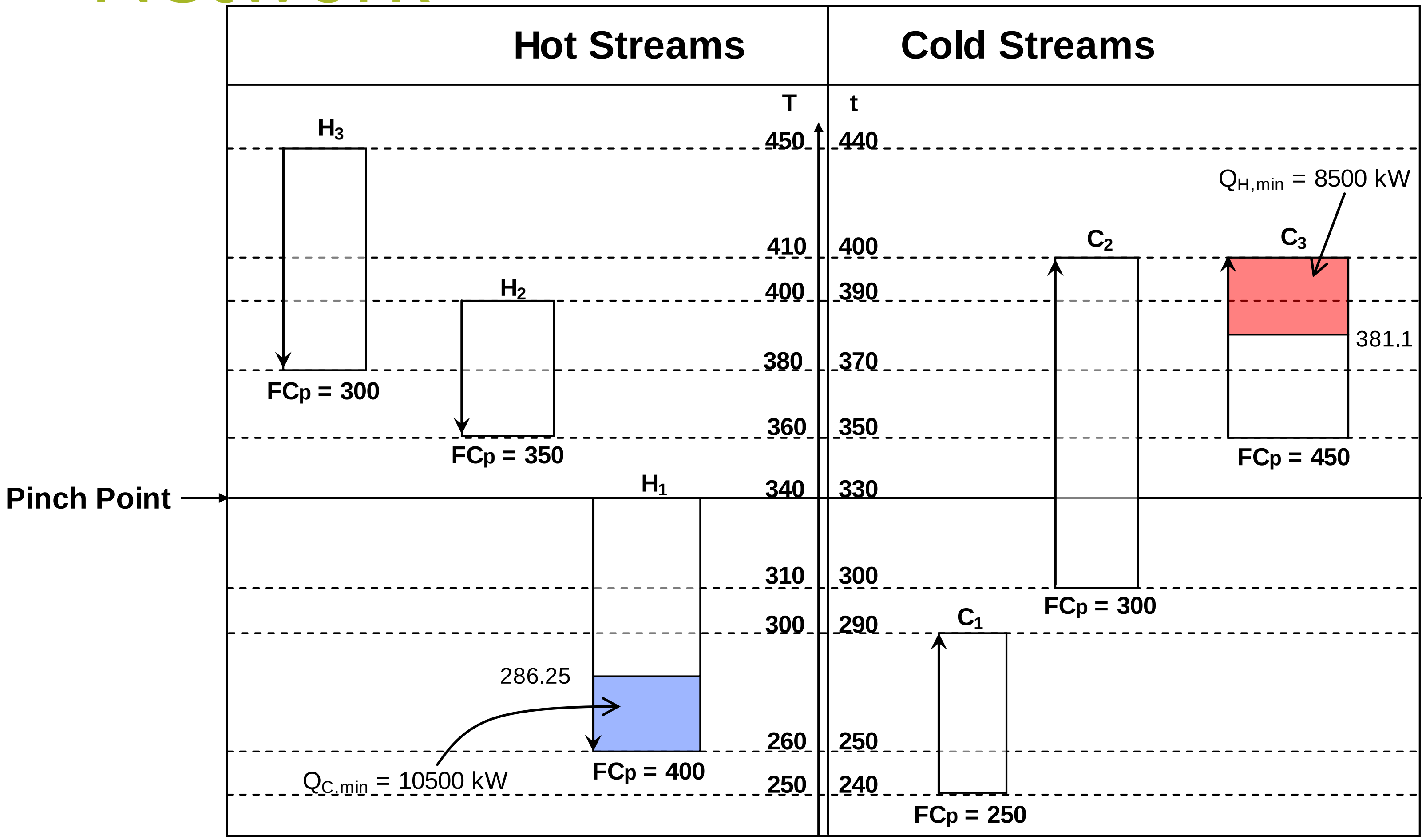
- Now, add $Q_{C,min}$ to the lowest point on the coldest hot stream and determine the resulting T_1 and T_2 for this exchange. Note that T_1, T_2, t_1, and t_2 now do not necessarily correspond to the same values as used earlier and are different for each exchanger

$$Q_{C,min} = FCp(T_2 - T_1)$$

- Do the same with $Q_{H,min}$, adding it to the highest point on the hottest cold stream

$$Q_{H,min} = FCp(t_2 - t_1)$$

Constructing the Heat Exchange Network



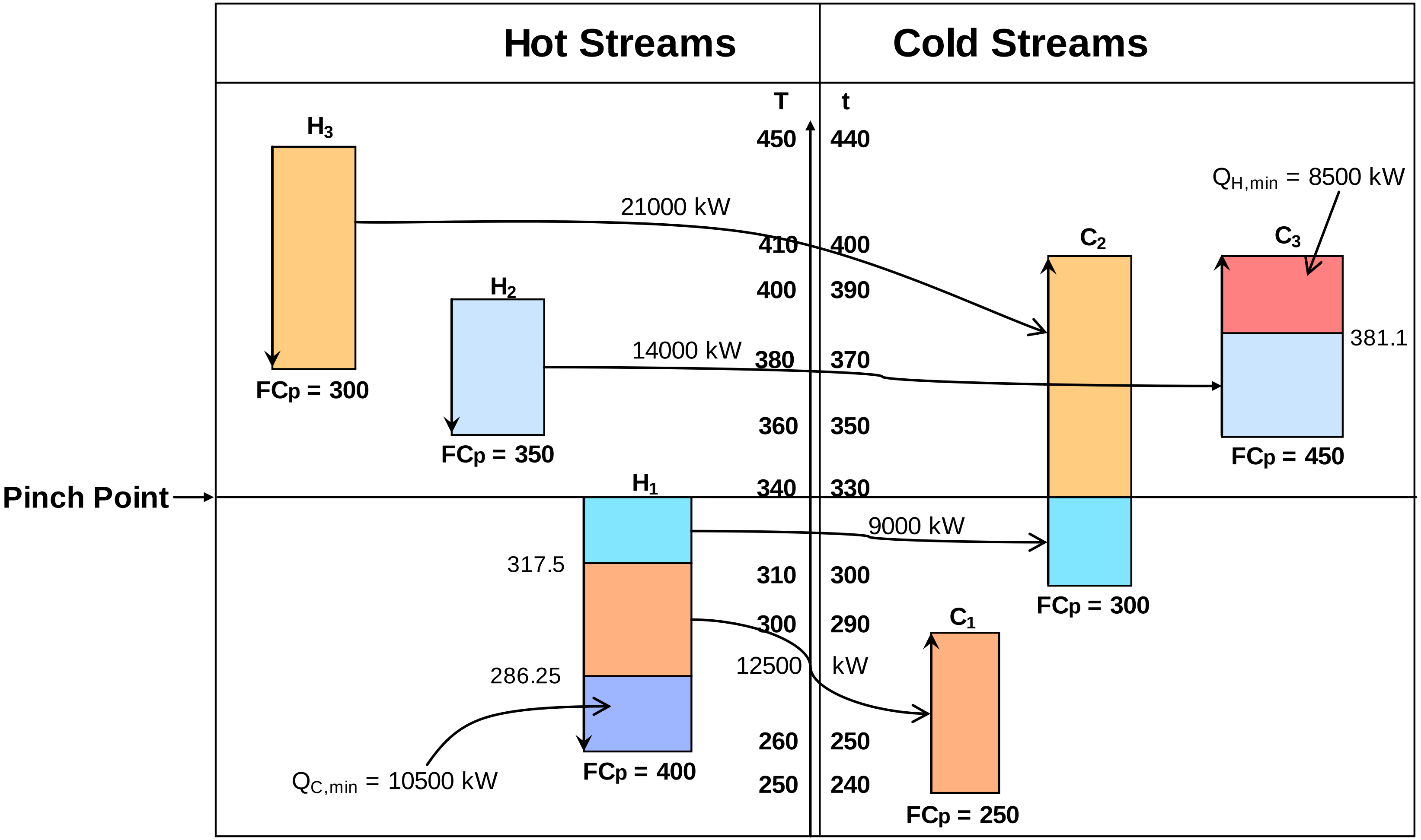
Constructing the Heat Exchange Network

- Now, working out from the pinch point, match up streams, remembering not to transfer heat across the pinch point and keeping ΔT_{min} in mind
- For each matched stream, determine the temperatures that exist for the inlet and outlet of the heat exchanger

$$Q_{ex} = FC_p(T_2 - T_1) = FC_p(t_2 - t_1)$$

- Having the table of stream data including enthalpy change on hand may be helpful for determining the best way to match a stream

Matched Streams



Heat Exchangers

- 4 heat exchangers, plus a heater and a cooler are needed to meet the optimum heat exchange requirements of this system

Heat Exchange Network

Heat Exchanger	T_2 (^oC)	T_1 (^oC)	t_2 (^oC)	t_1 (^oC)	Duty (kW)
H_3-C_2	450	380	400	330	21000
H_2-C_3	400	360	381.1	350	14000
H_1-C_2	340	317.5	330	300	9000
H_1-C_1	317.5	286.25	290	240	12500
$Q_{H,min}$-C_3	na	na	400	381.1	8500
$Q_{C,min}$-H_1	286.25	260	na	na	10500