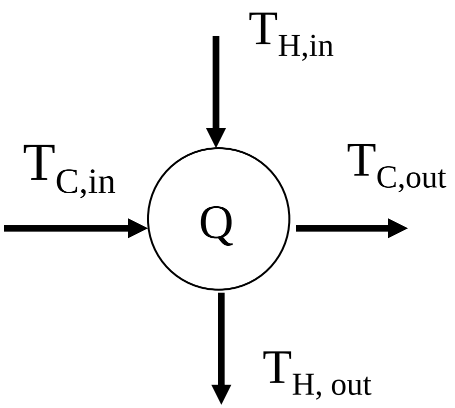
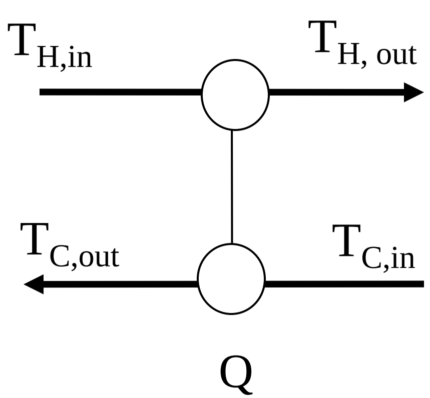
PART 1

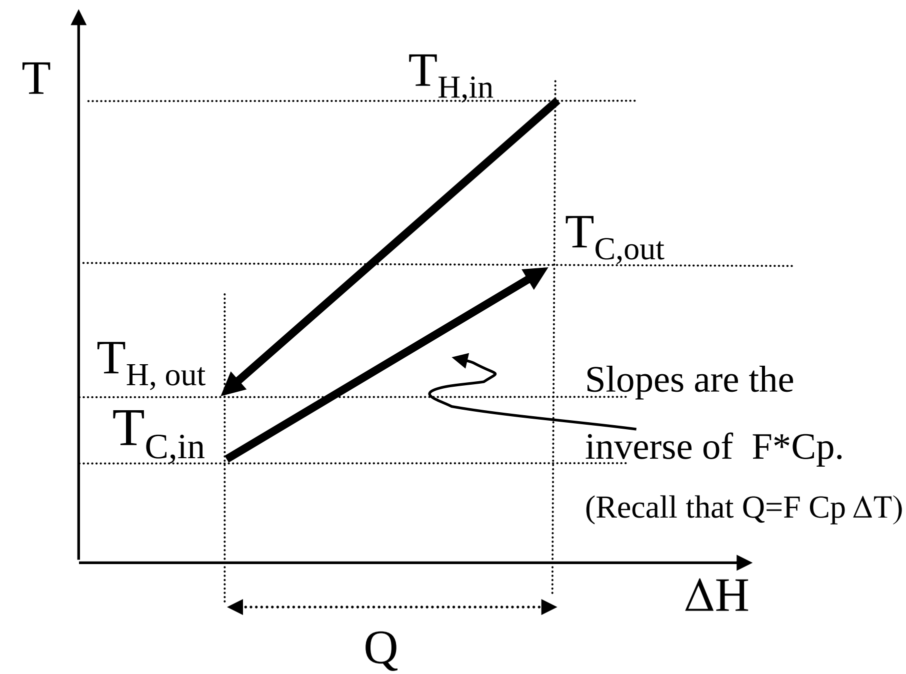
PINCH AND MINIMUM UTILITY USAGE

TEMPERATURE-ENTHALPY (T-H) DIAGRAMS

- Assume one heat exchanger. These are alternative representations

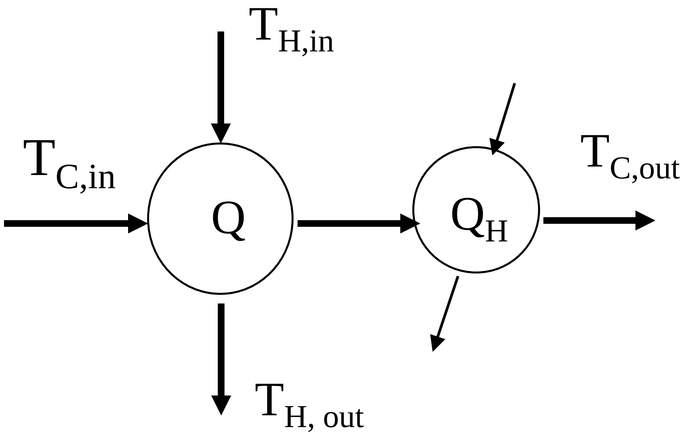


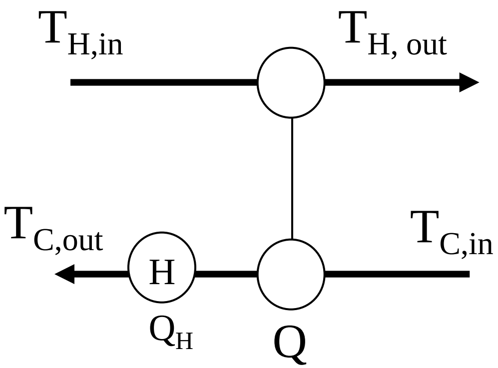


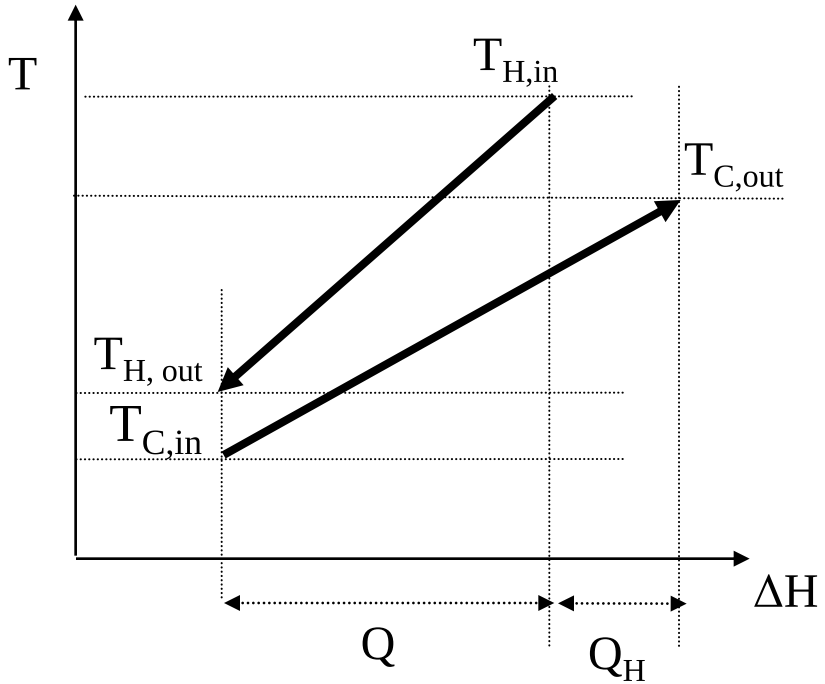


T-H DIAGRAMS

- Assume one heat exchanger and a heater

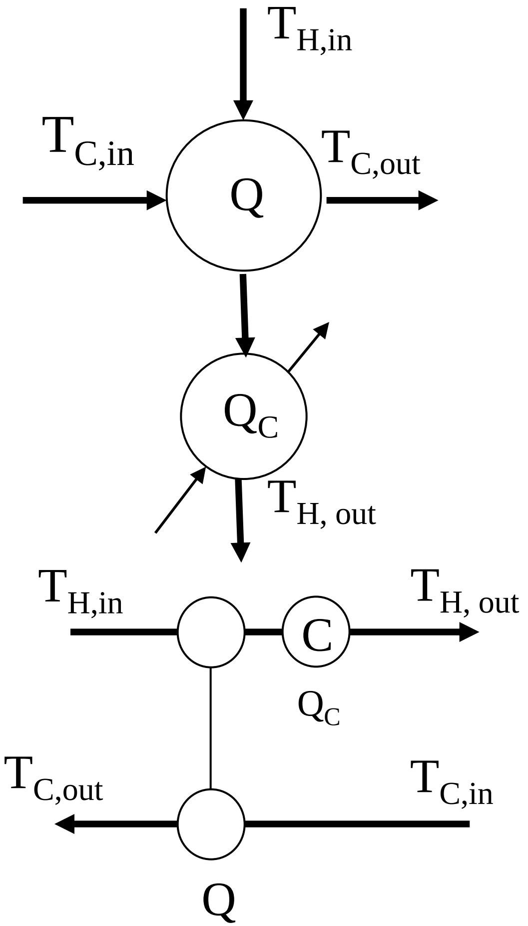


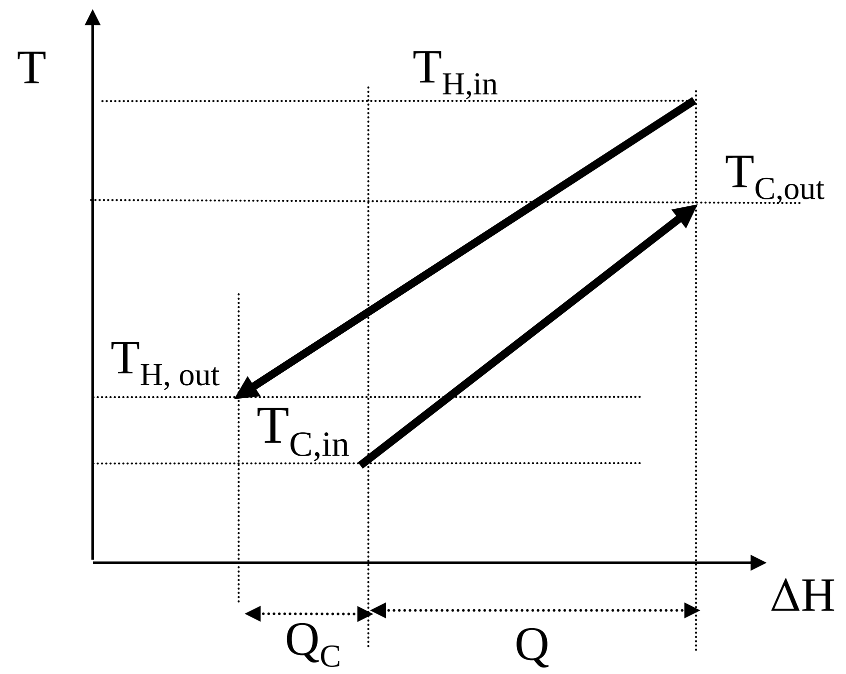




T-H DIAGRAMS

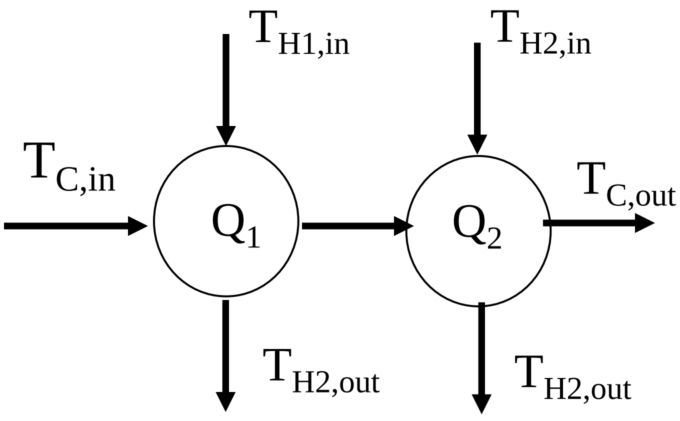
- Assume one heat exchanger and a cooler

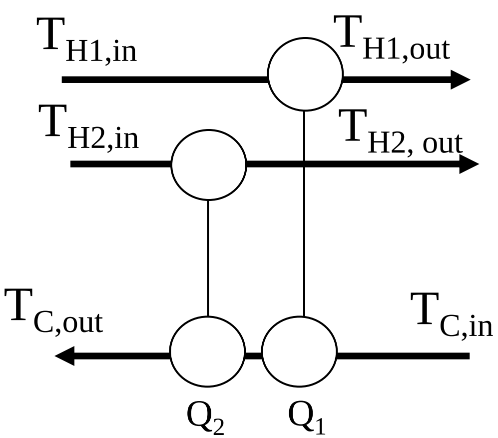


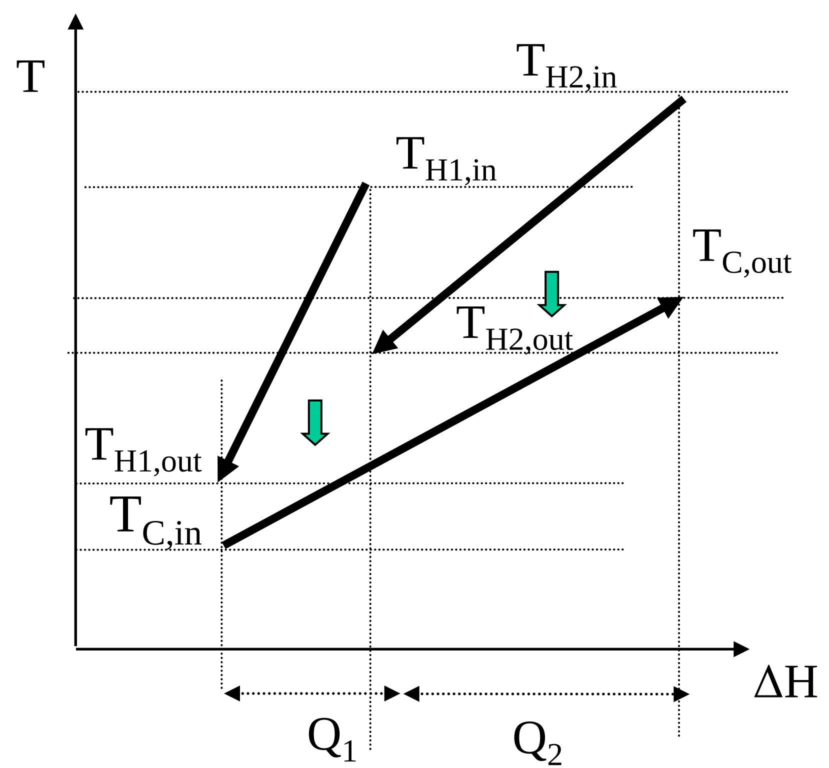


T-H DIAGRAMS

- Two hot-one cold stream

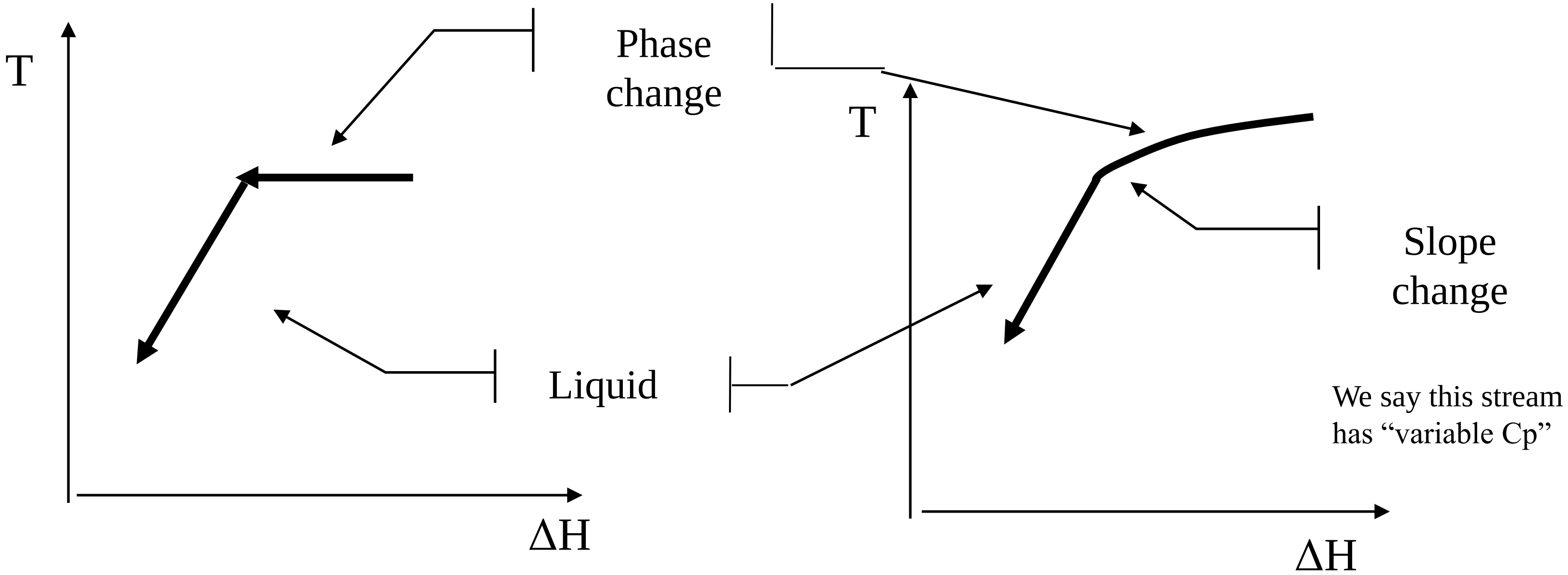






Notice the vertical arrangement of heat transfer

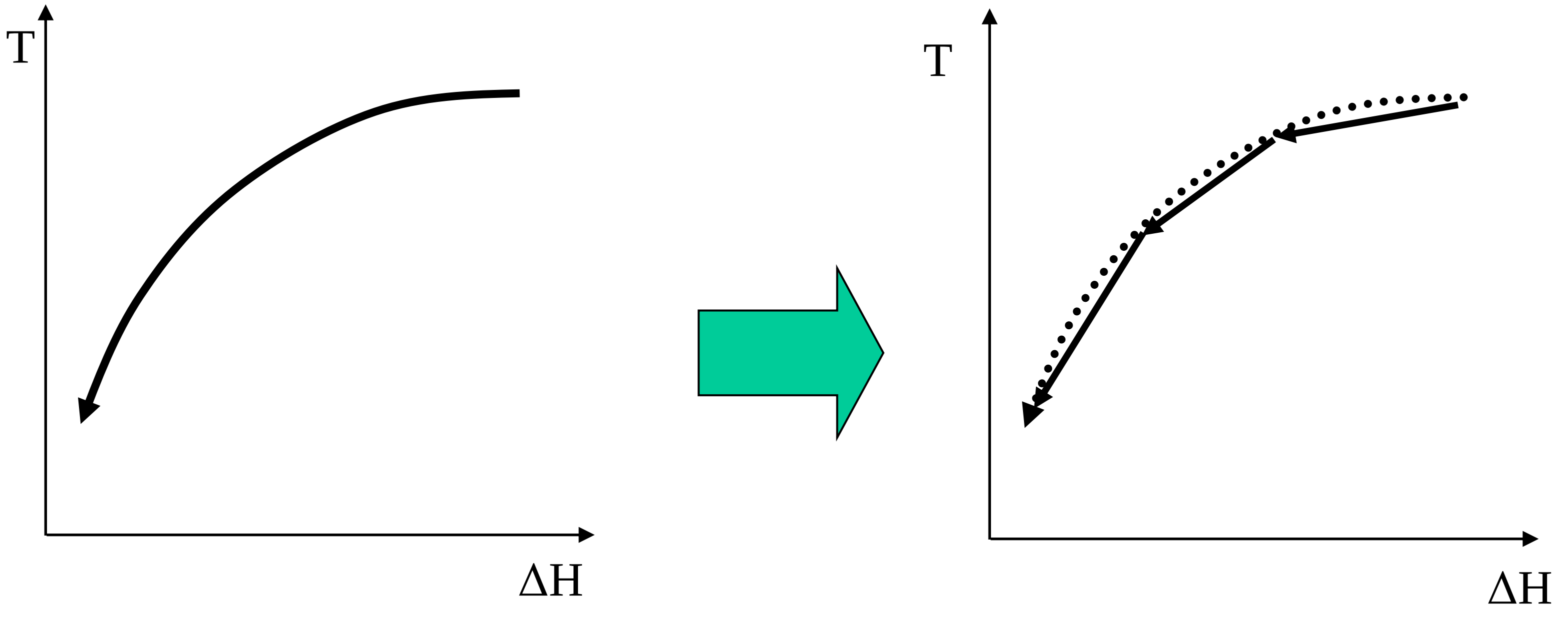
Streams under phase change



Single component

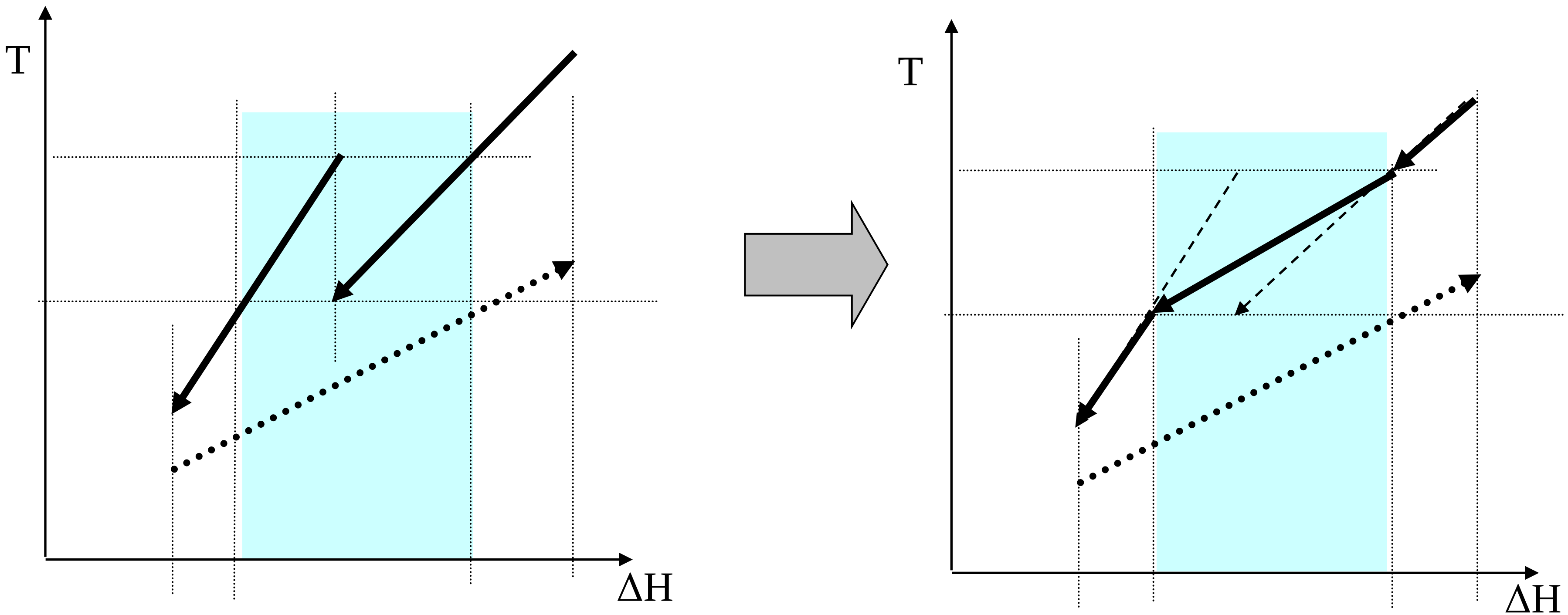
Multicomponent

Piece-wise linear representation



Composite Curves
(T-H DIAGRAMS)

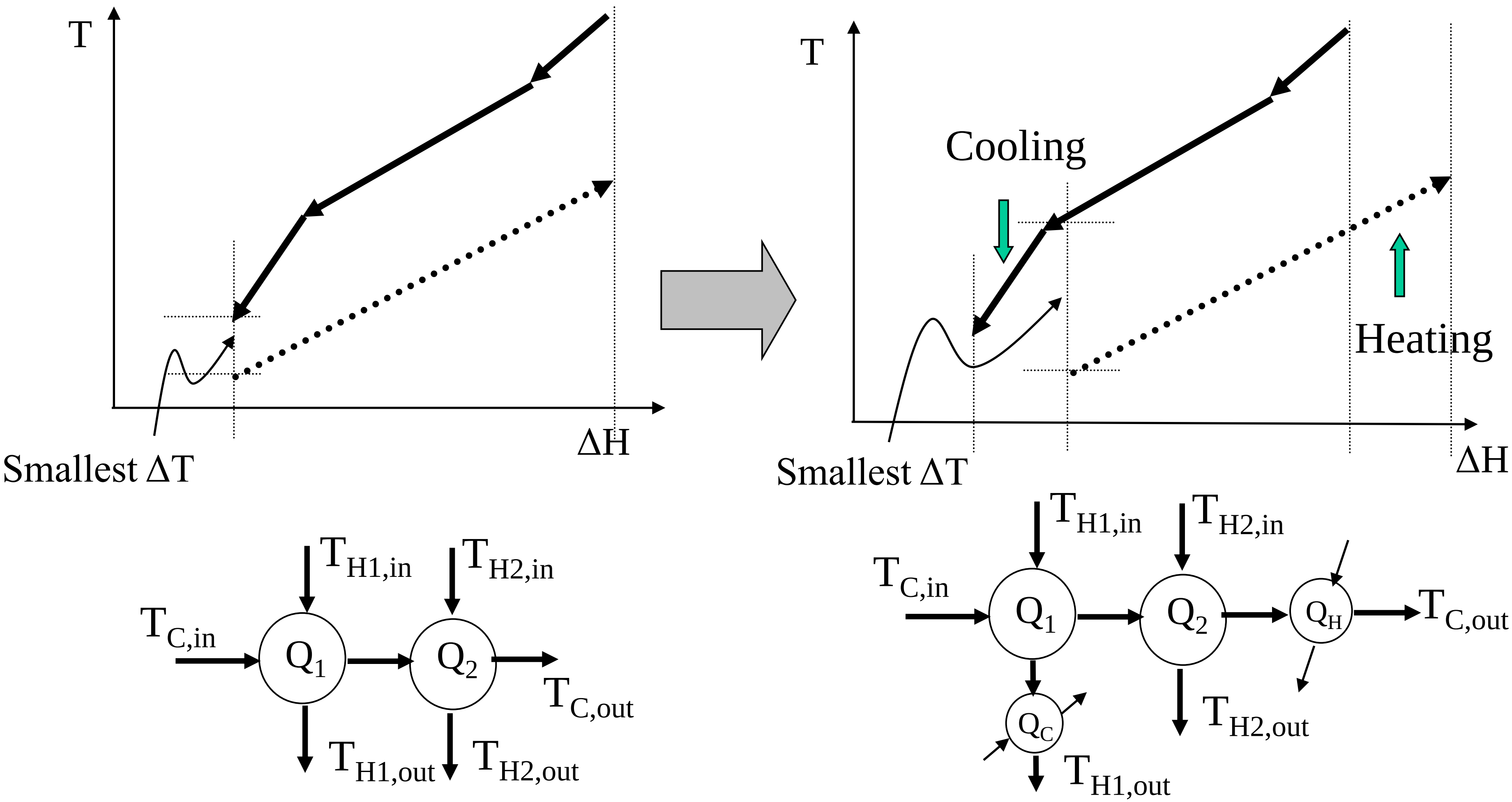
Obtained by lumping all the heat from different streams that are at the same interval of temperature.



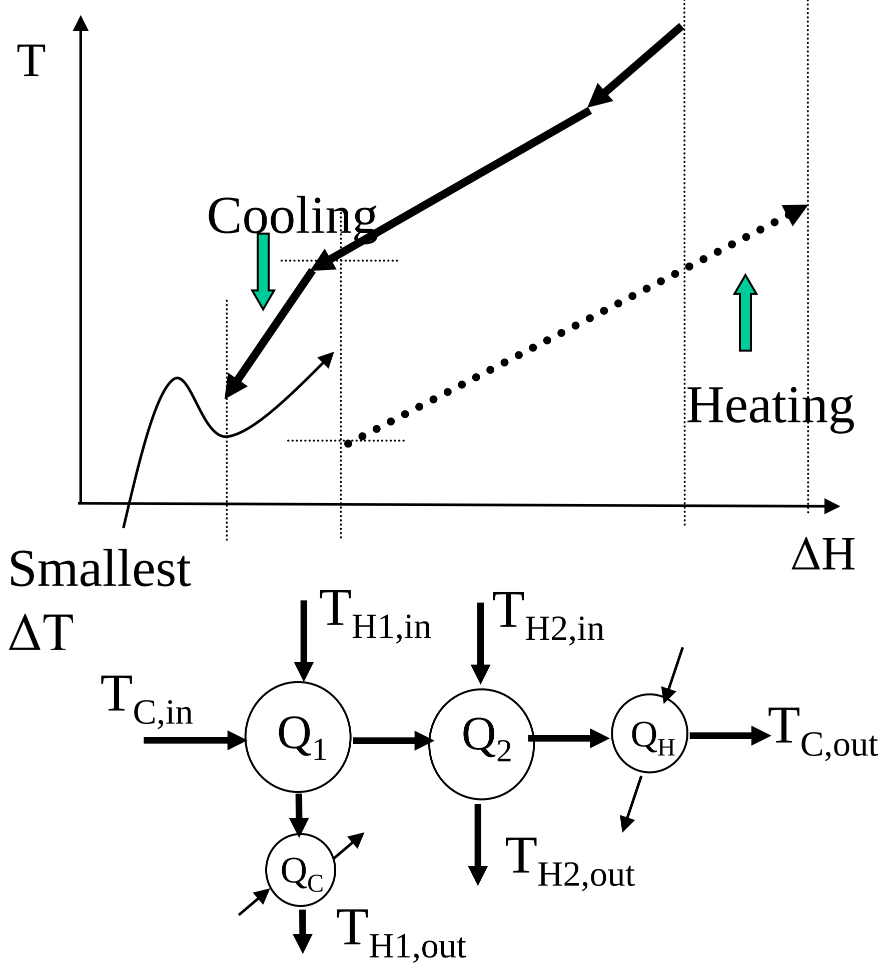
Remark: By constructing the composite curve we loose information on the vertical arrangement of heat transfer between streams

Composite Curves
(T-H DIAGRAMS)

- Moving composite curves horizontally



Composite Curves
(T-H DIAGRAMS)

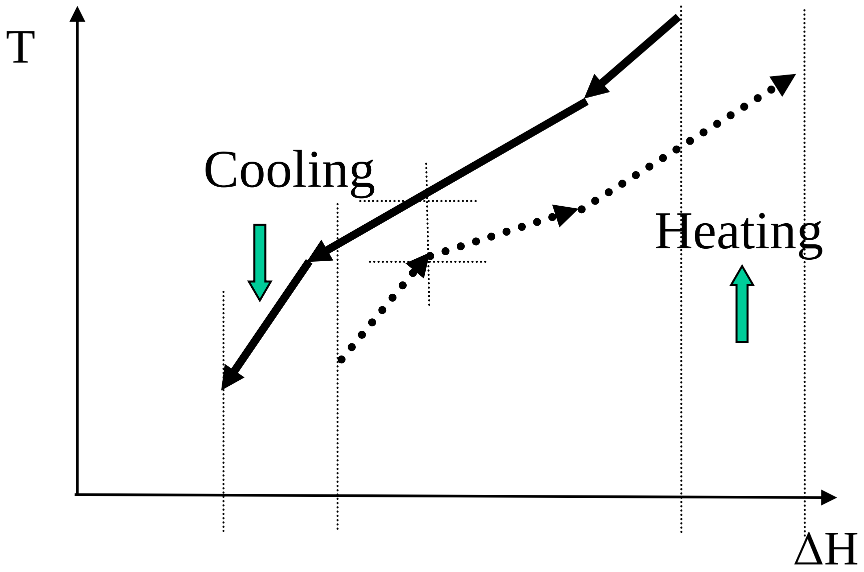


Moving the cold composite stream to the right

- Increases heating and cooling BY **<u>EXACTLY</u>** THE SAME AMOUNT
- Increases the smallest ΔT
- Decreases the area needed $A=Q/(U^* \Delta T)$

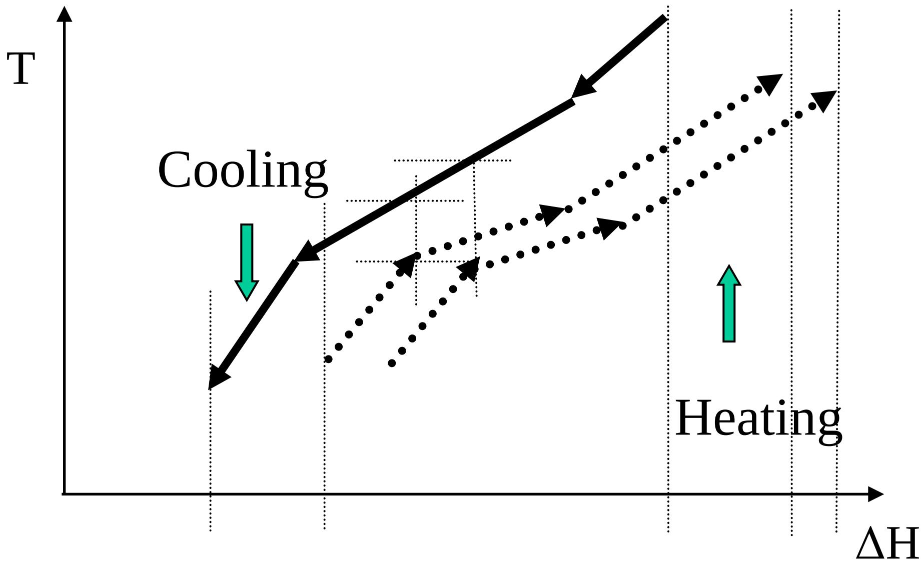
Notice that for this simple example the smallest ΔT takes place in the end of the cold stream

Composite Curves
(T-H DIAGRAMS)



- ***In general, the smallest*** ΔT can take place anywhere.
- We call the temperature at which this takes place THE PINCH.

Composite Curves
(T-H DIAGRAMS)



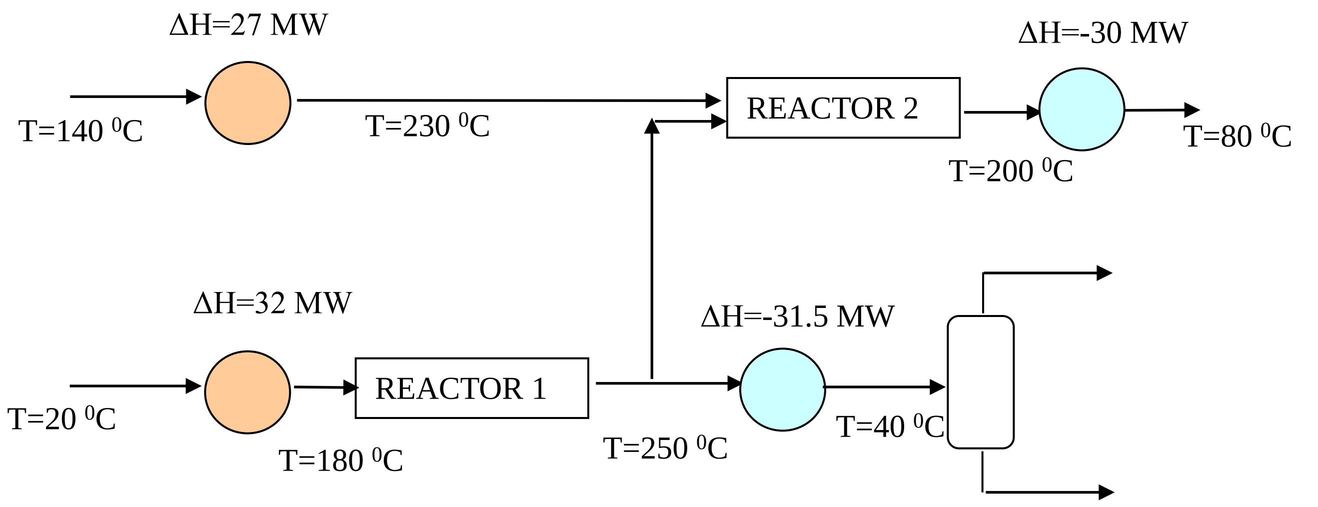
- ***From the energy point of view it is then convenient*** to move the cold stream to the left.
- However, the area may become too large.
- To limit the area, we introduce a minimum approach ΔT_{min}

ΔT_{min} is also known as HRAT (Heat Recovery Approximation Temperature)

GRAPHICAL PROCEDURE

- Fix ΔT_{min} (HRAT)
- Draw the hot composite curve and leave it fixed
- Draw the cold composite curve in such a way that the smallest temperature difference is equal to ΔT_{min}
- The temperature at which $\Delta T = \Delta T_{min}$ is the PINCH
- The non-overlap on the right is the Minimum Heating Utility and the non-overlap on the left is the Minimum Cooling Utility

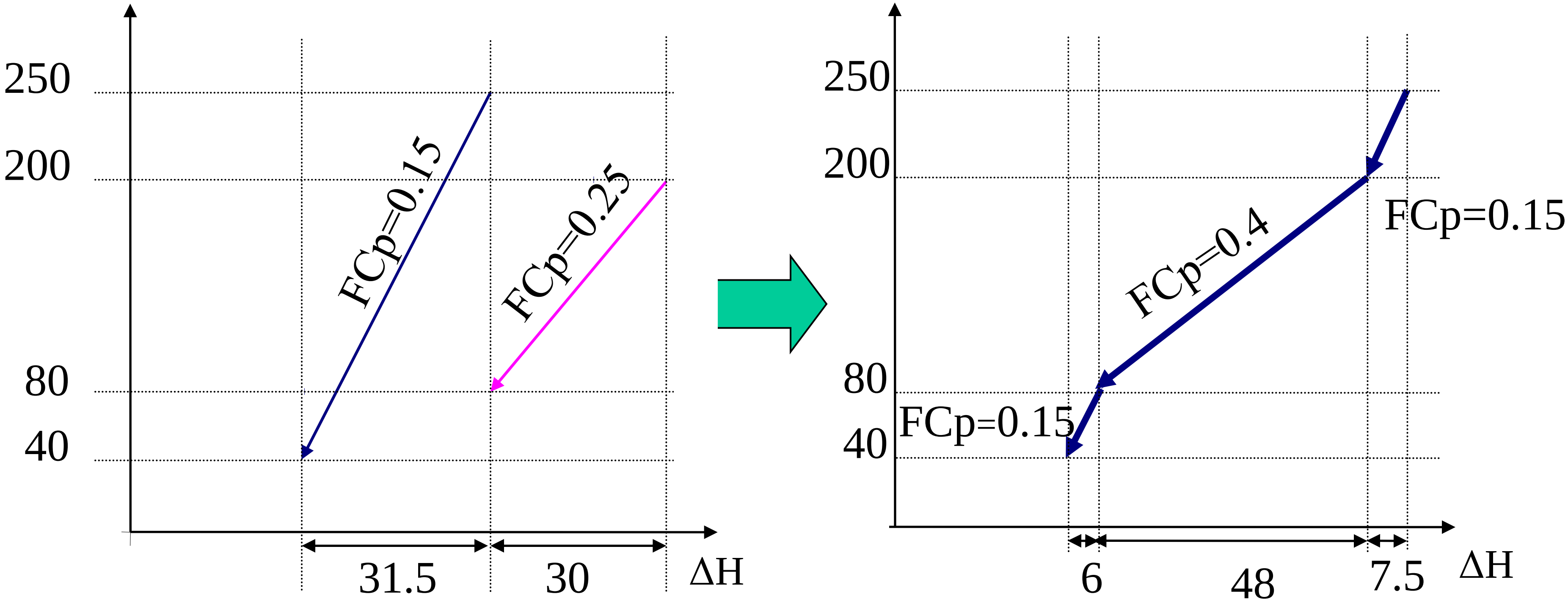
EXAMPLE



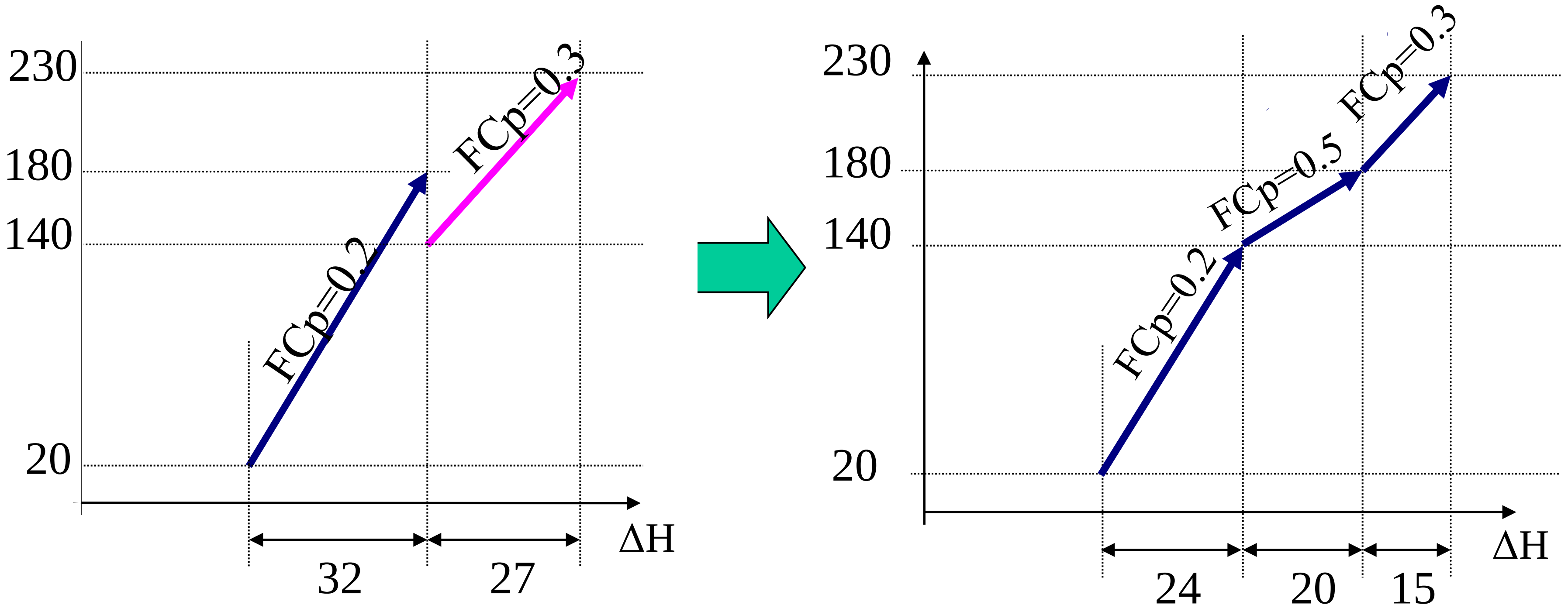
Stream	Type	Supply T (°C)	Target T (°C)	ΔH (MW)	F*Cp (MW °C^{-1})
Reactor 1 feed	Cold	20	180	32.0	0.2
Reactor 1 product	Hot	250	40	-31.5	0.15
Reactor 2 feed	Cold	140	230	27.0	0.3
Reactor 2 product	Hot	200	80	-30.0	0.25

ΔT_{min}=10 °C

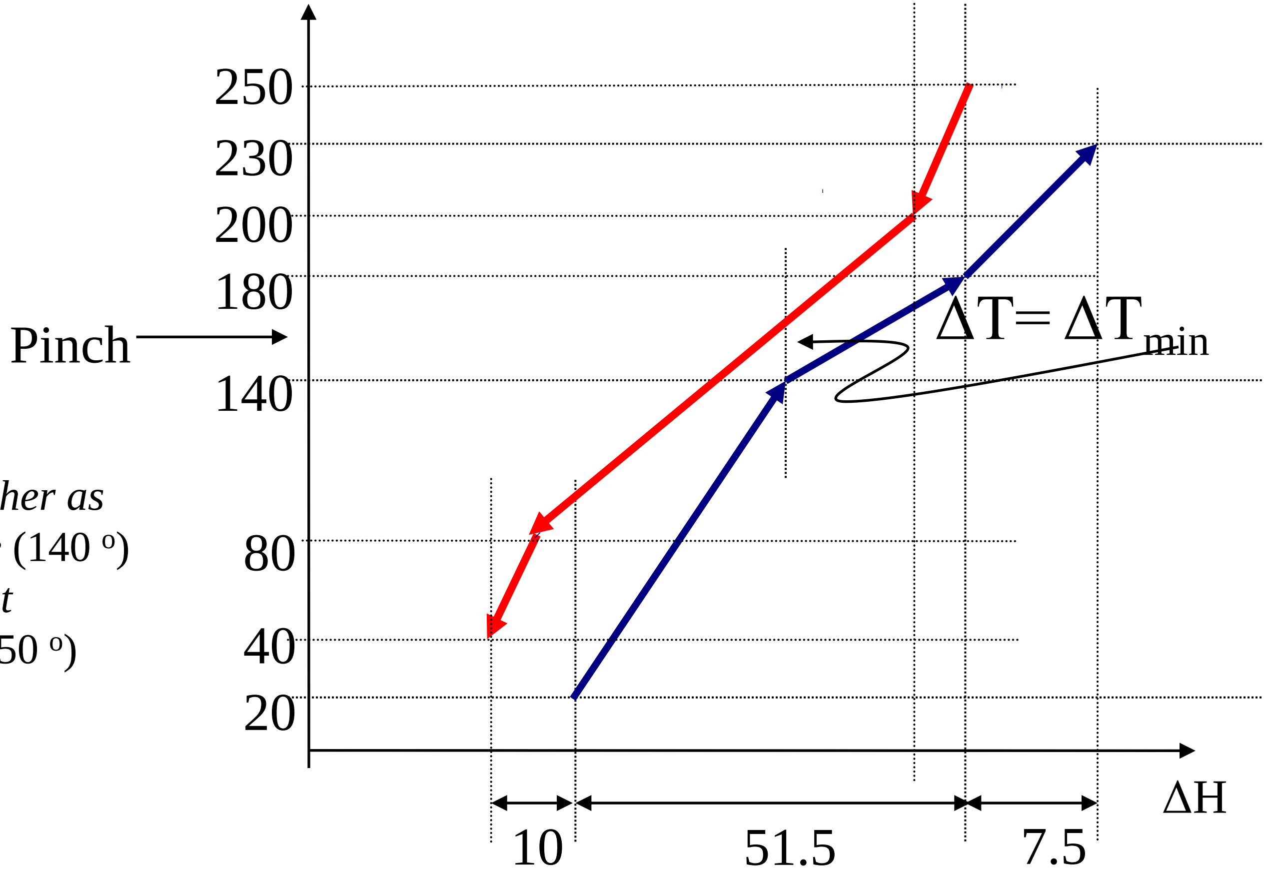
Hot Composite Curve



Cold Composite Curve



Pinch Diagram

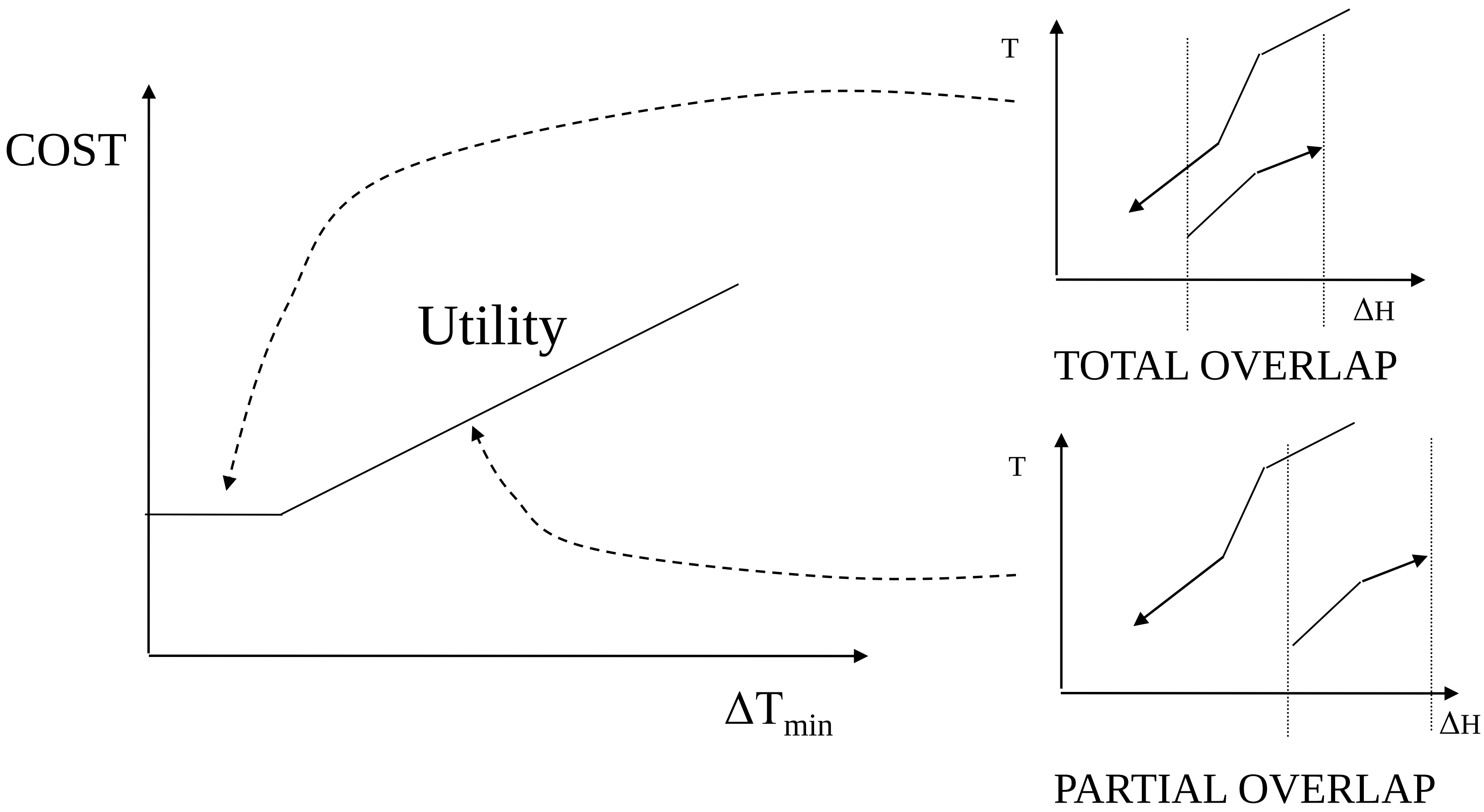


The pinch is defined either as

- *The cold temperature* (140 º)
- *The corresponding hot temp* (140 º+ΔT_{min}=150 º)
- *The average* (145 º)

Observation: The pinch is at the beginning of a cold stream or at the beginning of a hot stream

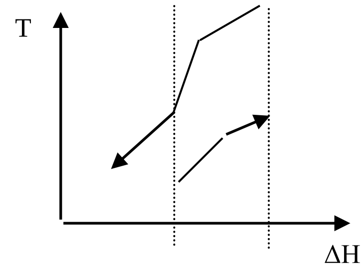
UTILITY COST vs. ΔT_{min}



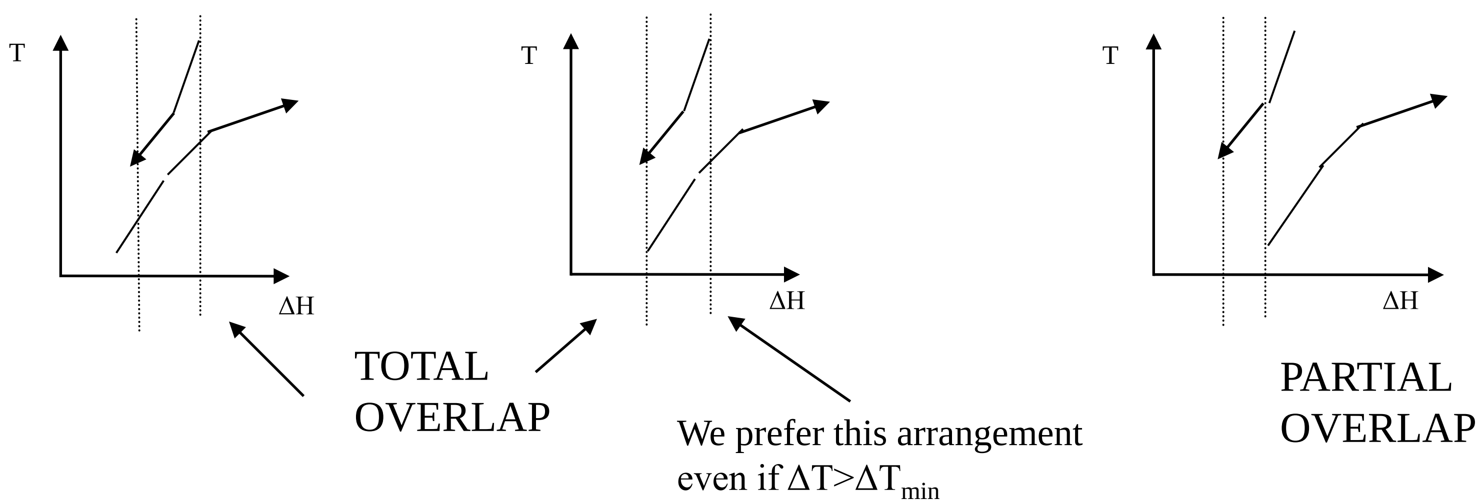
Note: There is a particular overlap that requires only cooling utility

Special Overlap Cases

- Overlap leads only to cooling utility



- Different instances where the cold stream overlaps totally the hot stream. Case where only heating utility



SUMMARY

- The pinch point is a temperature.
- Typically, it divides the temperature range into two regions.
- Heating utility can be used only above the pinch and cooling utility only below it.

PROBLEM TABLE

Composite curves are inconvenient. Thus a method based on tables was developed.

- STEPS:
  1. Divide the temperature range into intervals and shift the cold temperature scale
  2. Make a heat balance in each interval
  3. Cascade the heat surplus/deficit through the intervals.
  4. Add heat so that no deficit is cascaded

PROBLEM TABLE

- We now explain each step in detail using our example

Stream	Type	Supply T (°C)	Target T (°C)	ΔH (MW)	F*Cp (MW °C^{-1})
Reactor 1 feed	Cold	20	180	32.0	0.2
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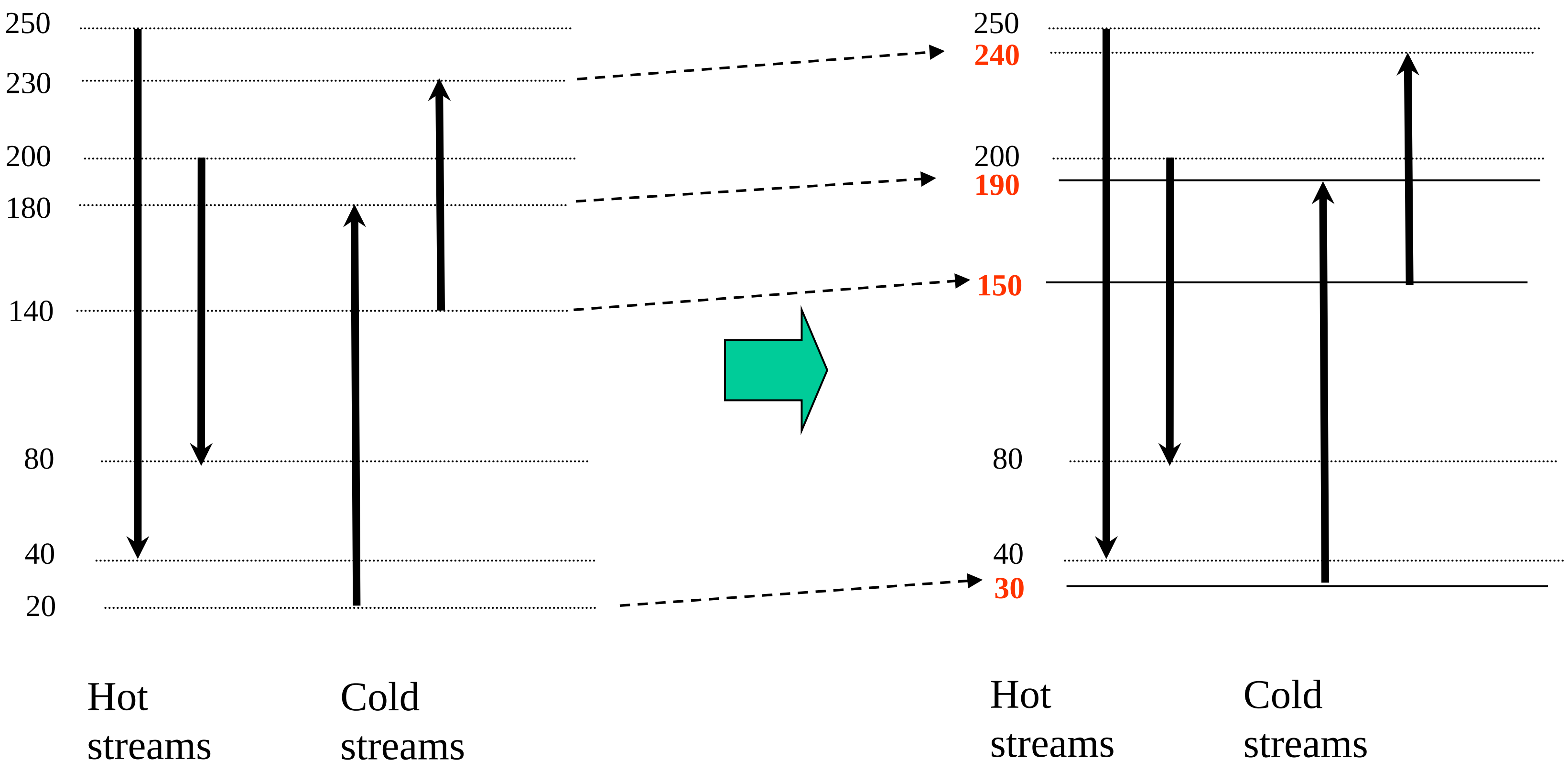
ΔT_{min}=10 °C

PROBLEM TABLE

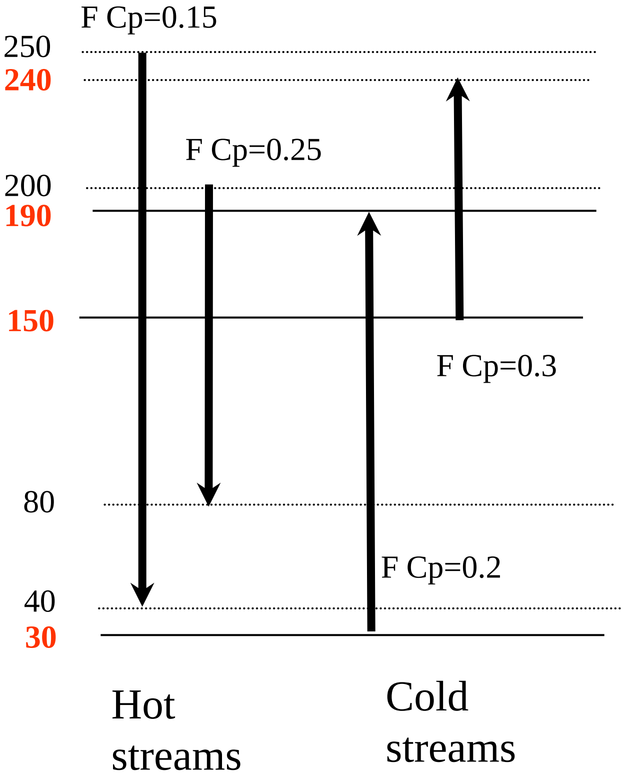
1. Divide the temperature range into intervals and shift the cold temperature scale



Now one can make heat balances in each interval. Heat transfer within each interval is feasible.

PROBLEM TABLE

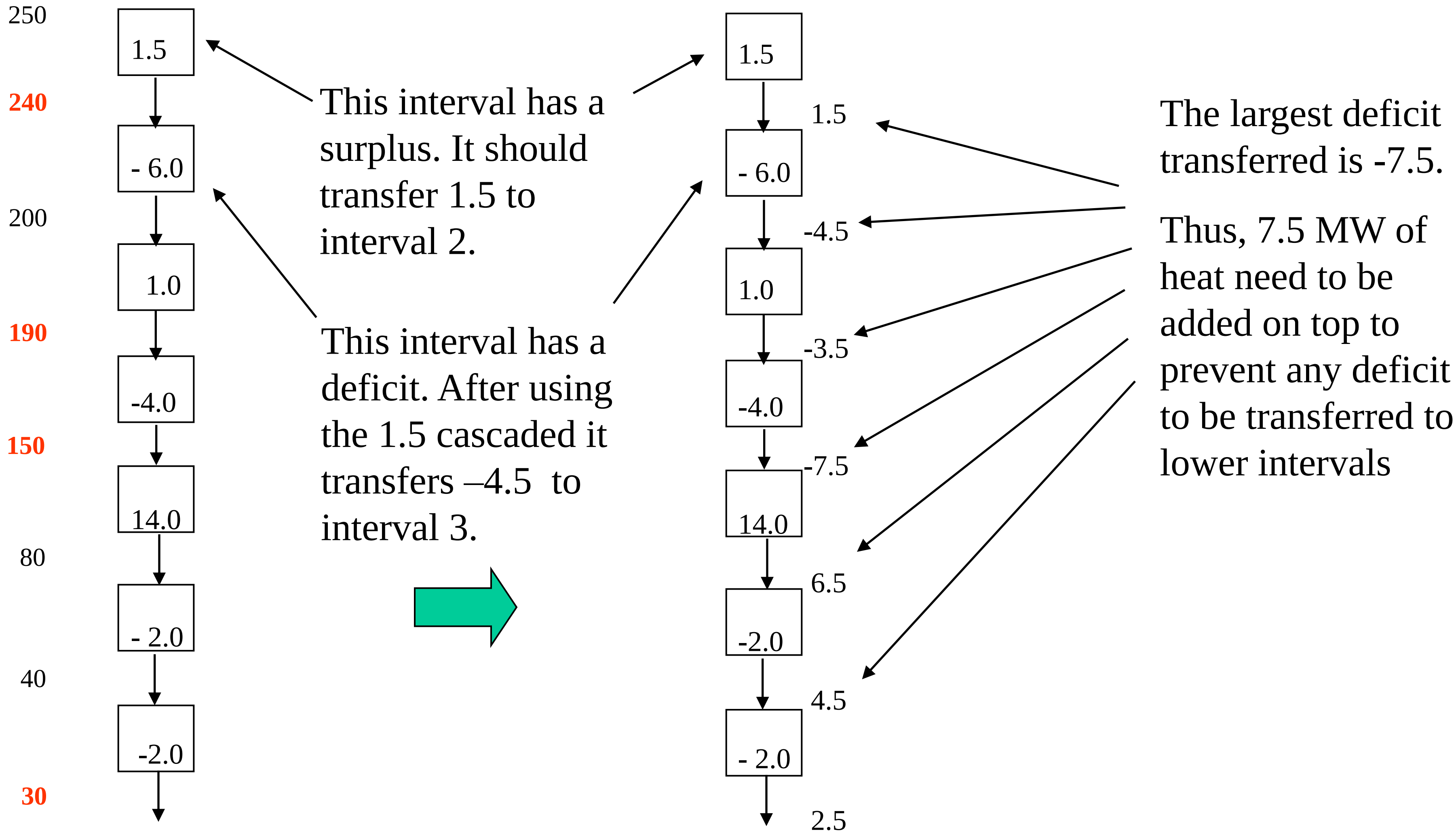
2. Make a heat balance in each interval.



$\Delta T_{interval}$	$\Delta H_{interval}$	**Surplus/Deficit**
10	1.5	Surplus
40	- 6.0	Deficit
10	1.0	Surplus
40	-4.0	Deficit
70	14.0	Surplus
40	-2.0	Deficit
10	- 2.0	Deficit

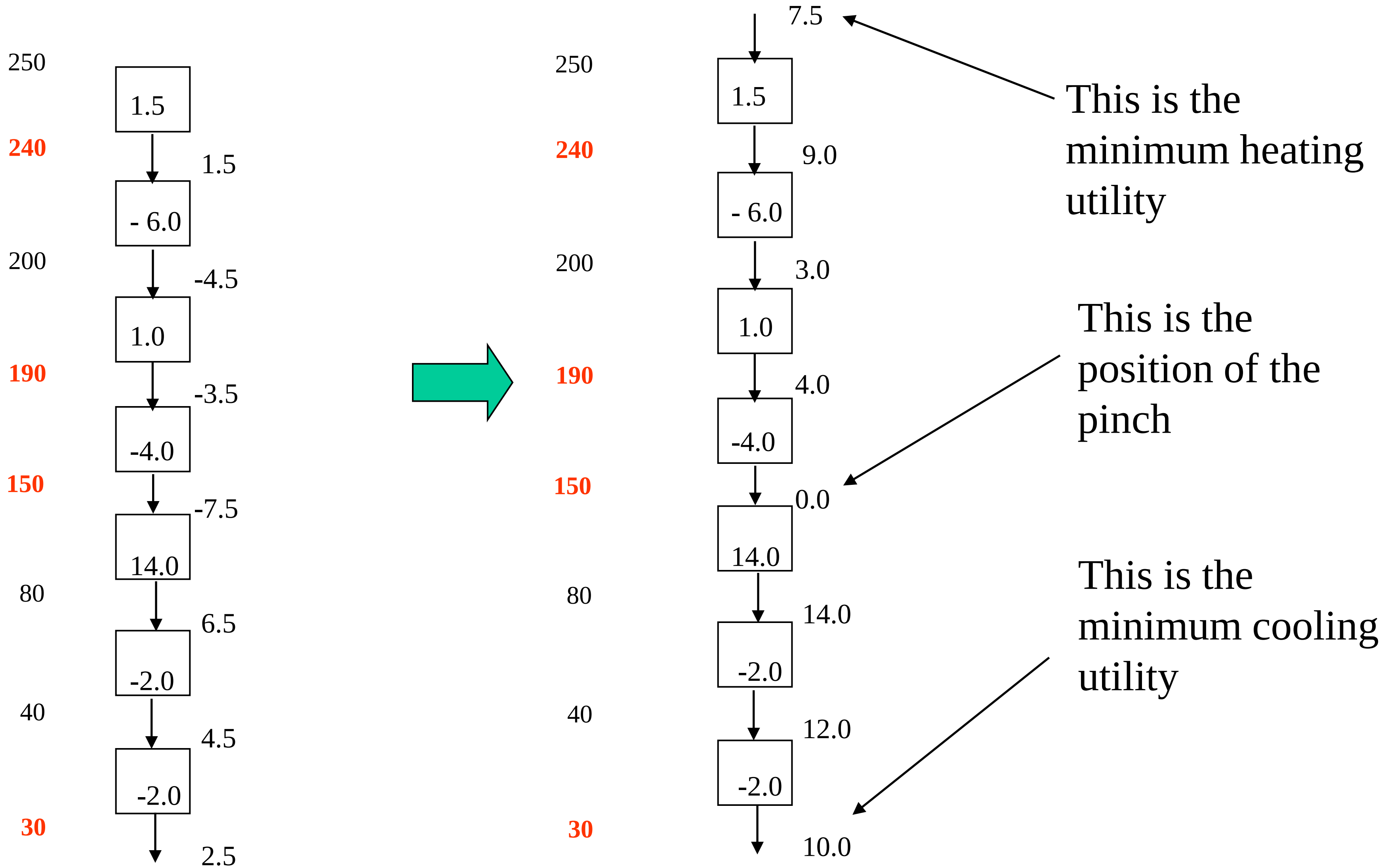
PROBLEM TABLE

3. Cascade the heat surplus through the intervals. That is, we transfer to the intervals below every surplus/deficit.



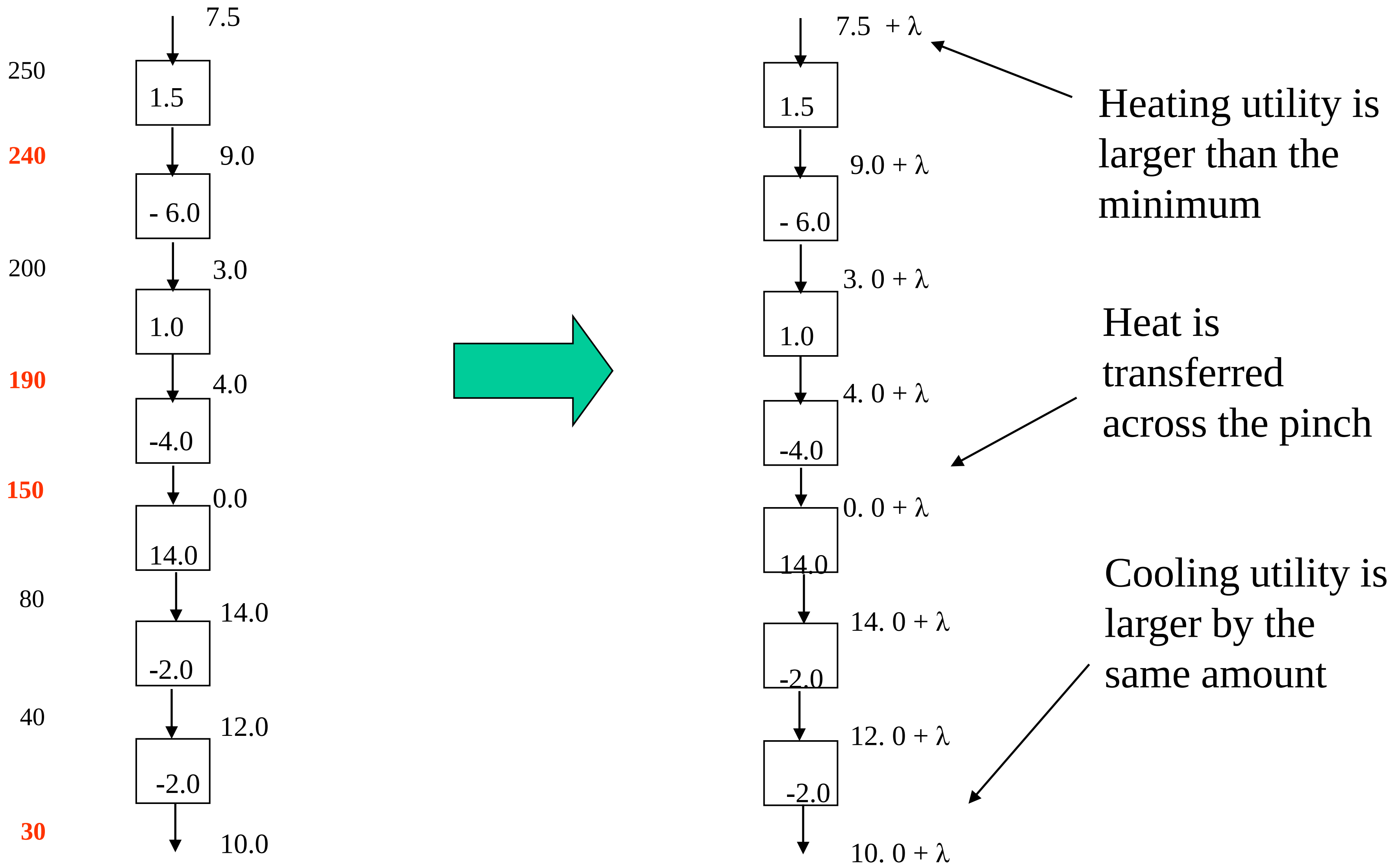
PROBLEM TABLE

4. Add heat so that no deficit is cascaded.



PROBLEM TABLE

If the heating utility is increased beyond 7.5 MW the cooling utility will increase by the same amount

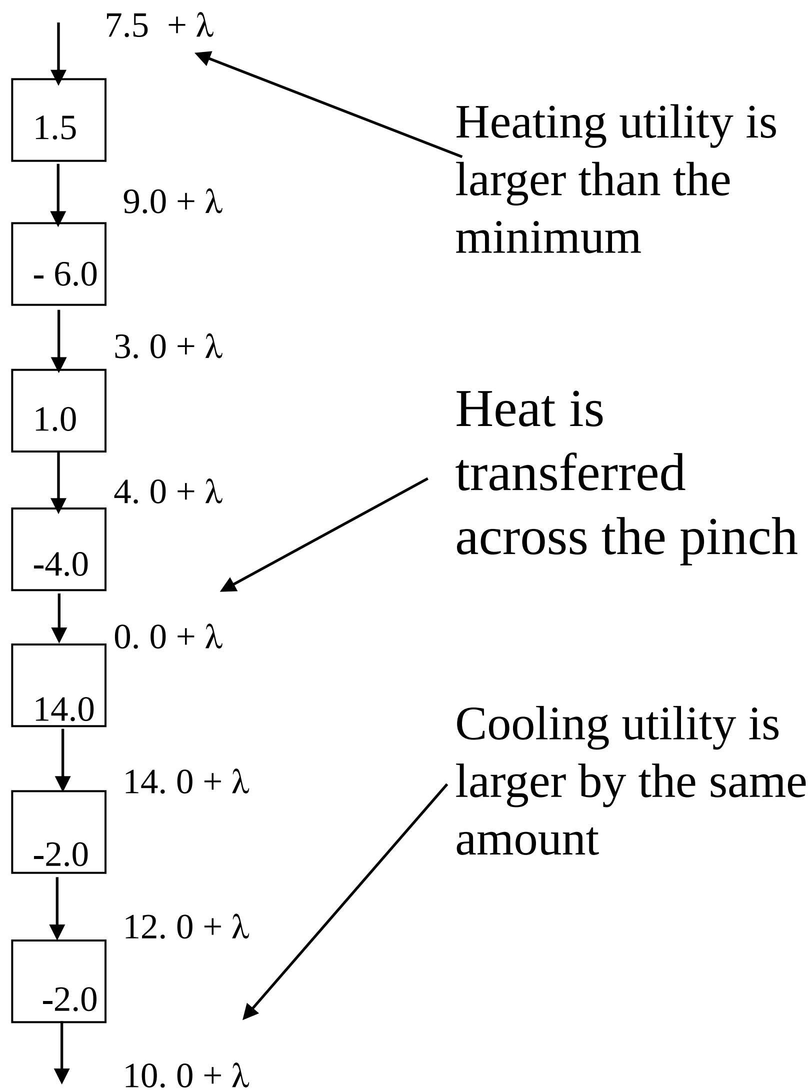


IMPORTANT CONCLUSION

DO NOT TRANSFER HEAT ACROSS THE PINCH

THIS IS A GOLDEN RULE OF PINCH TECHNOLOGY.

- ***WHEN THIS HAPPENS IN BADLY INTEGRATED PLANTS THERE ARE HEAT EXCHANGERS WHERE SUCH TRANSFER ACROSS THE PINCH TAKES PLACE***



Multiple Utilities