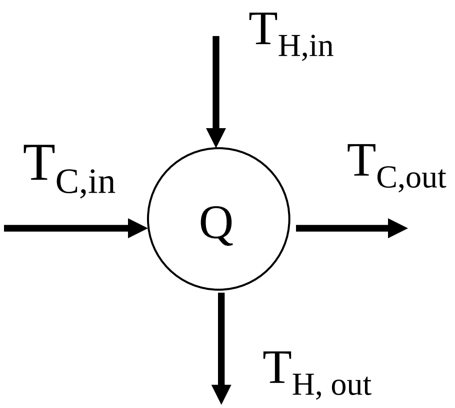
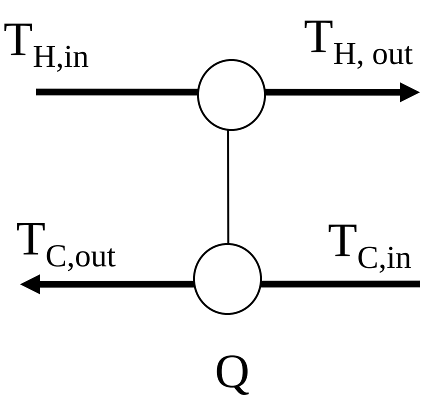
# *PART 1*

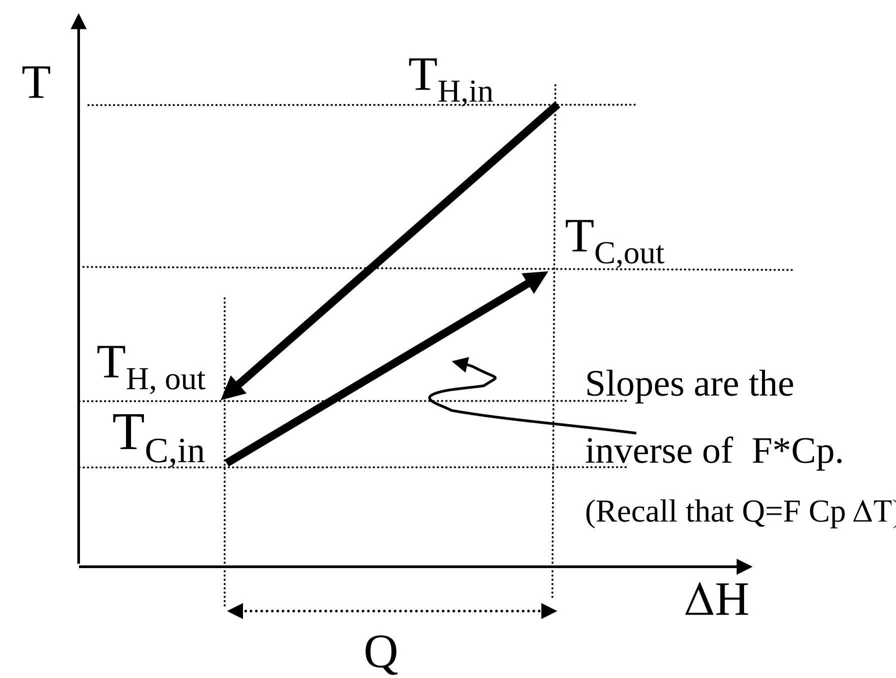
# PINCH AND MINIMUM UTILITY USAGE

# TEMPERATURE-ENTHALPY (T-H) DIAGRAMS

- Assume one heat exchanger. These are alternative representations

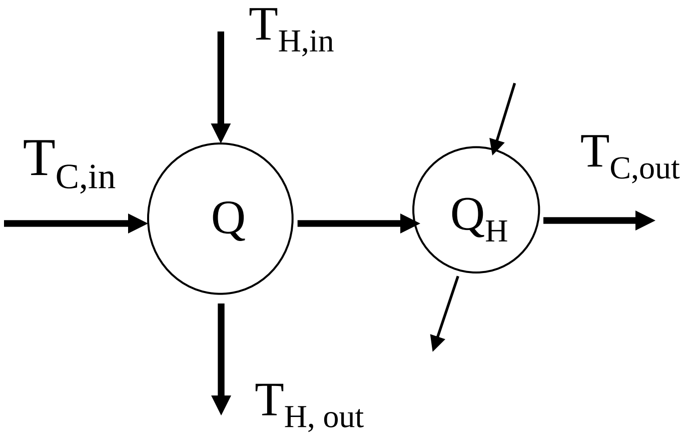


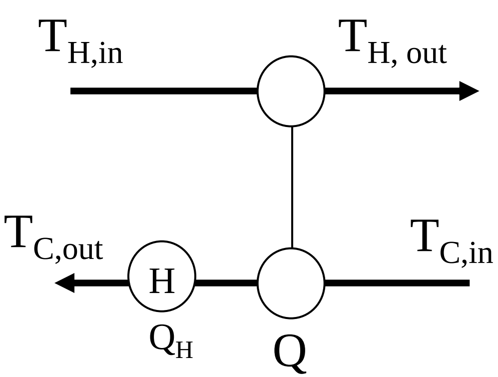



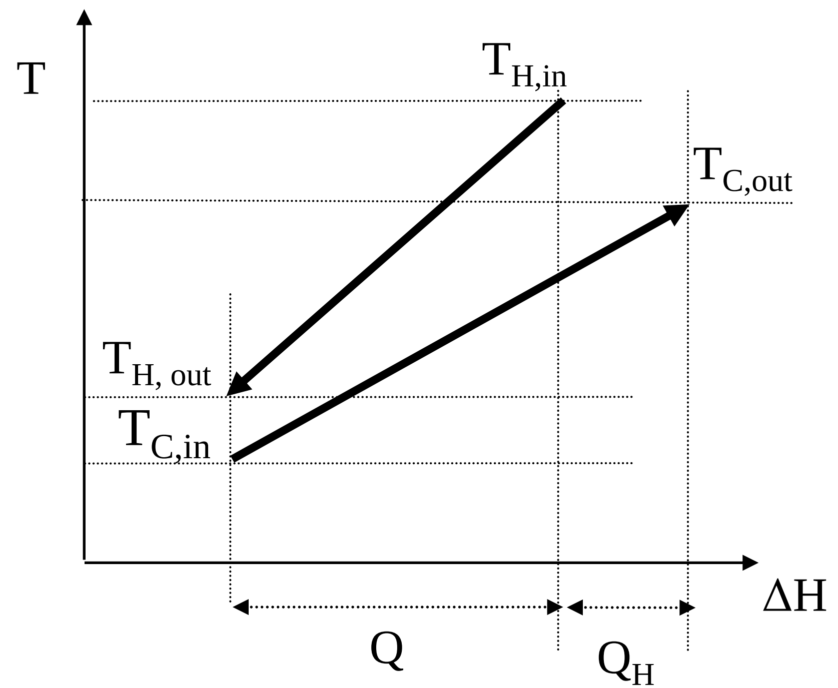



# T-H DIAGRAMS

- Assume one heat exchanger and a heater

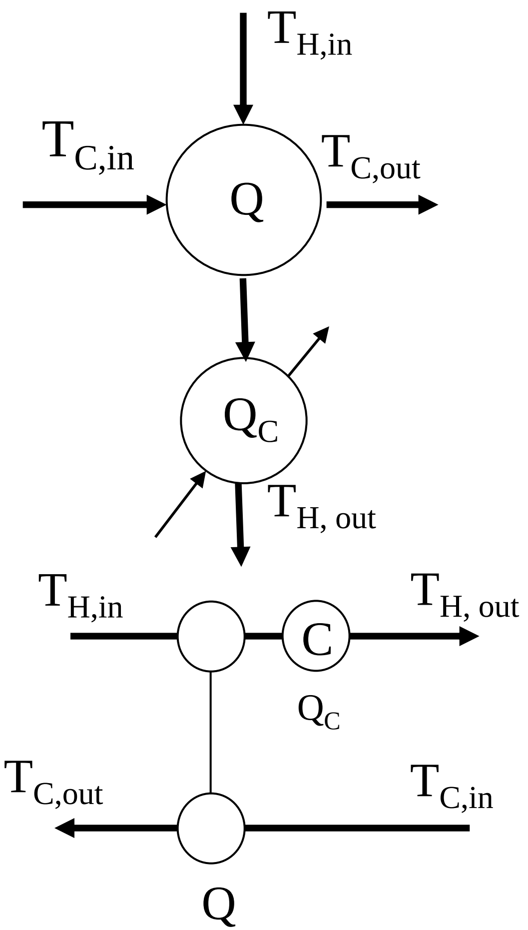


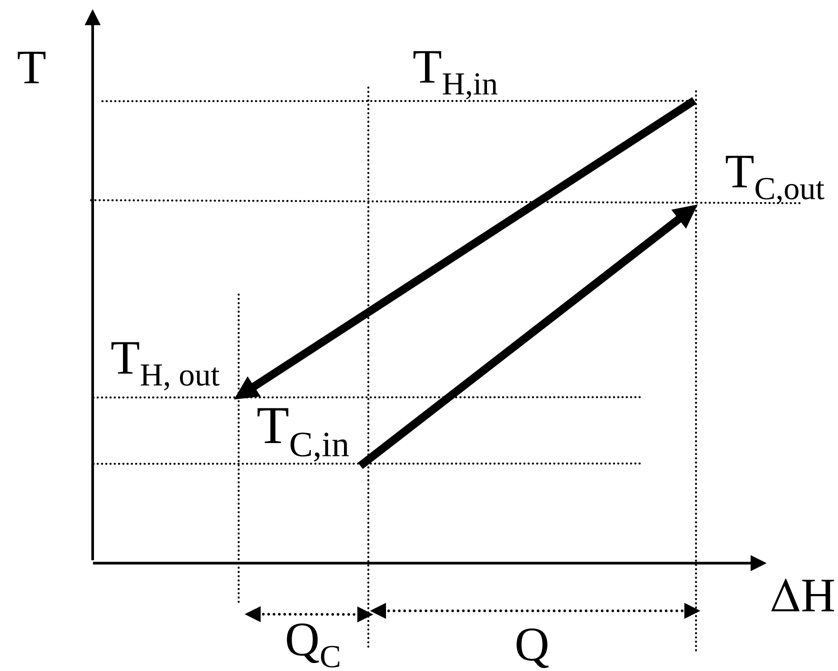



# T-H DIAGRAMS

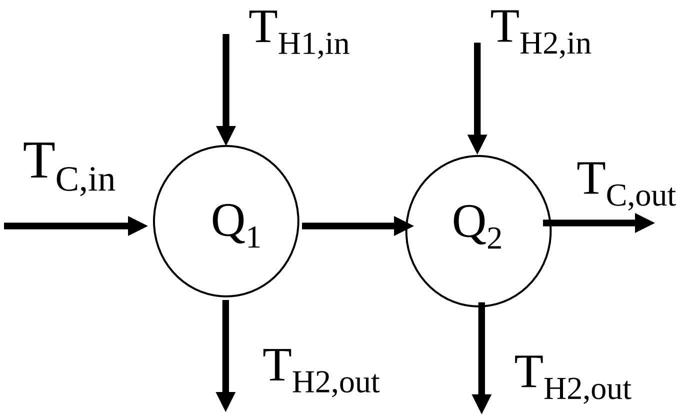
- Assume one heat exchanger and a cooler

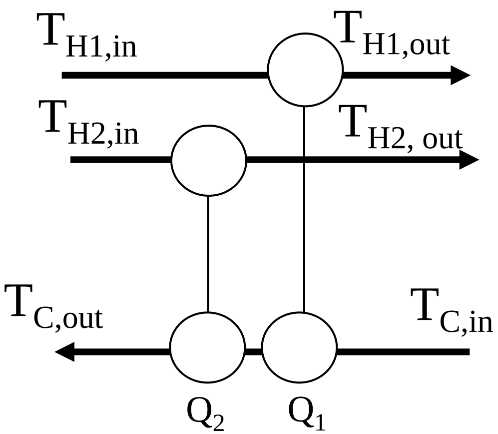


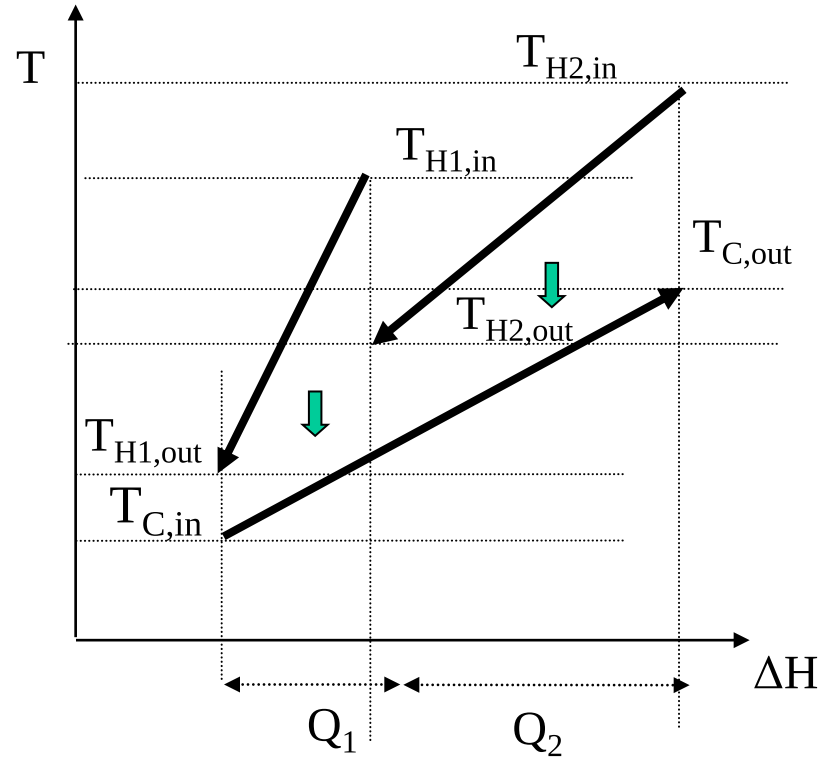



# T-H DIAGRAMS

- Two hot-one cold stream

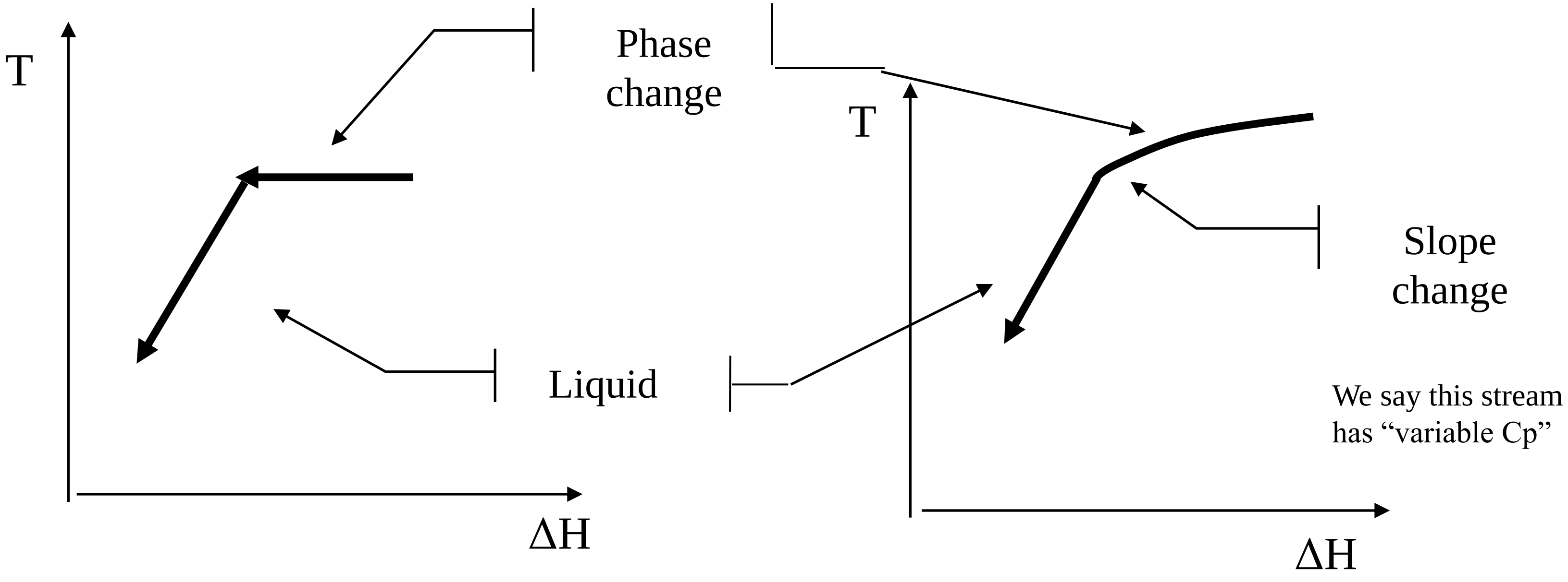



*Notice the vertical arrangement of heat transfer*

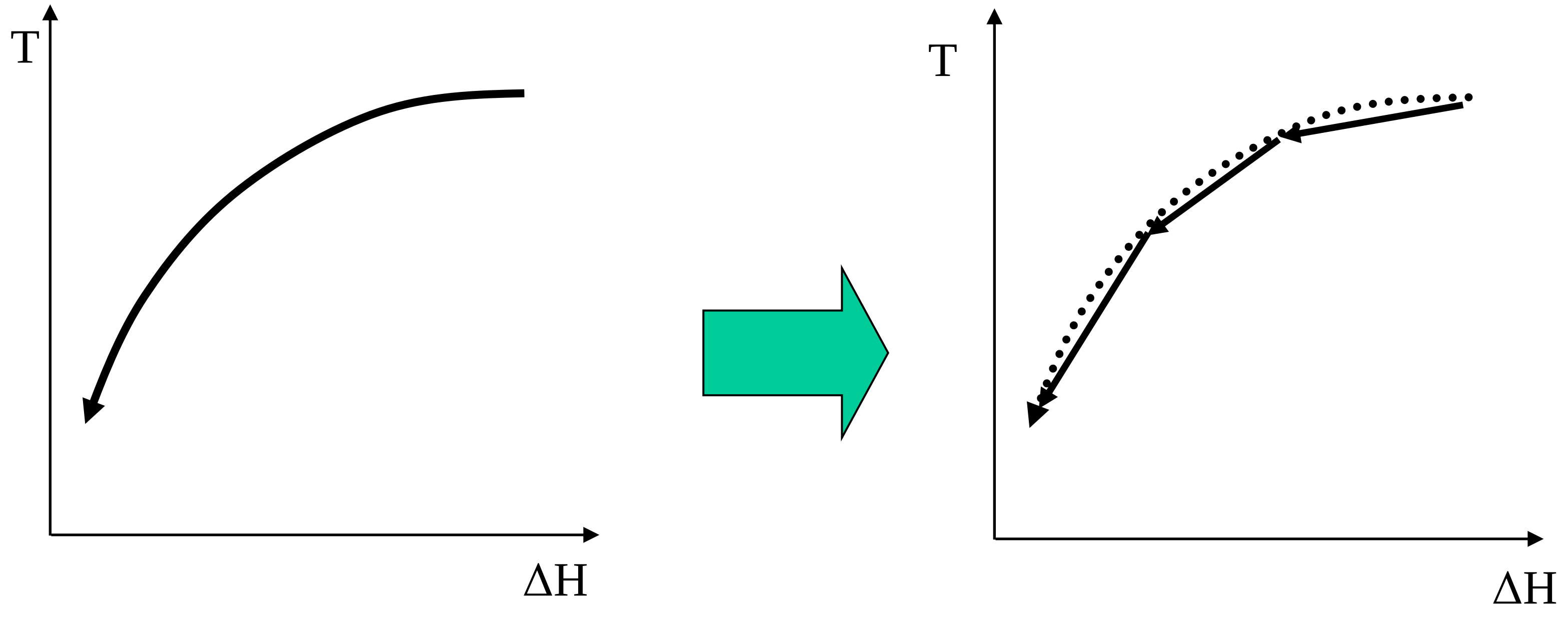
# Streams under phase change




Single component

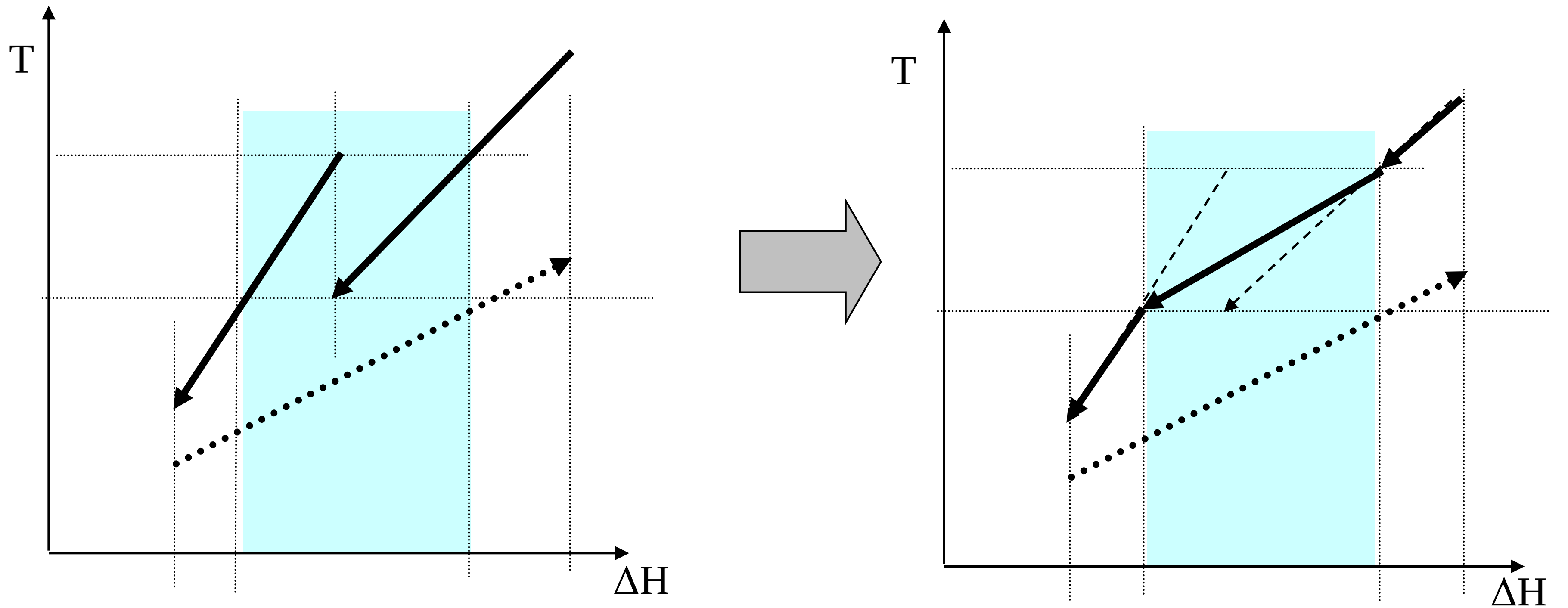
Multicomponent

# Piece-wise linear representation



# Composite Curves
# (T-H DIAGRAMS)

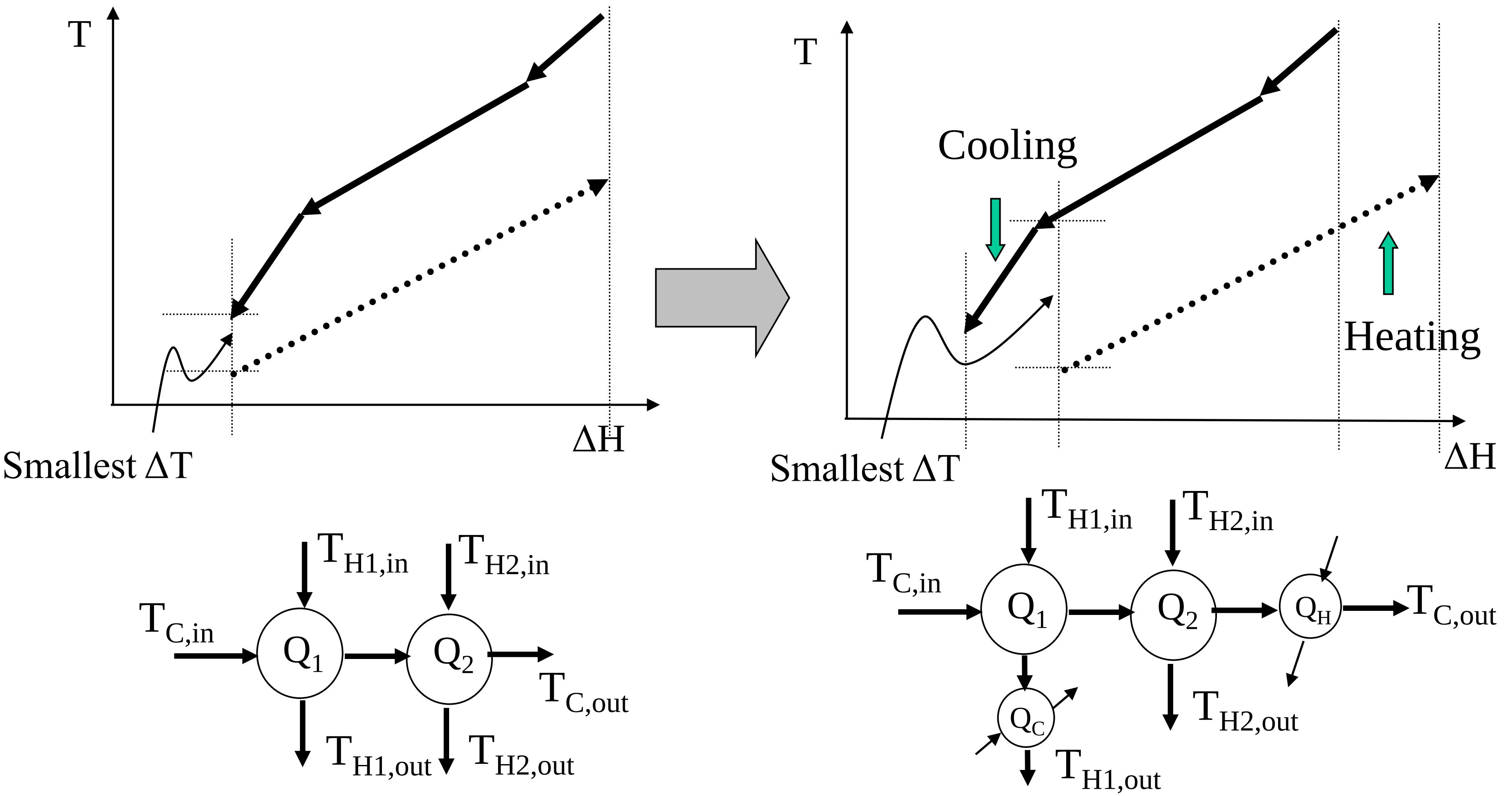
*Obtained by lumping all the heat from different streams that are at the same interval of temperature.*



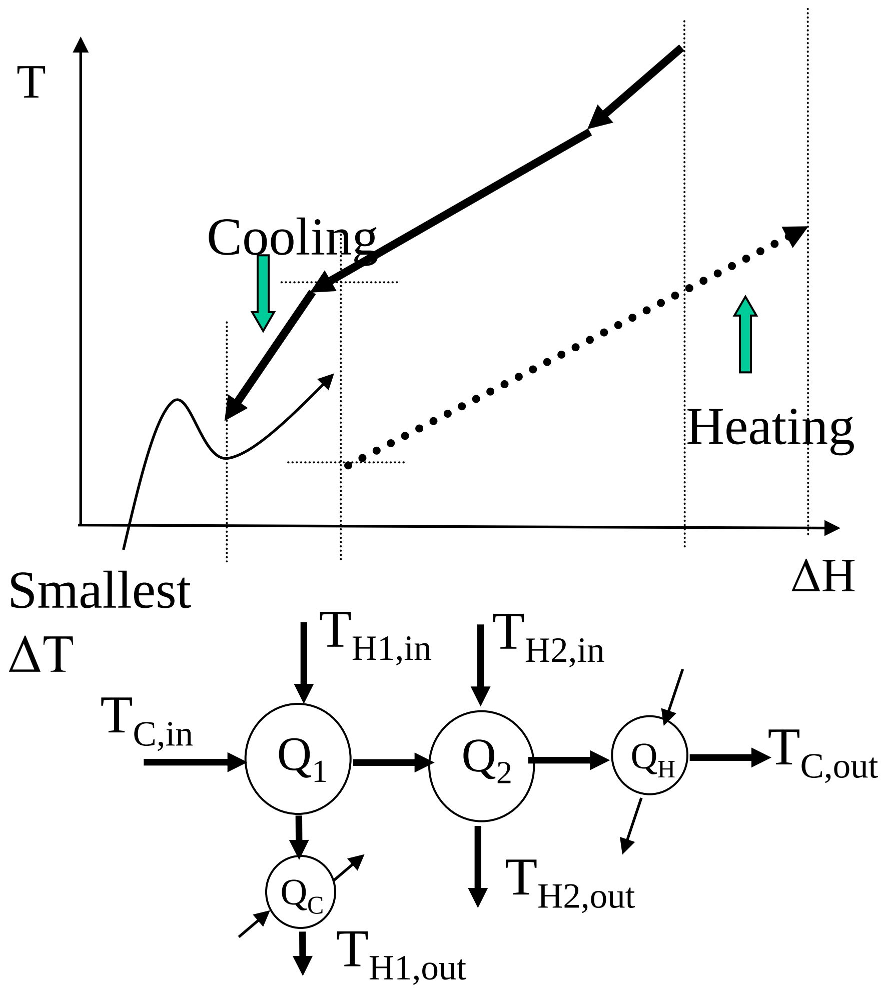

***Remark: By constructing the composite curve we loose information on the vertical arrangement of heat transfer between streams***

# Composite Curves (T-H DIAGRAMS)

- Moving composite curves horizontally



# Composite Curves
# (T-H DIAGRAMS)

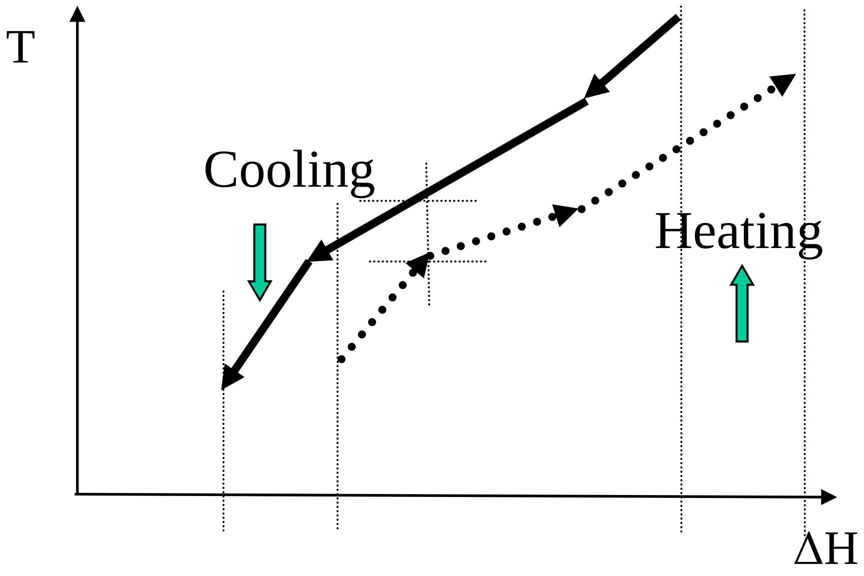



***Moving the cold composite stream to the right***

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

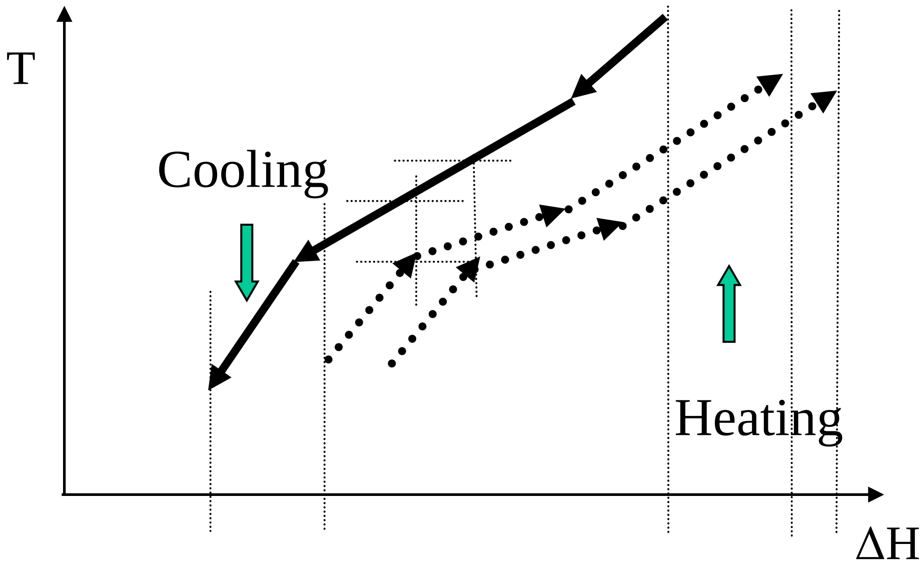
Notice that for this simple example the smallest ΔT takes place in the end of the cold stream

# 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)



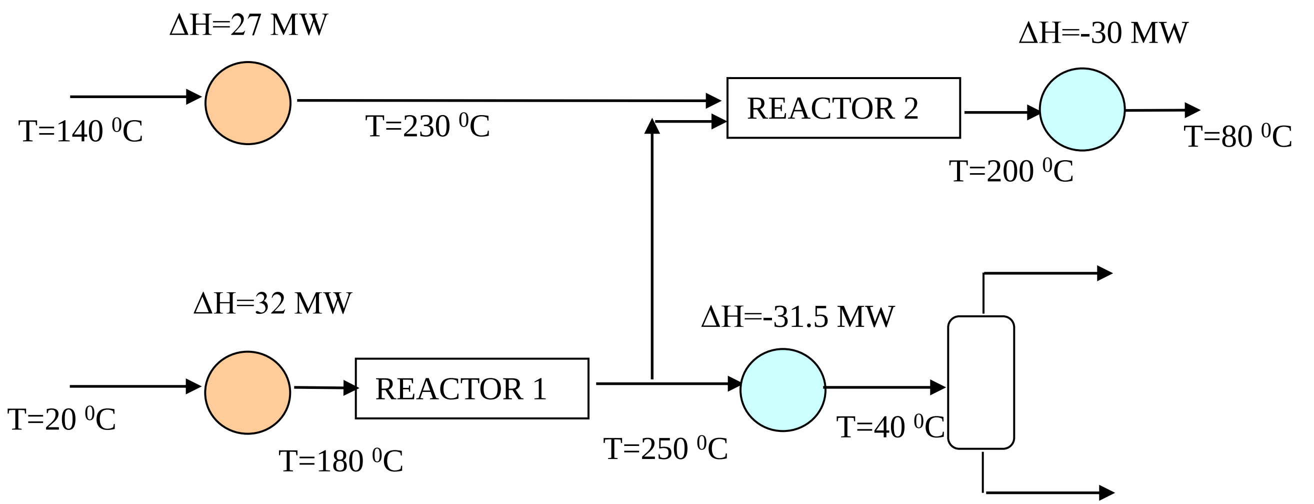

- ***From the energy point of view it is then convenient*** to move the cold stream to the left.
- However, the area may become too large.
- To limit the area, we introduce a minimum approach $\Delta T_{min}$

$\Delta T_{min}$ is also known as HRAT (Heat Recovery Approximation Temperature)

# GRAPHICAL PROCEDURE

- Fix $\Delta T_{min}$ (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 $\Delta T_{min}$
- 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

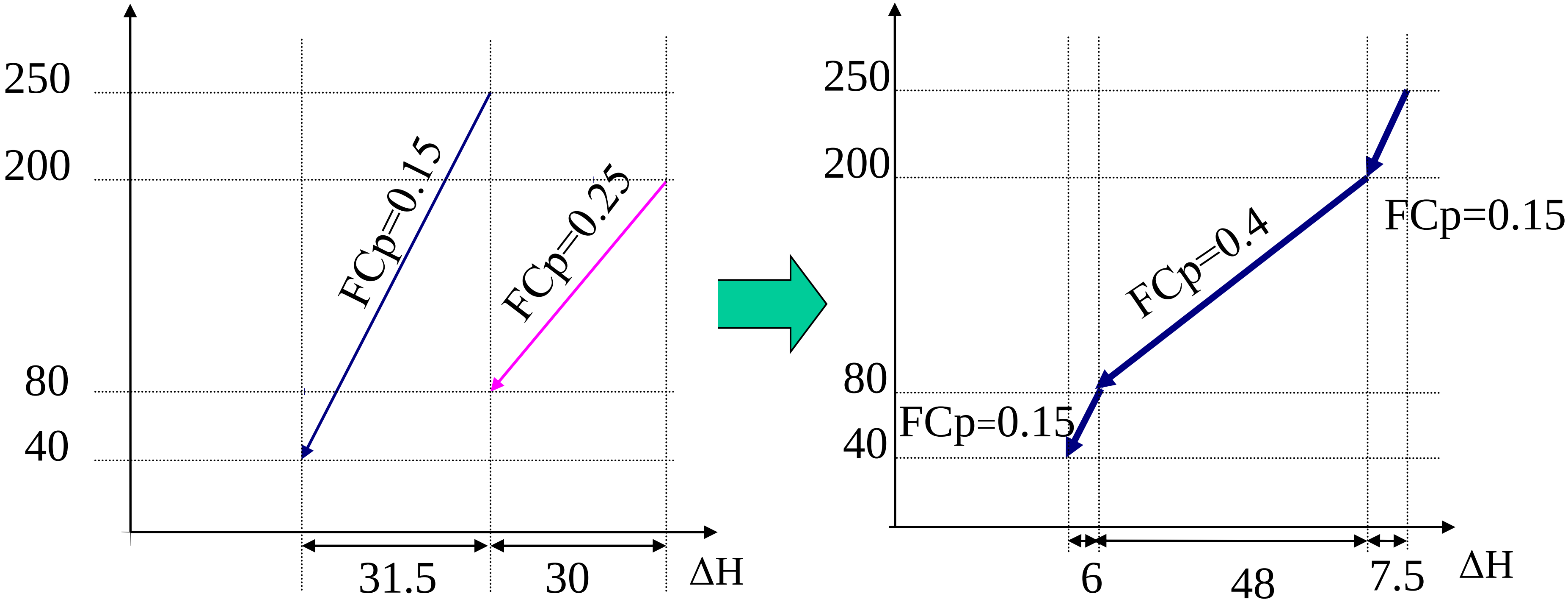
# EXAMPLE



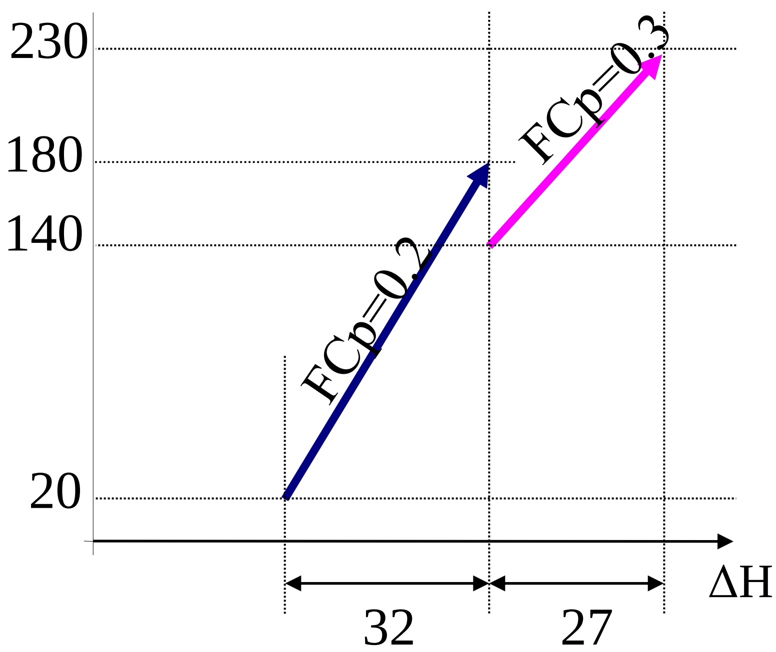

| Stream | Type | Supply T ($^{o}$C) | Target T ($^{o}$C) | ΔH (MW) | F*Cp (MW $^{o}C^{-1}$) |
|---|---|---|---|---|---|
| Reactor 1 feed | Cold | 20 | 180 | 32.0 | 0.2 |
| Reactor 1 product | Hot | 250 | 40 | -31.5 | 0.15 |
| Reactor 2 feed | Cold | 140 | 230 | 27.0 | 0.3 |
| Reactor 2 product | Hot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

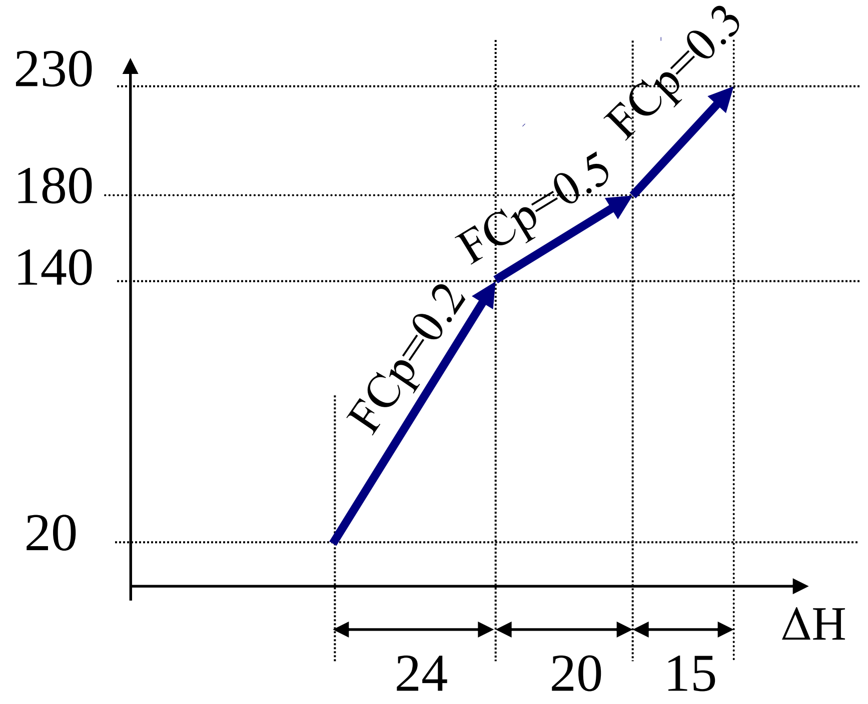
$\Delta T_{min}$=10 $^{o}$C

# Hot Composite Curve

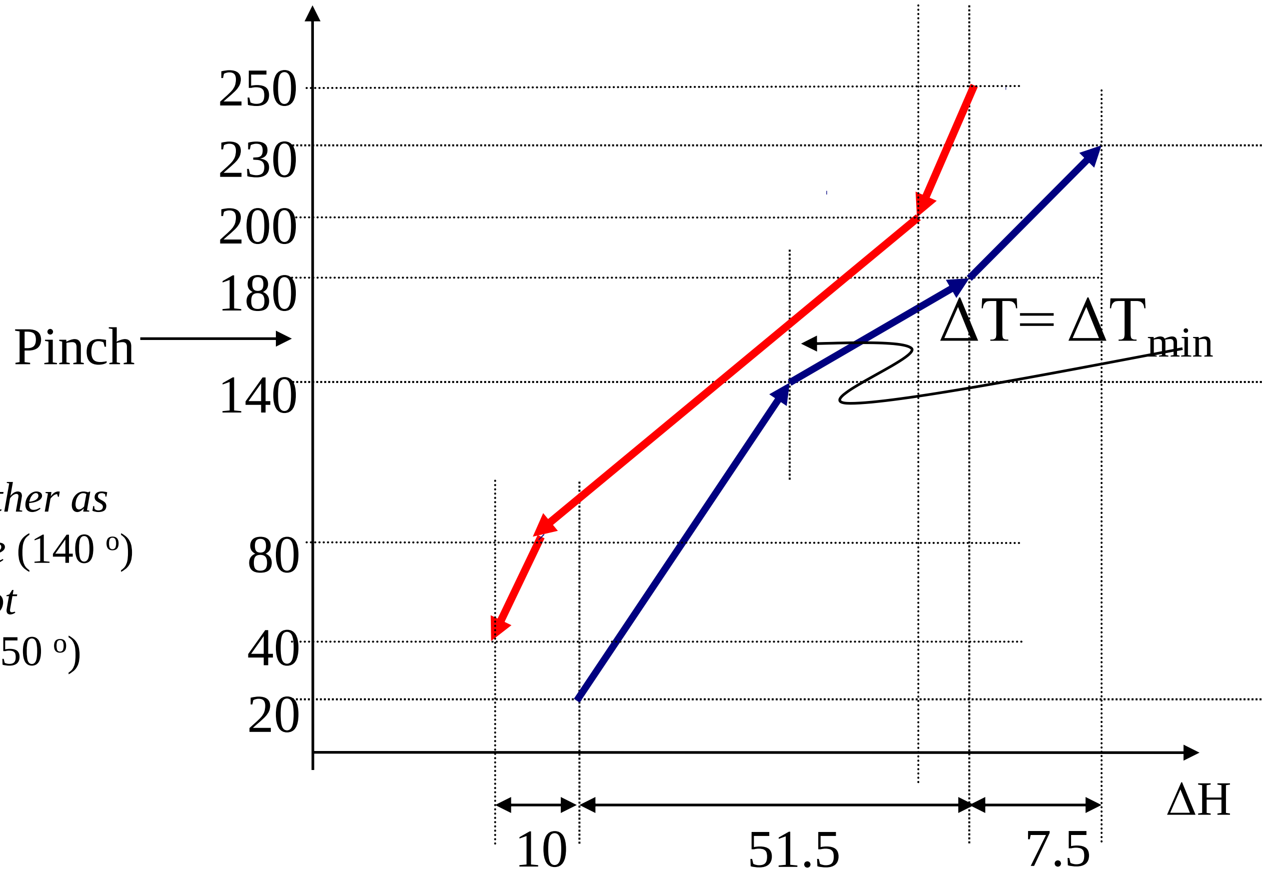


# Cold Composite Curve



# Pinch Diagram

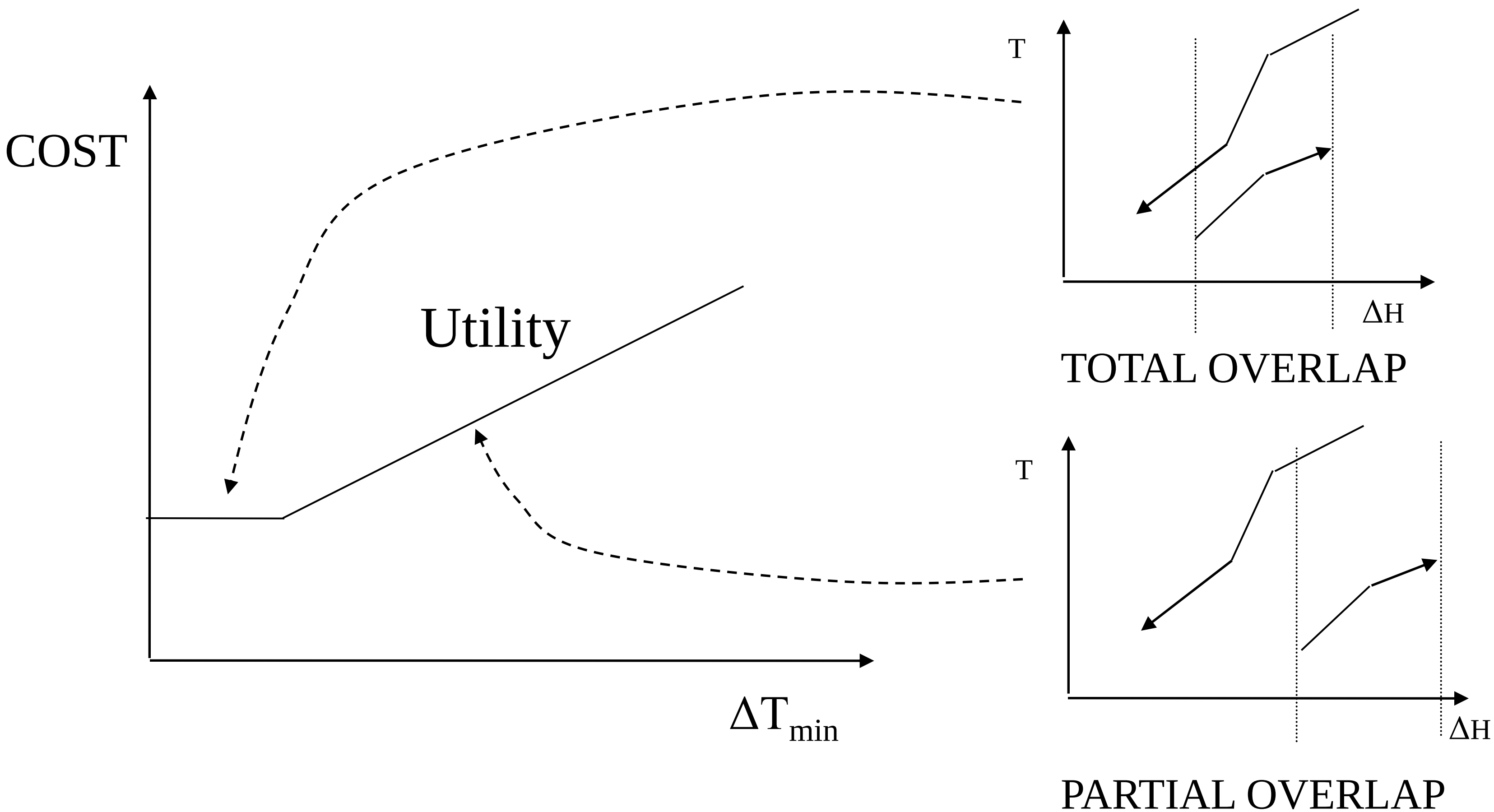



*The pinch is defined either as*

- *The cold temperature* (140 º)
- *The corresponding hot temp* (140 º+$\Delta T_{min}$=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***

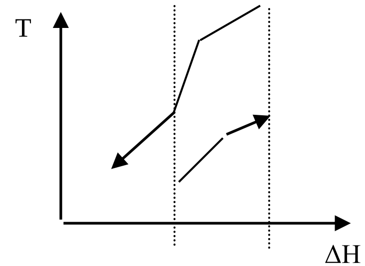
# UTILITY COST vs. $\Delta T_{min}$



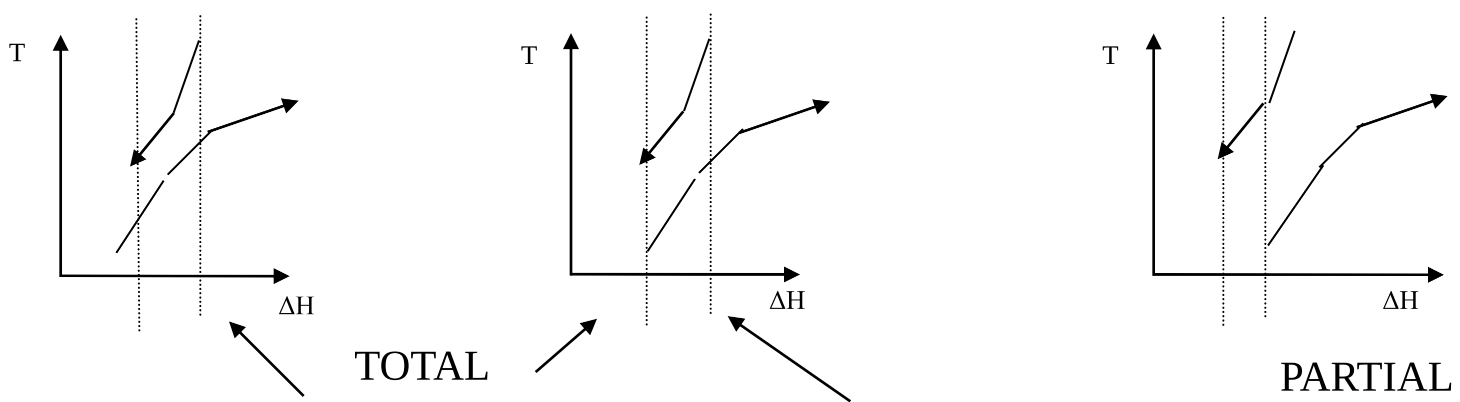

***Note: There is a particular overlap that requires only cooling utility***

# 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




TOTAL OVERLAP

We prefer this arrangement even if $\Delta T > \Delta T_{min}$

PARTIAL OVERLAP

# 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

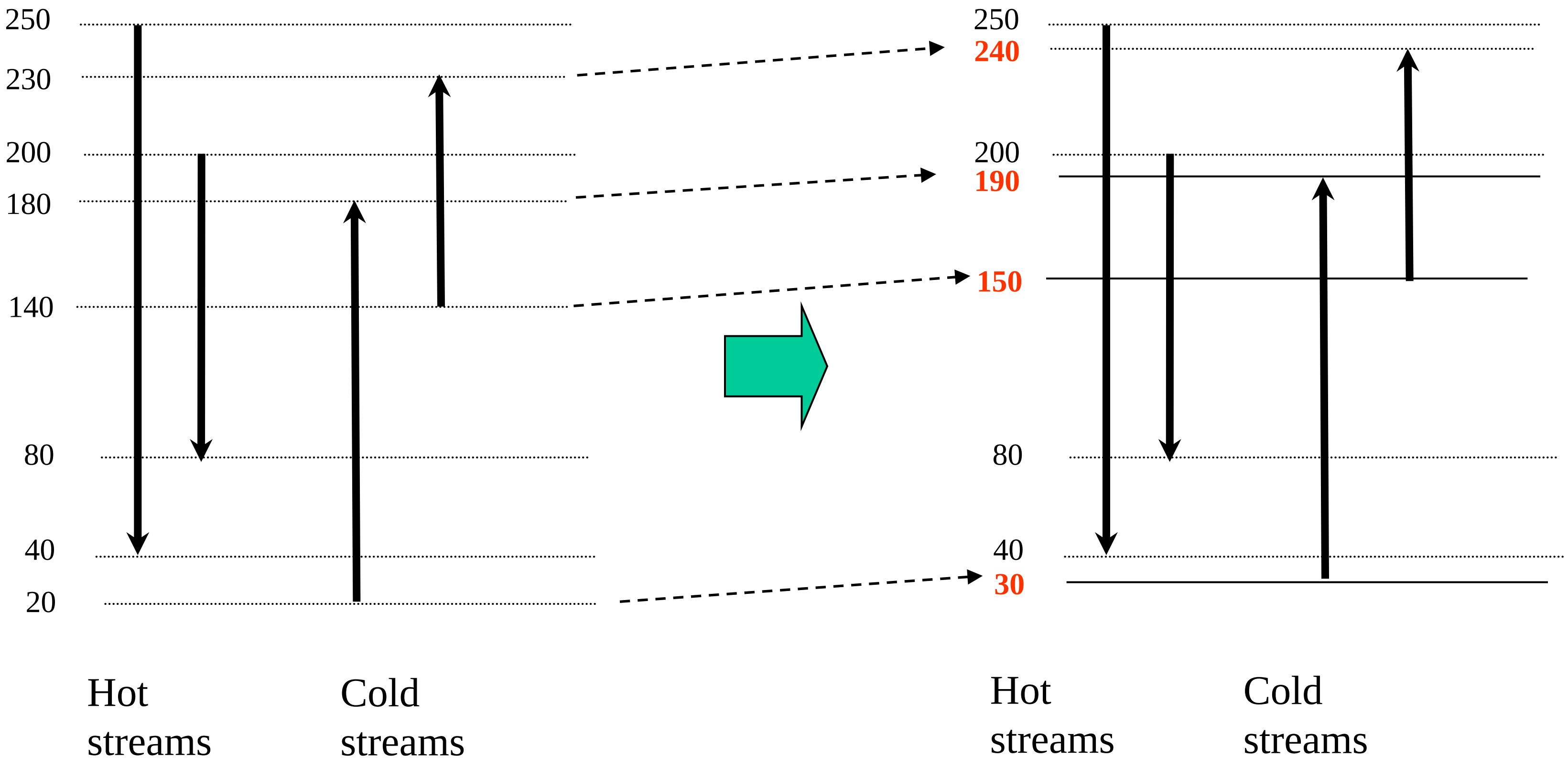
- We now explain each step in detail using our example

| 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 |
| 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 |

$\Delta T_{min}$=10 °C

# PROBLEM TABLE

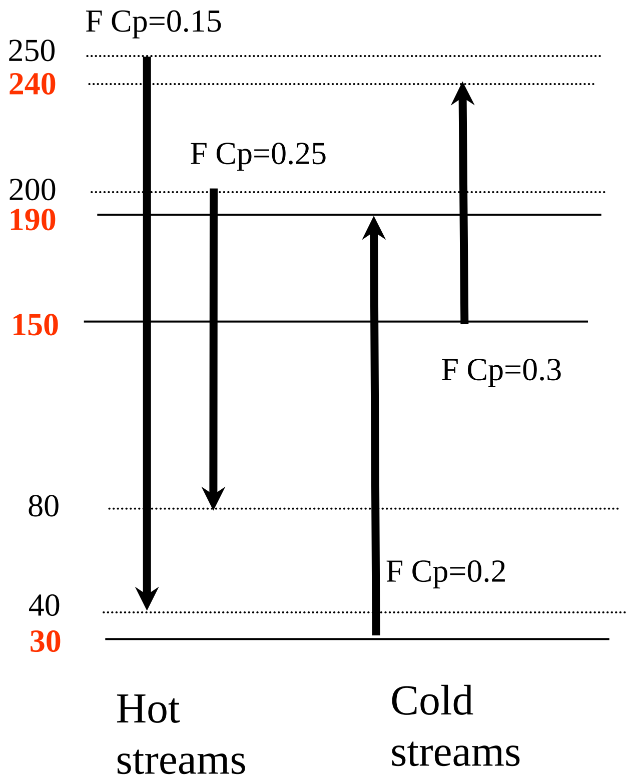
1. Divide the temperature range into intervals and shift the cold temperature scale




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

# PROBLEM TABLE

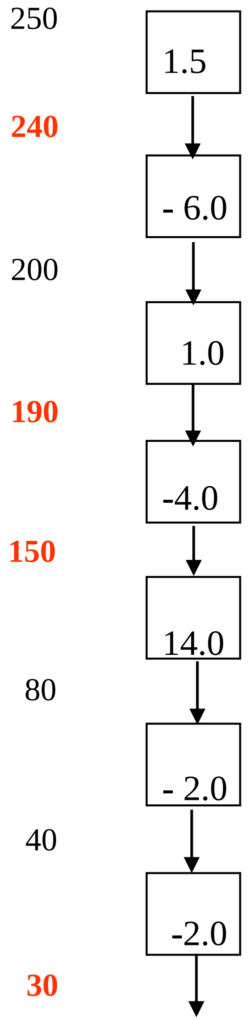
2. Make a heat balance in each interval.




| $\Delta T_{interval}$ | $\Delta H_{interval}$ | **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 |

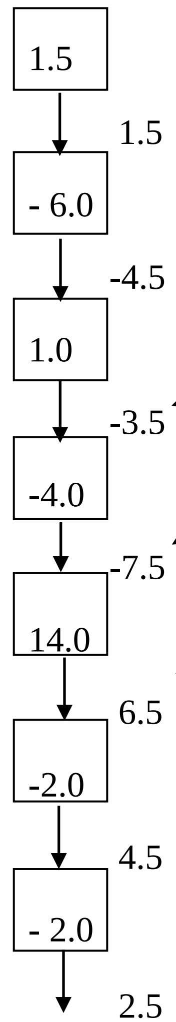
# PROBLEM TABLE

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




This interval has a surplus. It should transfer 1.5 to interval 2.

This interval has a deficit. After using the 1.5 cascaded it transfers –4.5 to interval 3.

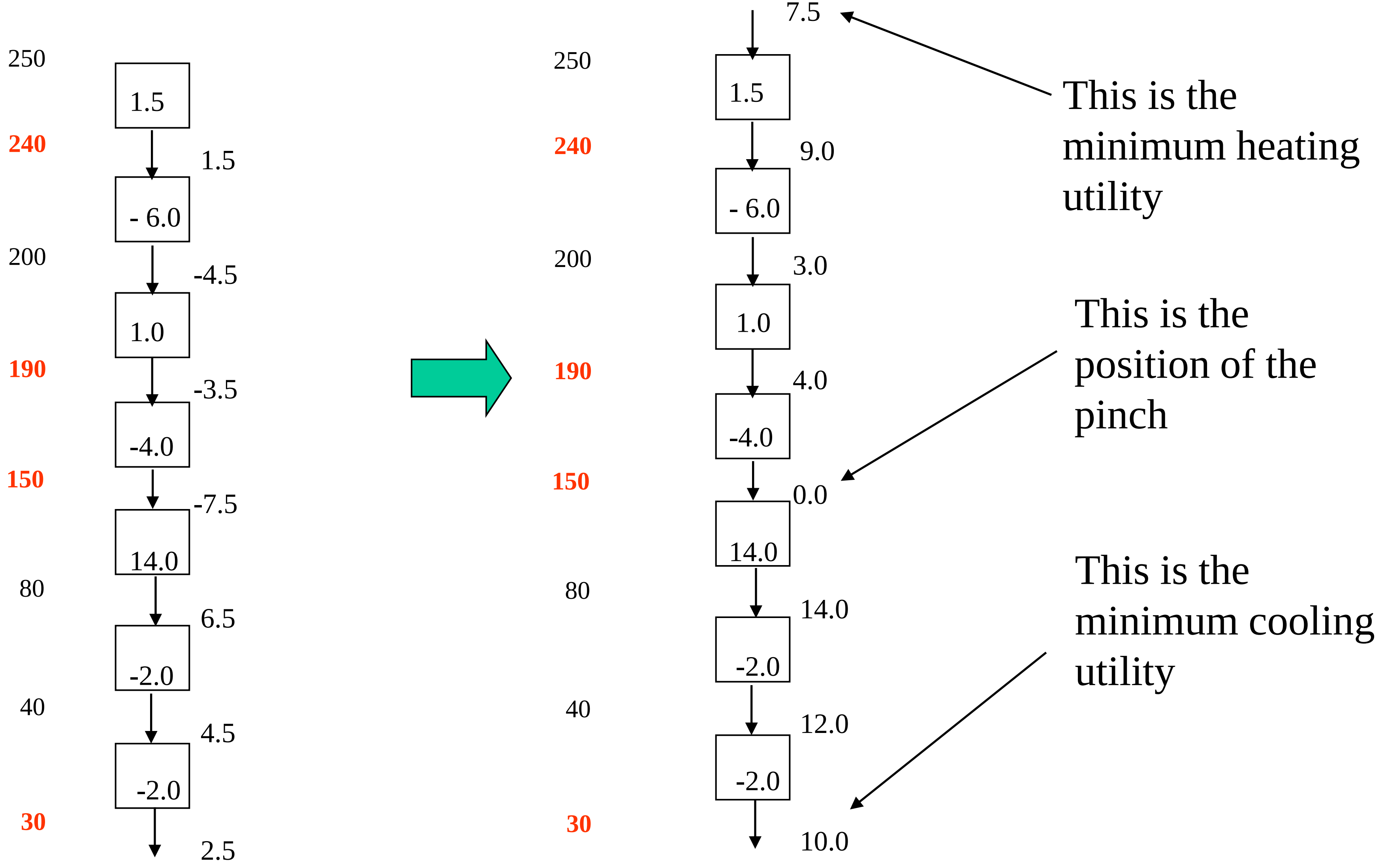



The largest deficit transferred is -7.5.

Thus, 7.5 MW of heat need to be added on top to prevent any deficit to be transferred to lower intervals

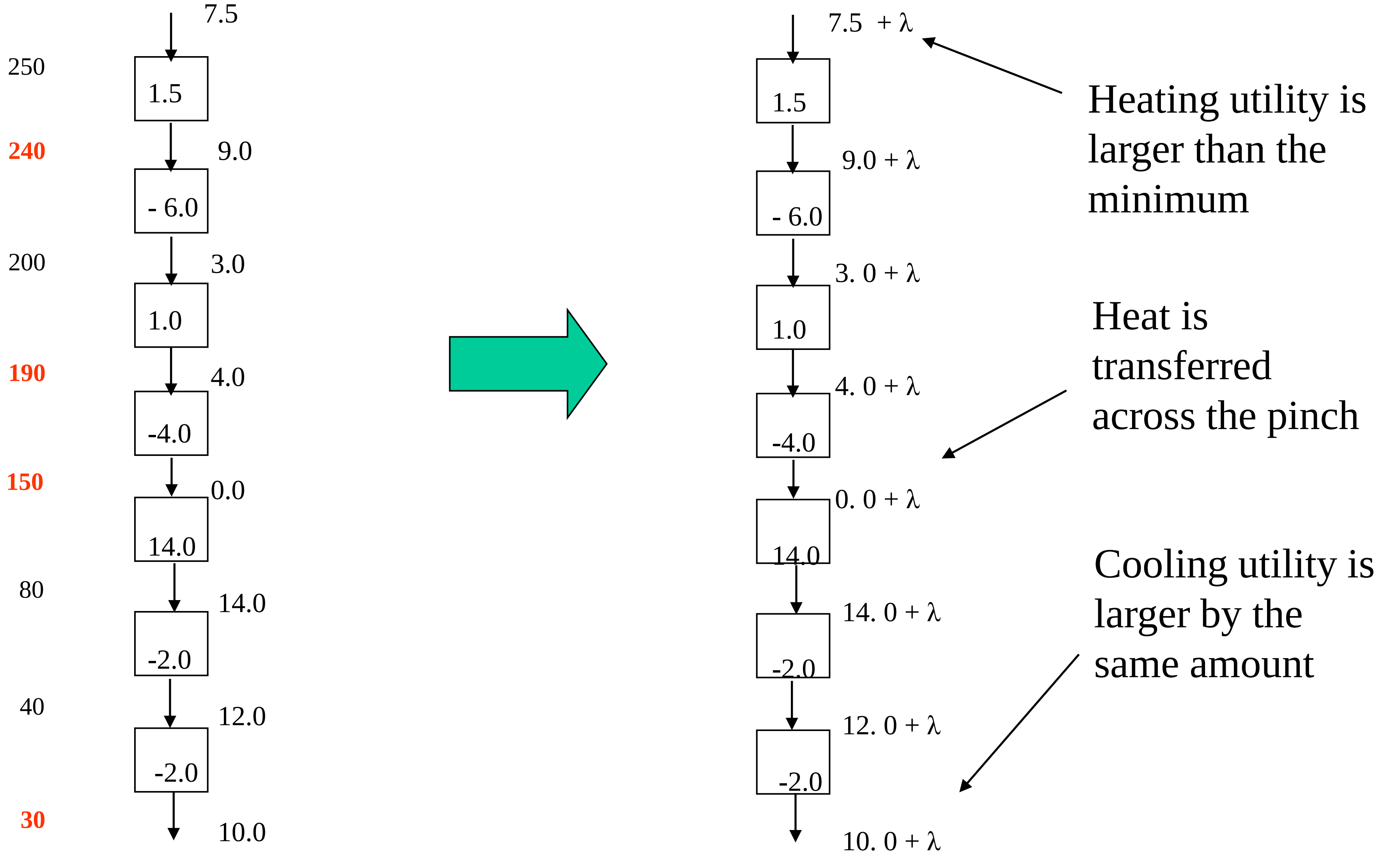
# PROBLEM TABLE

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

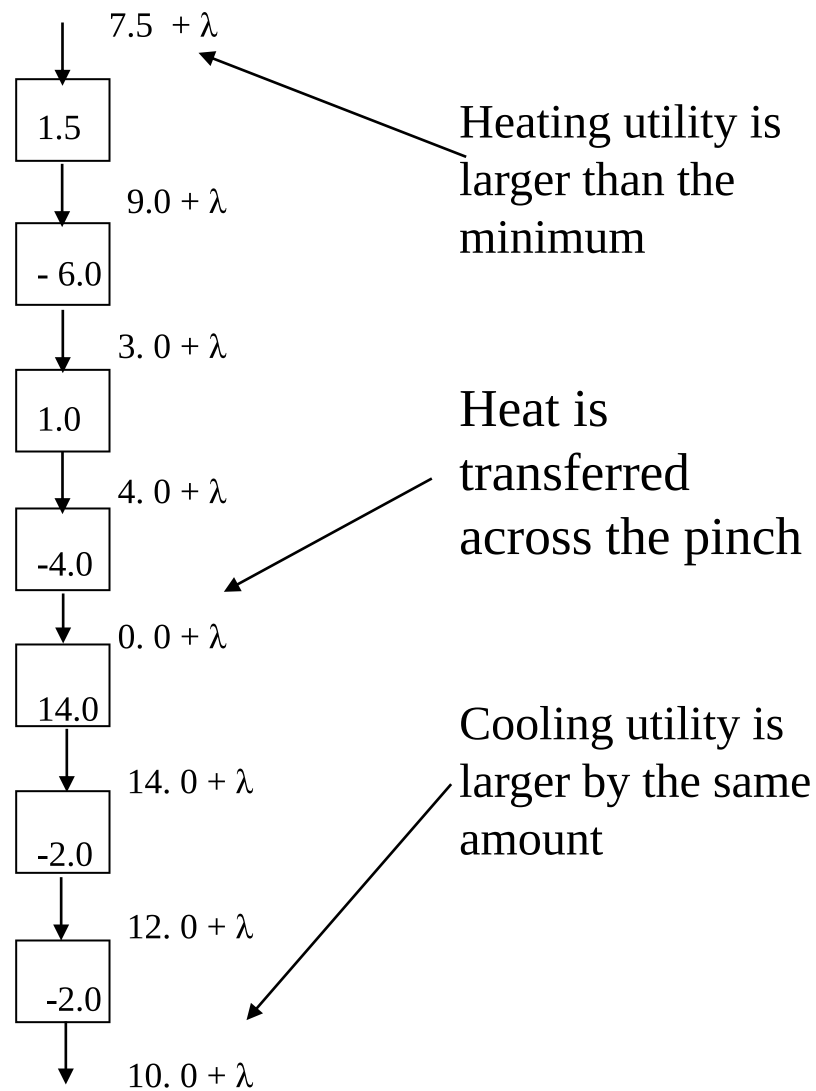


# IMPORTANT CONCLUSION

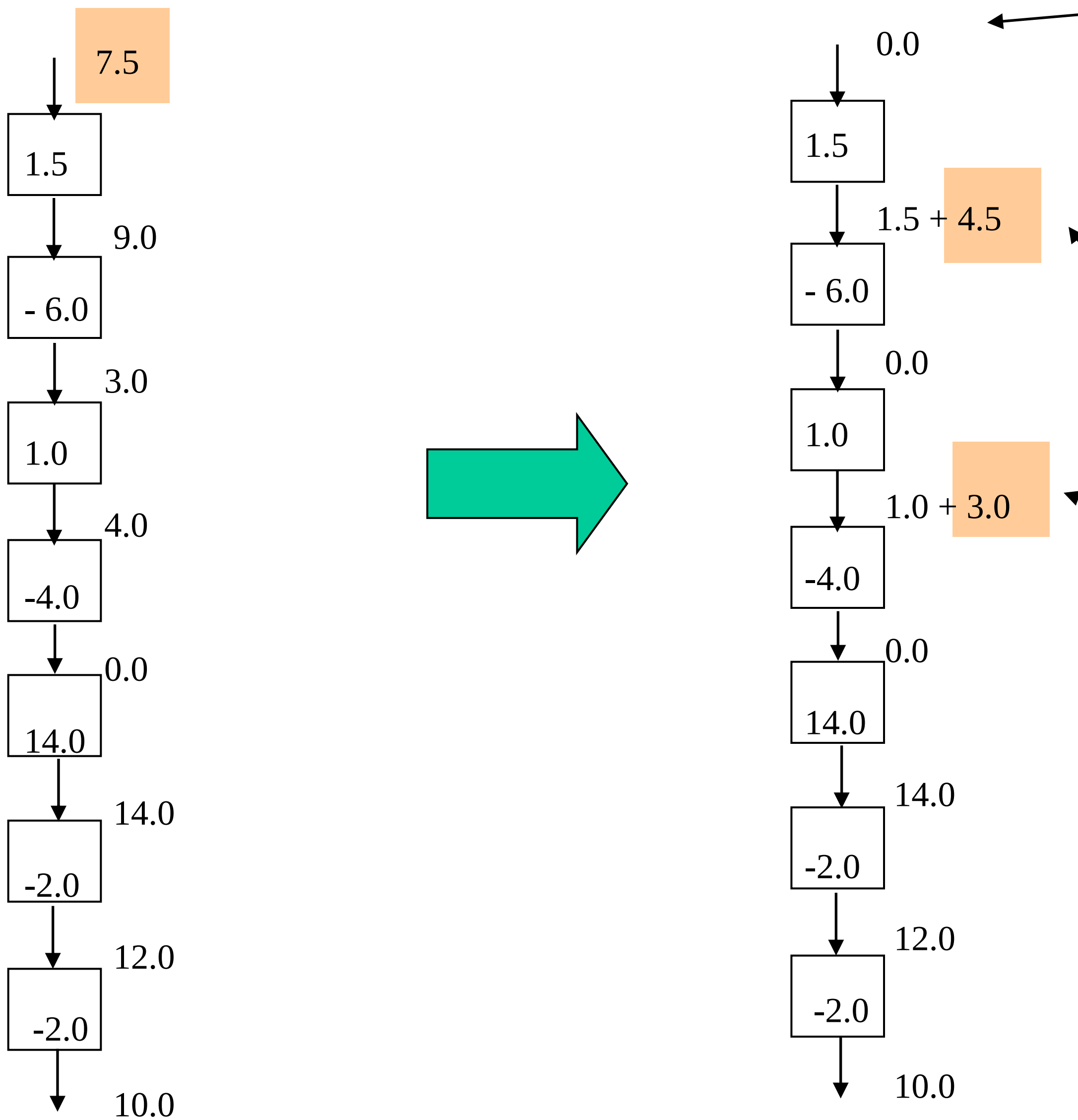
**DO NOT TRANSFER HEAT ACROSS THE PINCH**

***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




Heating utility at the largest temperature is now zero.

These are the minimum values of heating utility needed at each temperature level.