CHEMICAL ENGINEERING DESIGN & SAFETY

CHE 4253

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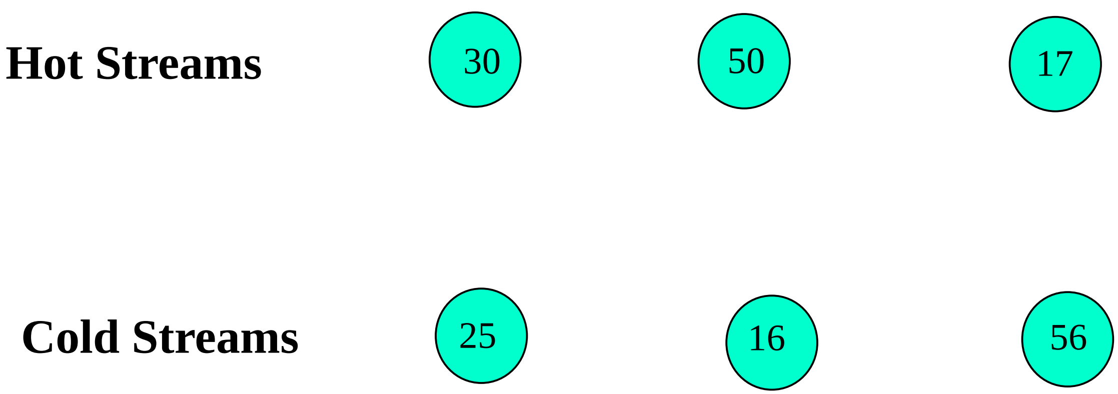
Heat Integration

2-Pinch Analysis: Minimum Area & Units

MINIMUM NUMBER OF UNITS

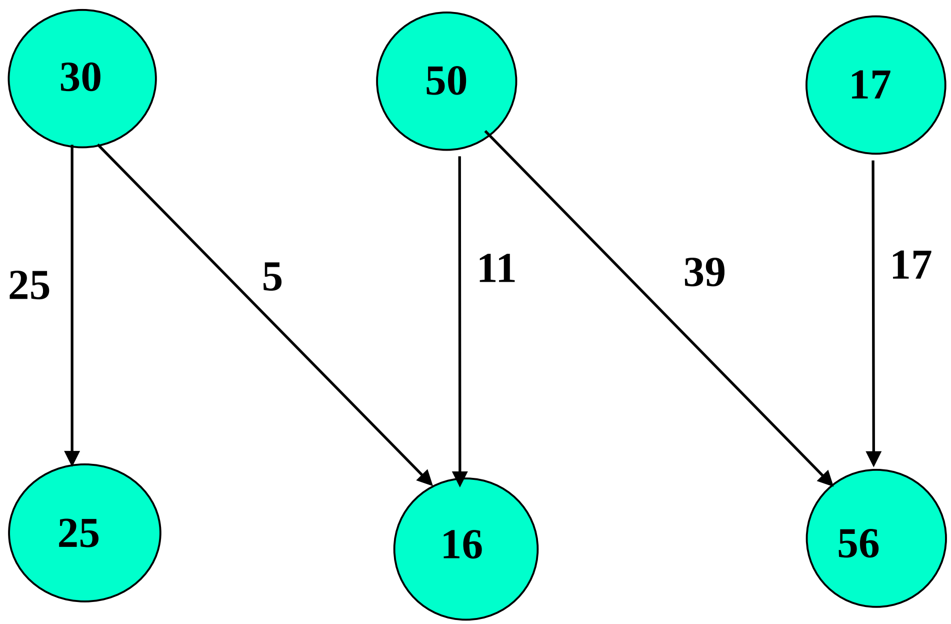
We use an example.

Consider the following 3 hot streams and 3 cold streams. Assume that all heat transfer is possible: What is the minimum number of exchangers needed?



MINIMUM NUMBER OF UNITS

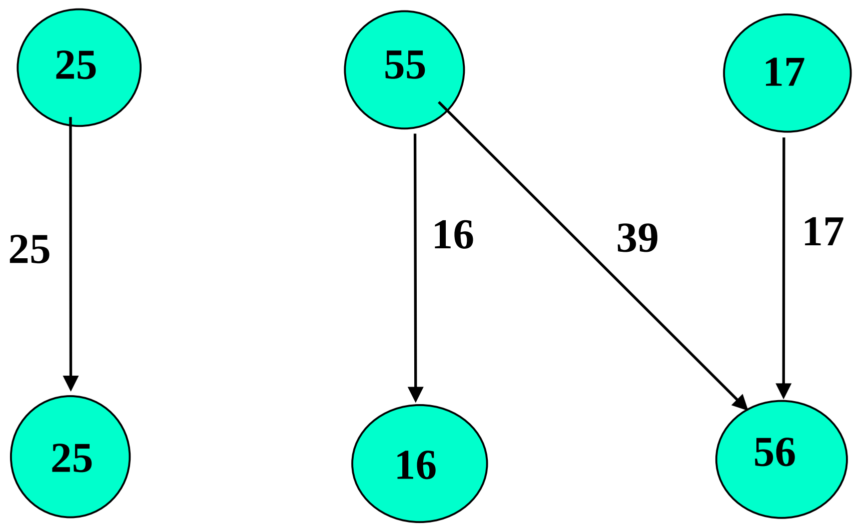
Five heat exchangers are needed, possibly less in some other cases. Here is how you solve the problem specifically.



The general answer is N=S-1 . When does one need less?

MINIMUM NUMBER OF UNITS

When there is an exact balance between two streams or a subset of streams.



The general answer is N=S-P. P is the number of independent subsystems. (Two in this case)

GENERAL FORMULA FOR UNIT TARGETING

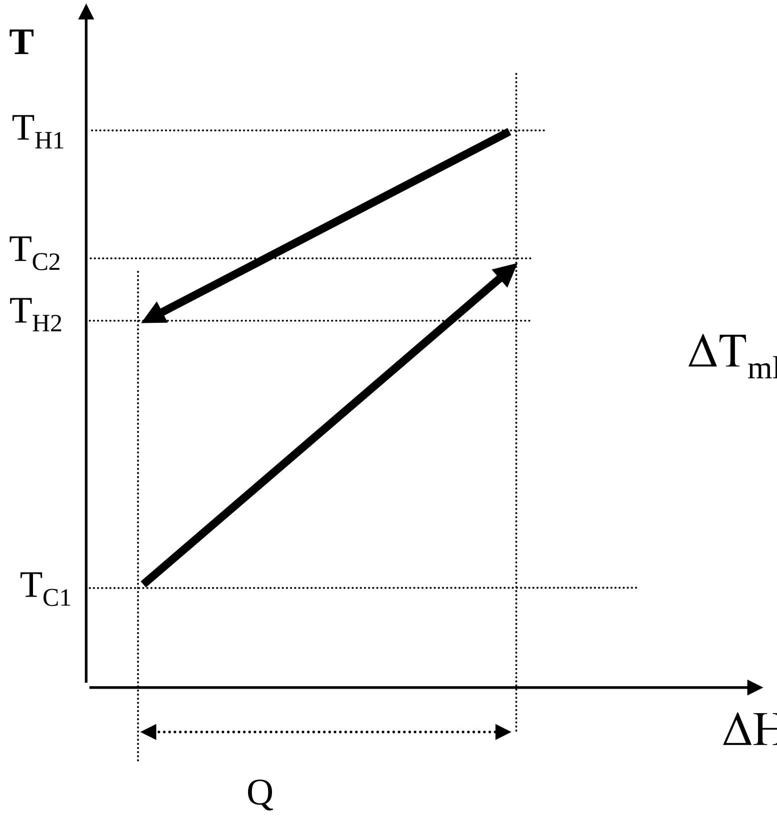
$$N_{min} = (S-P)_{\text{above pinch}} + (S-P)_{\text{below pinch}}$$

We need to consider systems where the heat transfer is possible.

If we do not consider two separate problems, above and below the pinch we can get misleading results.

TOTAL AREA TARGETING

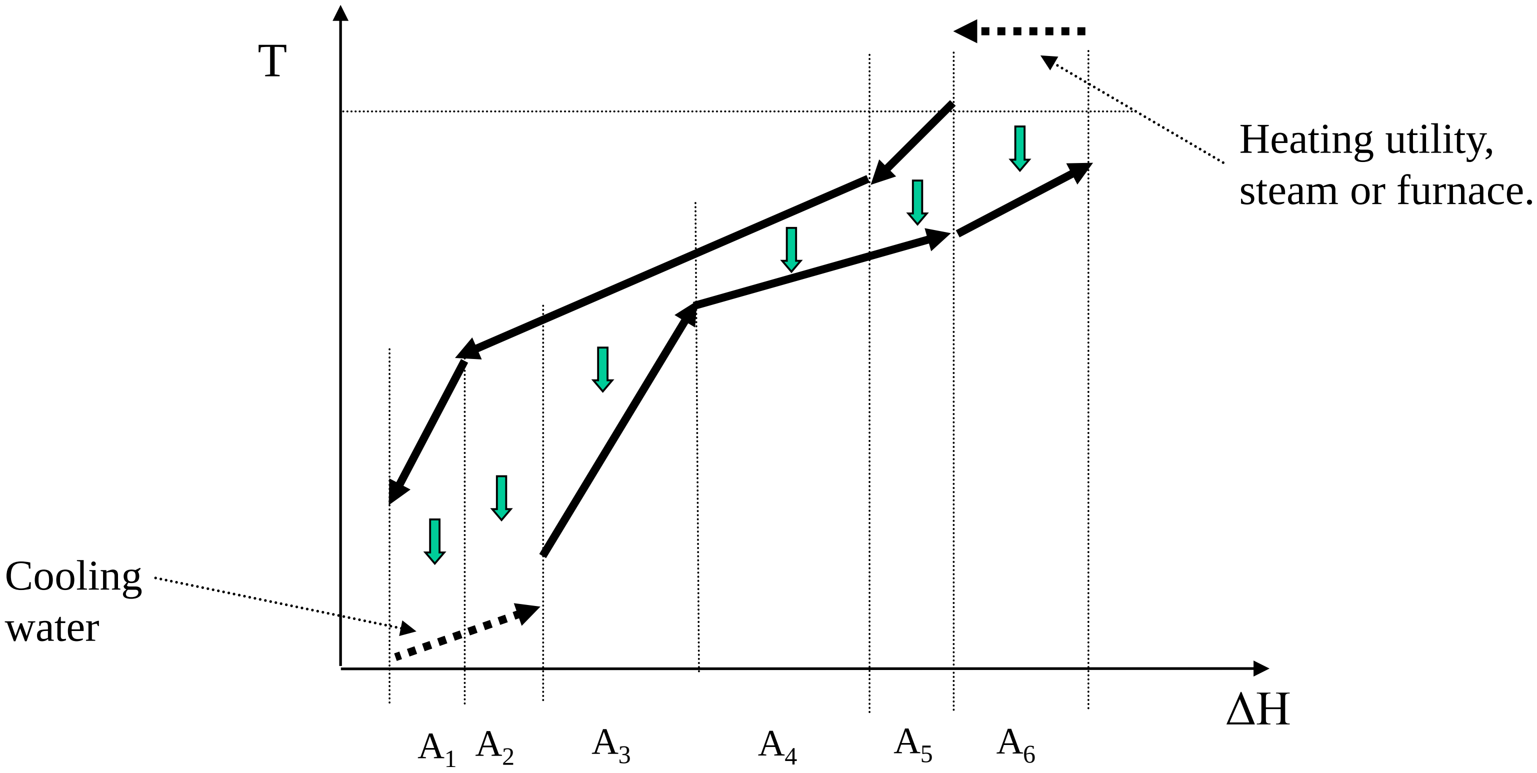
Because $A=Q/(U^*\Delta T_{ml})$, one can calculate the area easily in the following situation.



$$\Delta T_{ml} = \frac{(T_{H1}-T_{C2})-(T_{H2}-T_{C1})}{\ln \dfrac{(T_{H1}-T_{C2})}{(T_{H2}-T_{C1})}}$$

TOTAL AREA TARGETING

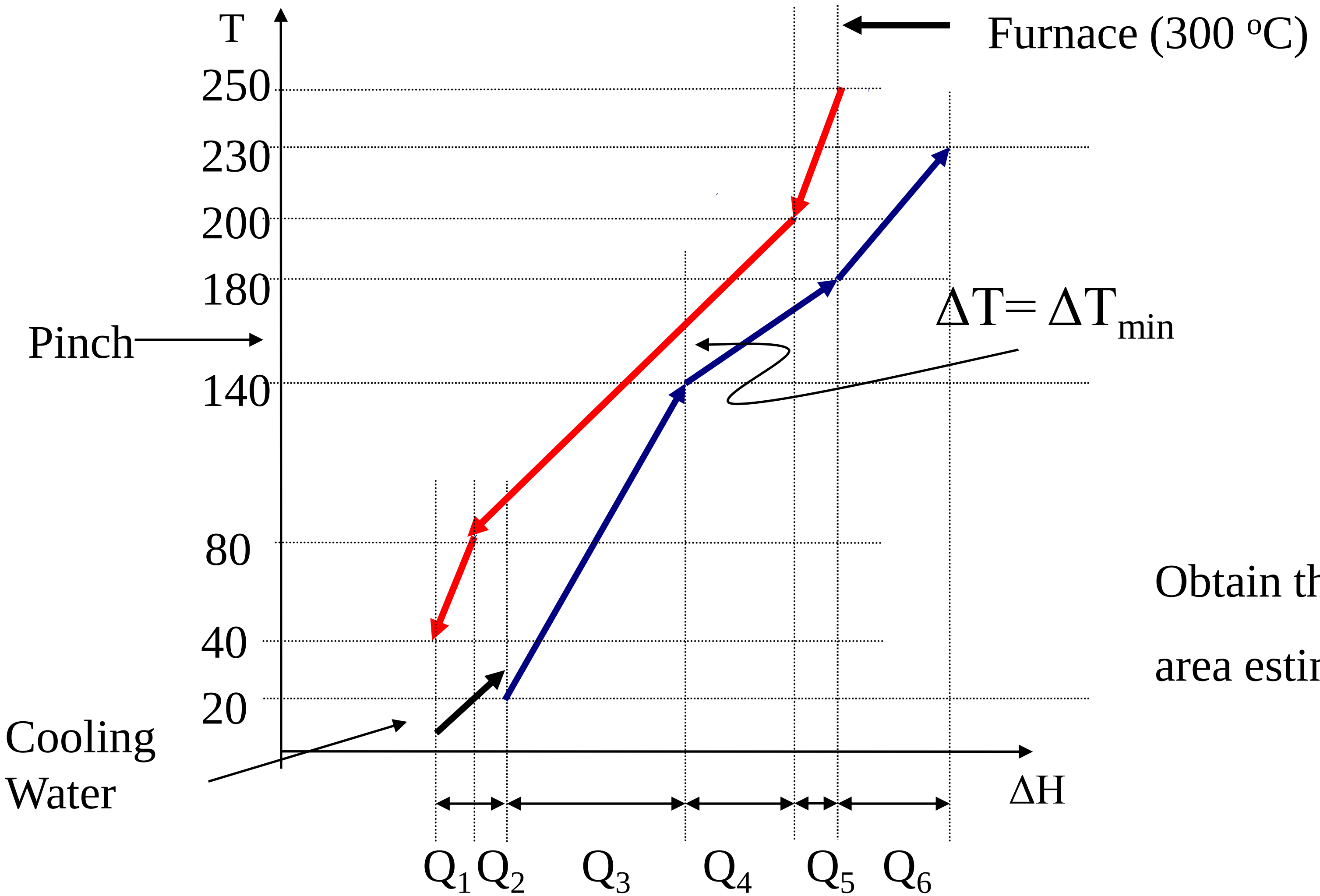
Since area=Q/(U ΔT_{ml}), the composite curve diagram provides one way of estimating the total area involved. Isolate all regions with a pair of straight line sections and calculate the area for each.



The above scheme of heat transfer is called VERTICAL HEAT TRANSFER

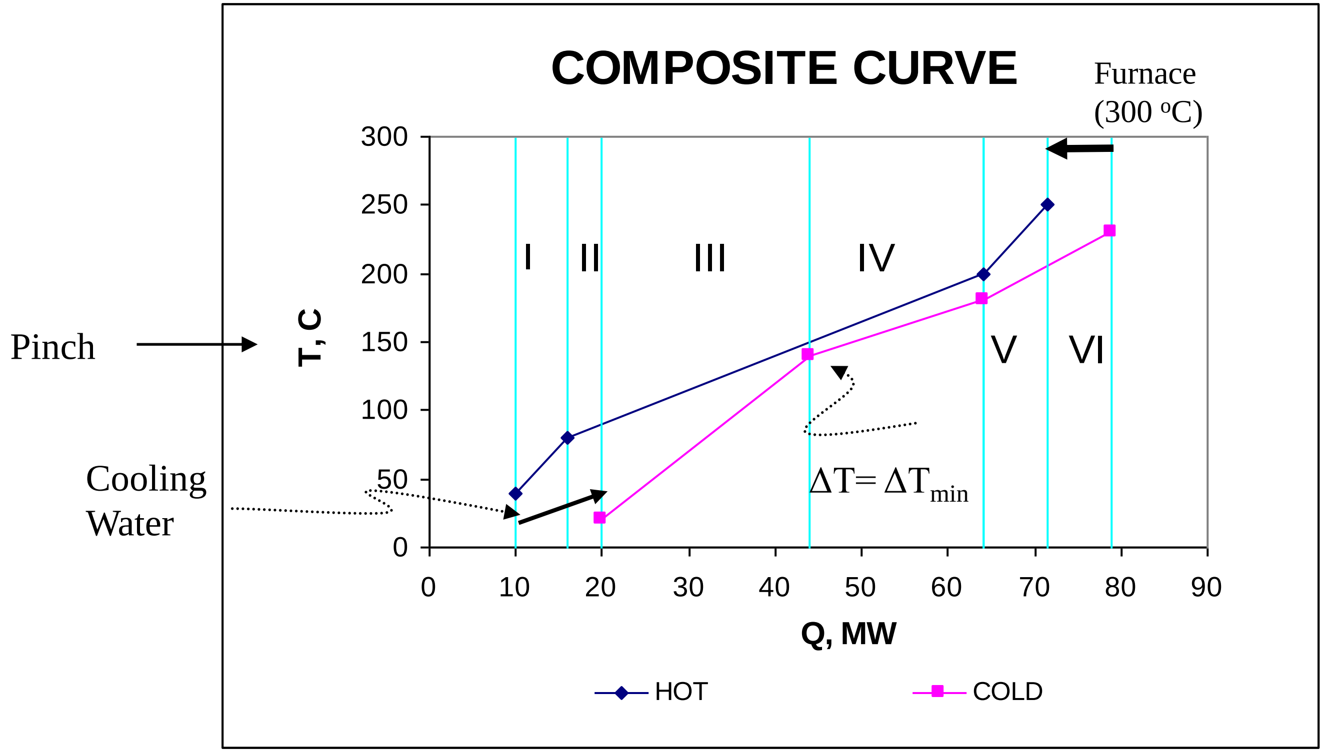
EXAMPLE

We now calculate the values of Q in each interval and estimate the corresponding area. Use U= 0.001 MW m^{-2} ^{o}C



Obtain the total area estimate

EXAMPLE



Units:

Q= MW

T= ºC

A= m²

Interval	Q(MW)	TH1	TH2	TC1	TC2
I	6	80	40	20	15
II	4	90	80.00	30	20
II	24	150	90.00	140	20
IV	20	200	150	180	140
V	7.5	250	200	205	180
VI	7.5	300	250	230	205

EXAMPLE

Interval	Q(MW)	TH1	TH2	TC1	TC2	ΔTml	A
I	6	80	40	20	15	39.98	150.1
II	4	90	80.00	30	20	60.00	66.7
II	24	150	90.00	140	20	30.83	778.4
IV	20	200	150	180	140	14.43	1386.3
V	7.5	250	200	205	180	30.83	243.3
VI	7.5	300	250	230	205	56.58	132.5

Units: Q= MW T= ^{o}C , A= m^2

U= 0.001 MW m^{-2} ^{o}C

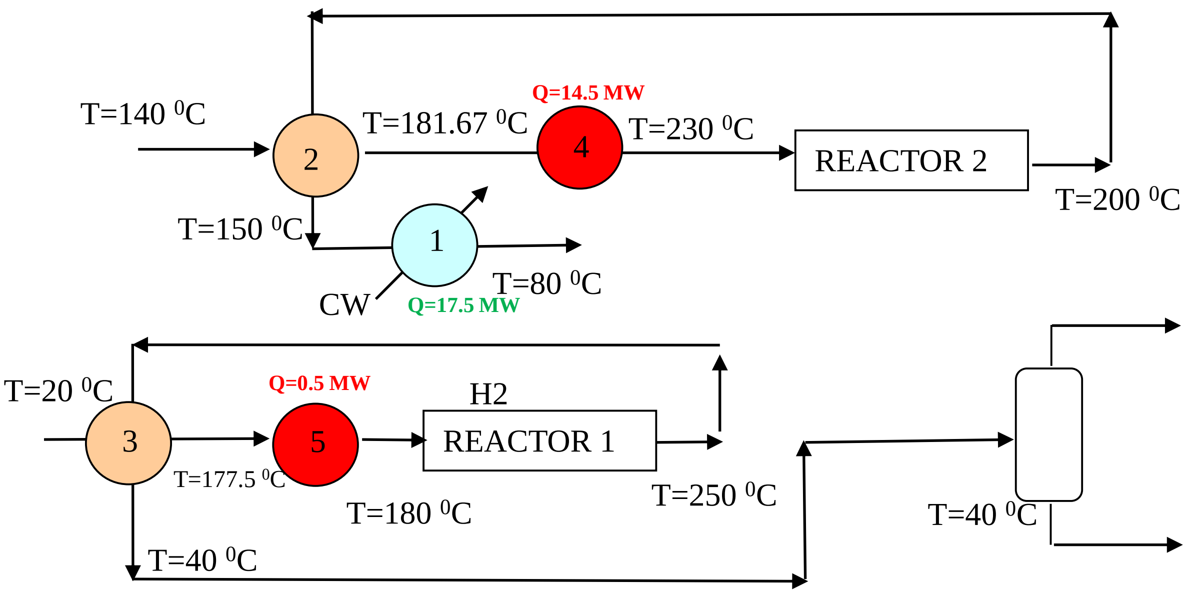
COSTING

$$Total\ Annualized\ Cost =$$

$$= C_E\ E + C_A\, Area + C_{unit}\, N_{units}$$

There are more complex formulas.

EXAMPLE



Stream	Type	Supply T (°C)	Target T (°C)	F*Cp (MW °C⁻¹)
Reactor 1 feed	Cold	20	180	0.2
Reactor 1 product	Hot	250	40	0.15
Reactor 2 feed	Cold	140	230	0.3
Reactor 2 product	Hot	200	80	0.25

Exchanger	Q(MW)	TH1	TH2	TC1	TC2	ΔTml	A
1	17.5	150	80	30	15	89.71	195.1
2	12.5000001	200	150.00	181.66667	140	13.75	909.2
3	31.5	250	40.00	177.5	20	40.77	772.7
4	14.5	300	250	230	181.66667	69.16	209.6
5	0.5	300	250	180	177.5	94.26	5.3

Units: Q= MW T= °C A= m²

U= 0.001 MW m⁻² °C

Energy Cost = $1.465 /MW-hr (5 $/MMBTU)

Area cost = Matches $C_{unit}=0$

A= 2092 m⁻² Energy= 15 MW

Energy Cost = $200,000 *Area cost* = $ *282,900*

TAC=$200,000+28,290= =$228,290 (n=10)

A=2716.3 m⁻² (Minimum area) Energy=7.5 MW

Energy Cost = $100,000 *Area cost* = $ *228,800*

TAC=$100,000+22,880= =$128,290 (n=10)

QUESTION

- ***Is the total area predicted this way, realistic? That is, is it close enough to a value that one would obtain from a final design?***

YES, Within 10-15%

QUESTION

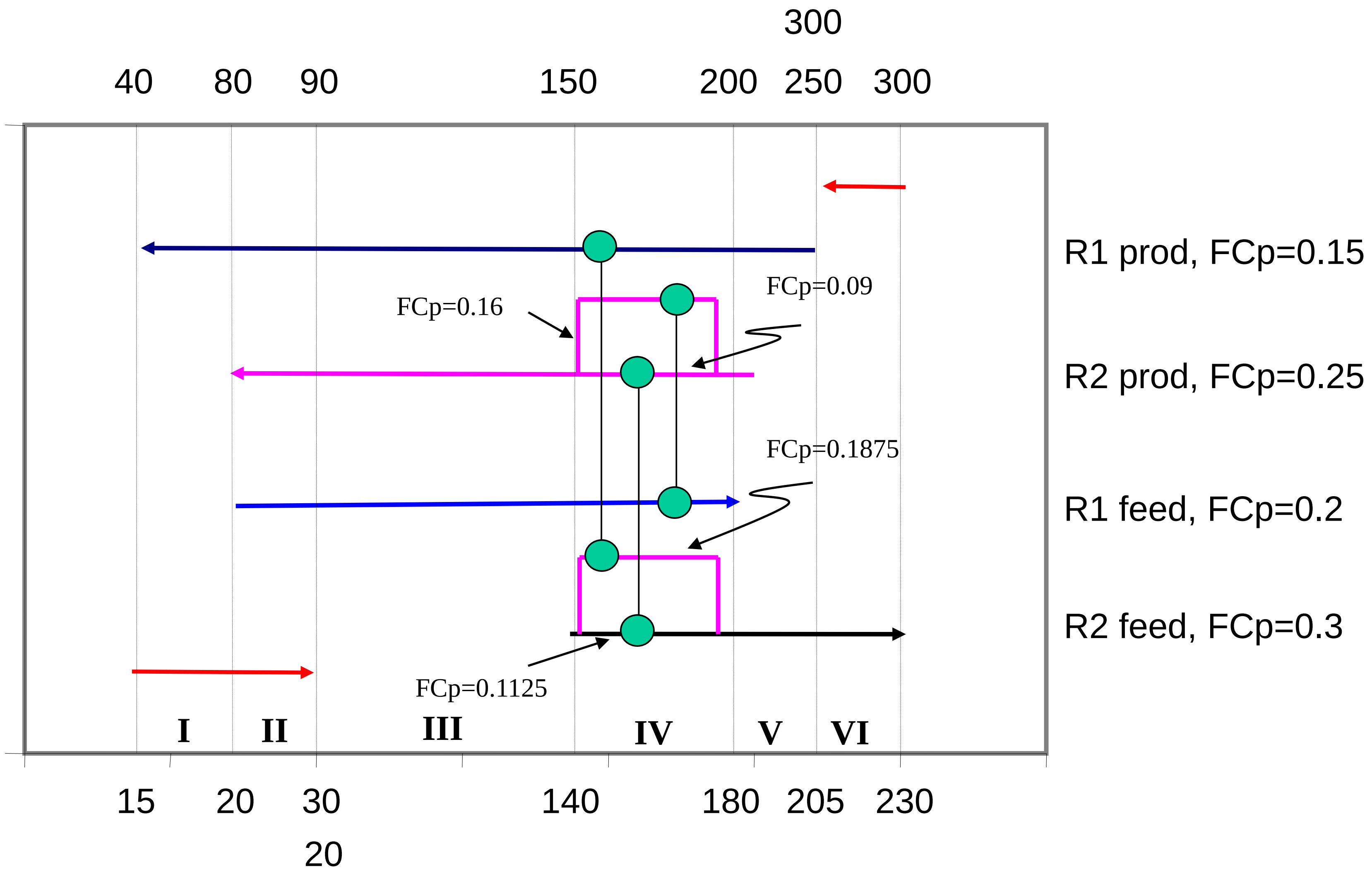
- ***How complex is a design built using the vertical transfer?***

Very Complex. Take for example interval 4. There are four streams in this interval.

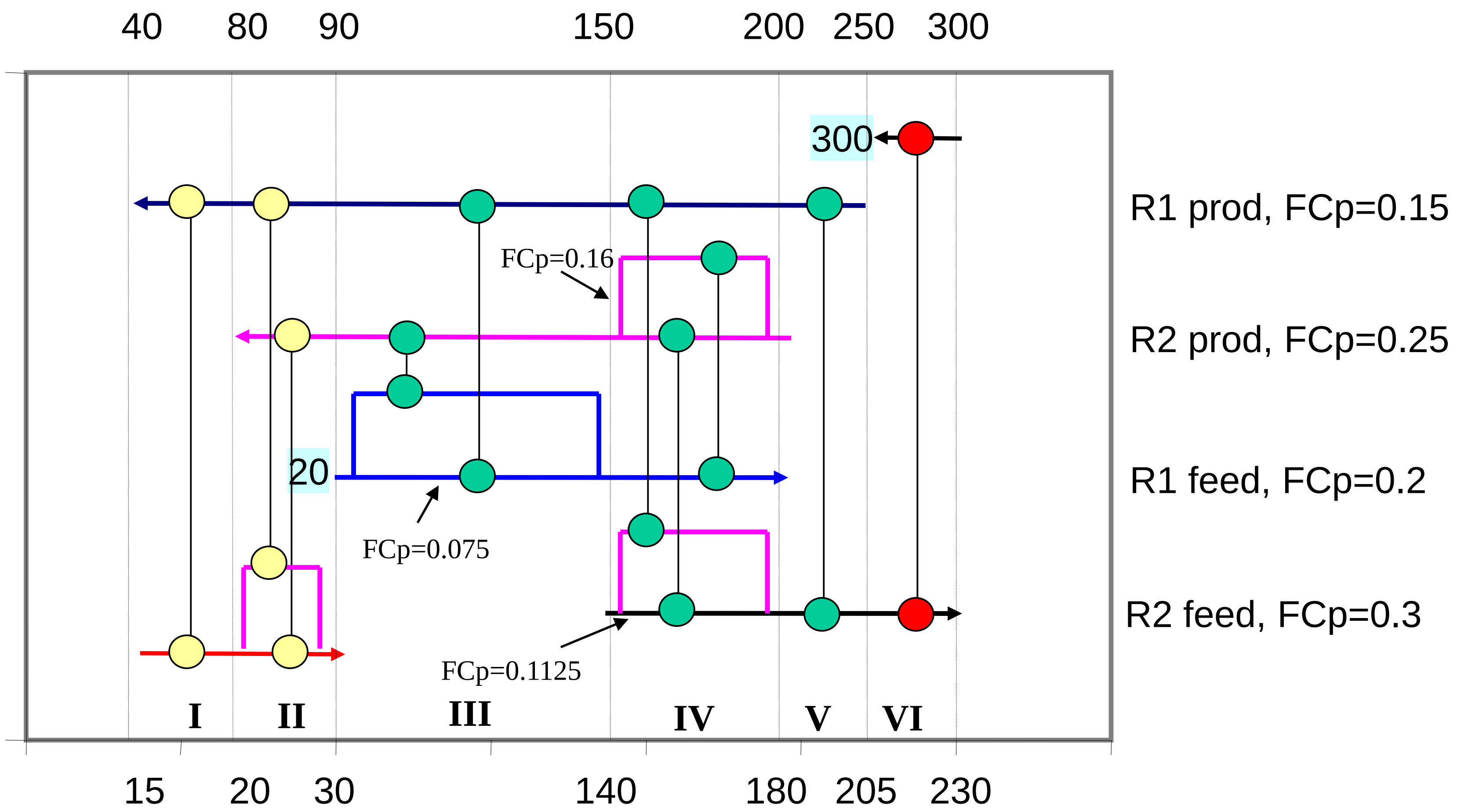
Stream	Type	Supply T	Target T	ΔH	F*Cp
			(°C)	(°C)	(MW)
(MW °C^{-1})					
Reactor 1 feed	Cold	140	180	8.0	0.2
Reactor 1 product	Hot	200	150	-7.5	0.15
Reactor 2 feed	Cold	140	180	12.0	0.3
Reactor 2 product	Hot	200	150	-12.5	0.25

This implies at least three heat exchangers, just in this interval.

HEAT EXCHANGER NETWORK



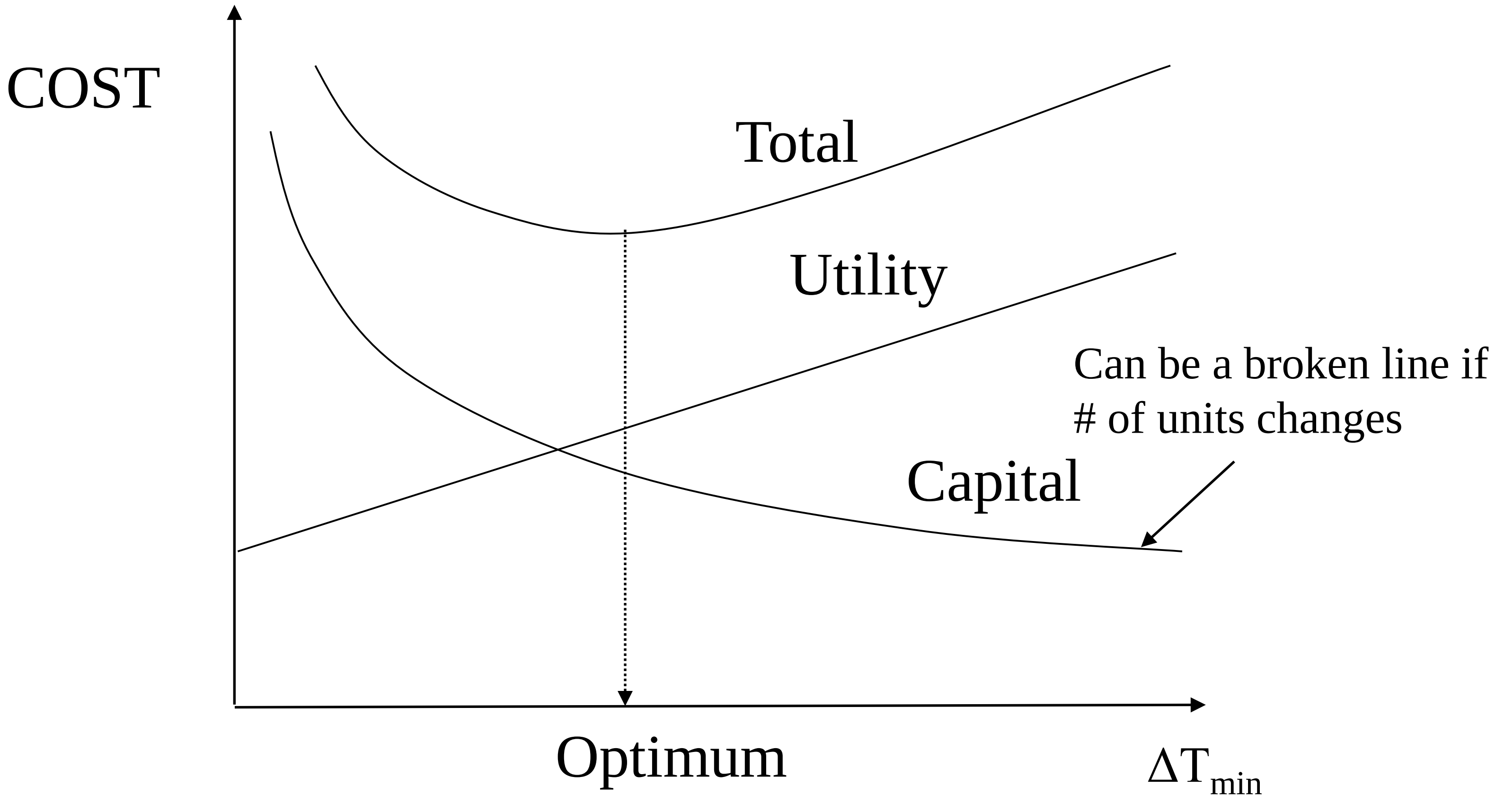
HEAT EXCHANGER NETWORK



TOTAL= 10 Exchangers

SUPERTARGETING

- Economy of the system is dependent on ΔT_{min}



SUPERTARGETING

- Economy of the system is dependent on ΔT_{min}