SKF4153- PLANT DESIGN

HEAT INTEGRATION

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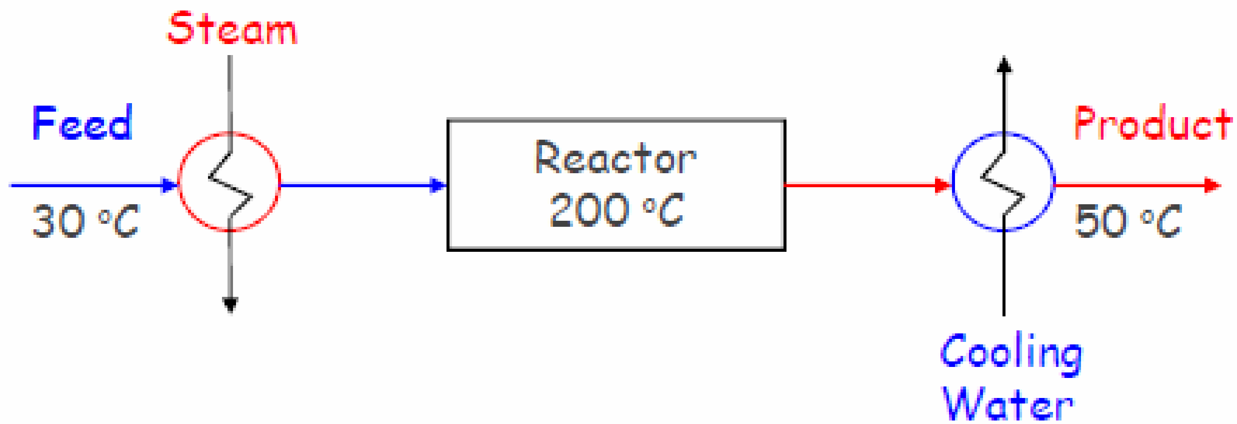
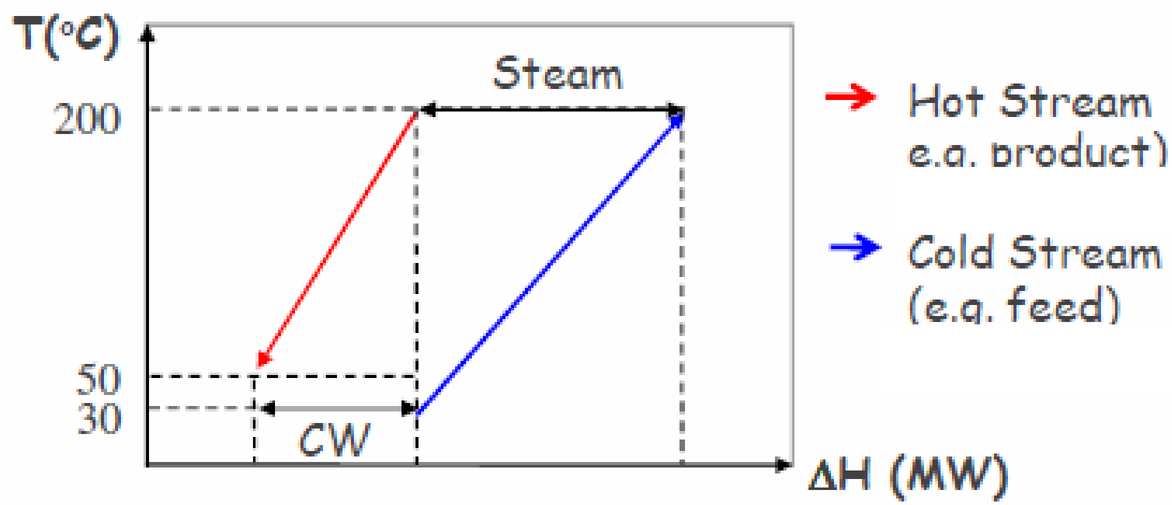
BY NC SA

Process B-4 integration

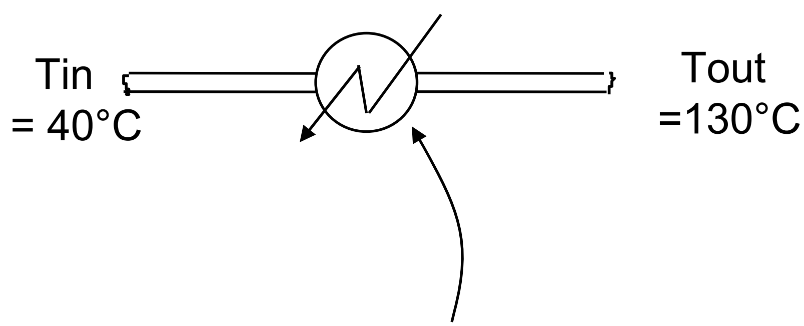


T-ΔH Plot



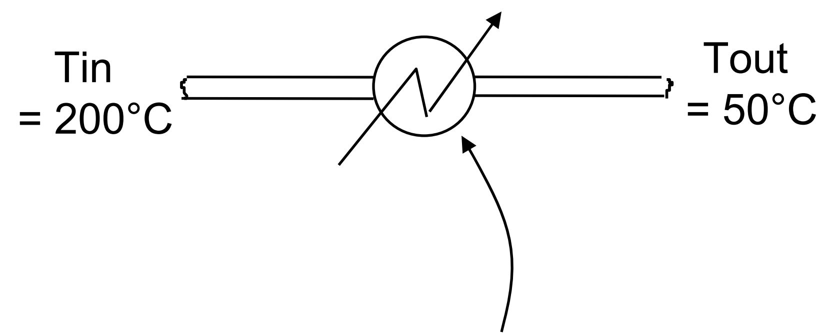
Heat Recovery Problem

Stream that needs heating -
A "*cold*" *stream* (heat sink)



Steam is used for heating

Stream that needs cooling -
A "*hot*" *stream* (heat source)

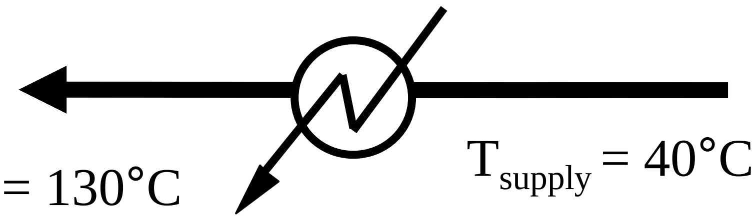


Cooling water is used for cooling

Consider heat exchange between the process streams to save hot utility (steam) and cold utility (cooling water).

How Much Heating Is Needed?

A Cold Stream (that needs heating)

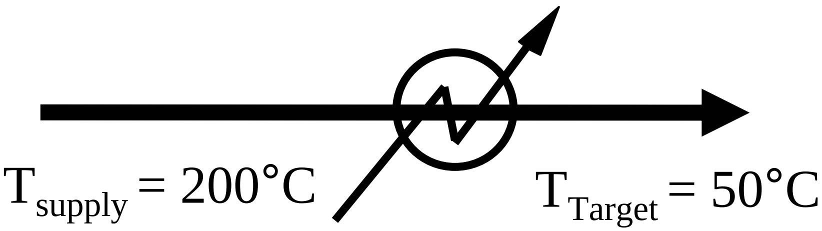


Heat Capacity Flowrate FC_P (MW/K)	Enthalpy Change ΔH (MW)
2.0	?

$$
\begin{aligned}
\Delta H &= FC_p \Delta T \\
&= FC_P (T_{target} - T_{supply}) \\
&= 2.0\,(130°C - 40\,°C) \\
&= 180\ \text{MW}
\end{aligned}
$$

How Much Cooling Is Needed?

<u>A Hot Stream</u> (that needs cooling)

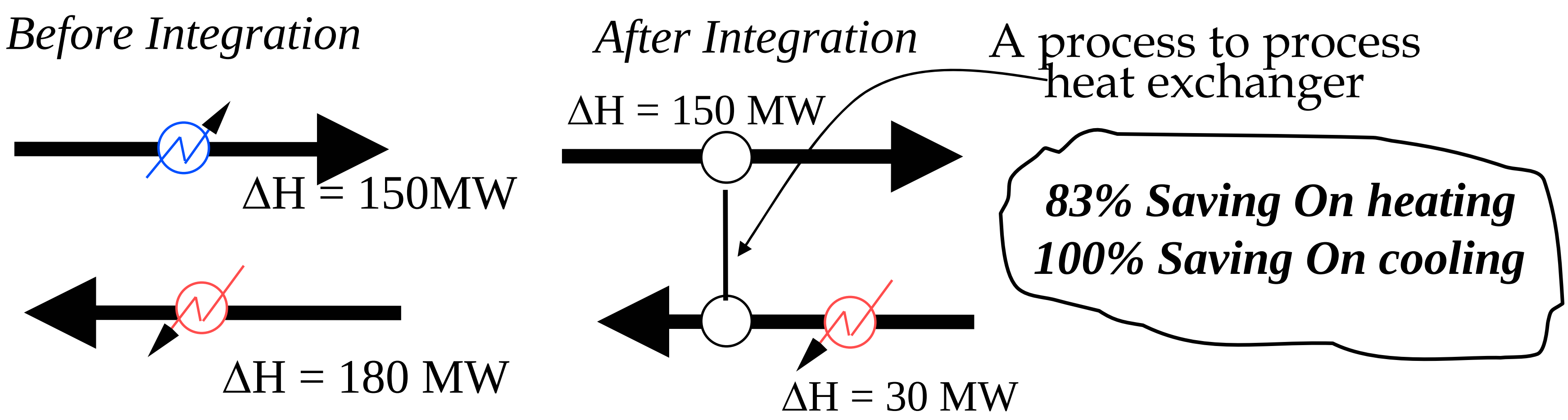


Heat Capacity Flowrate FC_P (MW/K)	Enthalpy Change ΔH (MW)
1.0	?

$$\begin{aligned}\Delta H &= FC_p \Delta T \\ &= FC_P (T_{target} - T_{supply}) \\ &= 1.0\ (50\ ^\circ C - 200^\circ C) \\ &= -150\ MW\end{aligned}$$

Heat Exchange Between Process Streams

Stream Number	Stream Type	T_{supply} (°C)	T_{target} (°C)	FC_P (MW/K)	ΔH (MW)
1	Cold	40	130	2.0	180
2	Hot	200	50	1.0	150



Pinch Design Targets

A systematic tool to design heat recovery networks for maximum energy recovery

Targets set ahead of design…..

(Use 1st Law of Thermodynamics)

What are the:

- Minimum heating requirement (Usually Steam Rate)
- Minimum cooling requirement (Usually CW Rate)
- Minimum number of units

Process Energy Targets

Process *energy targets* (steam and cooling water requirements) can be obtained from,

☆ *Composite Curves*

- cumulative process heat availability (surplus)
- cumulative process heat requirement (deficit)

🕐 *Problem Table* Algorithm

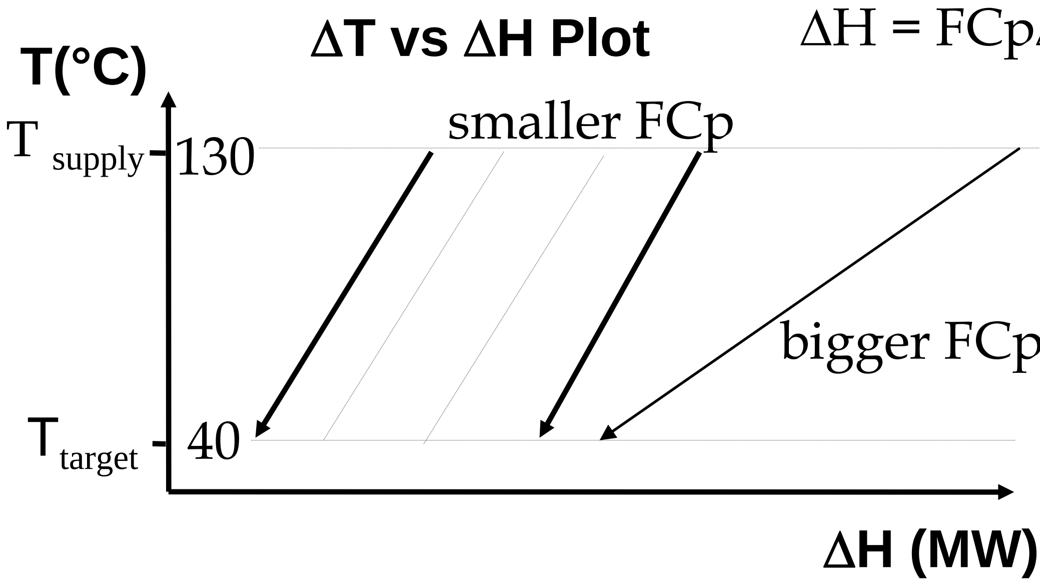
- process heat surpluses and deficits within some specified temperature intervals

Composite Curve

Temperature - Enthalpy Diagram

Given the stream Information :

Stream Number	Stream Type	T_{supply} (°C)	T_{target} (°C)	FC_P (MW/K)	ΔH (MW)
1	Cold	40	130	2.0	180

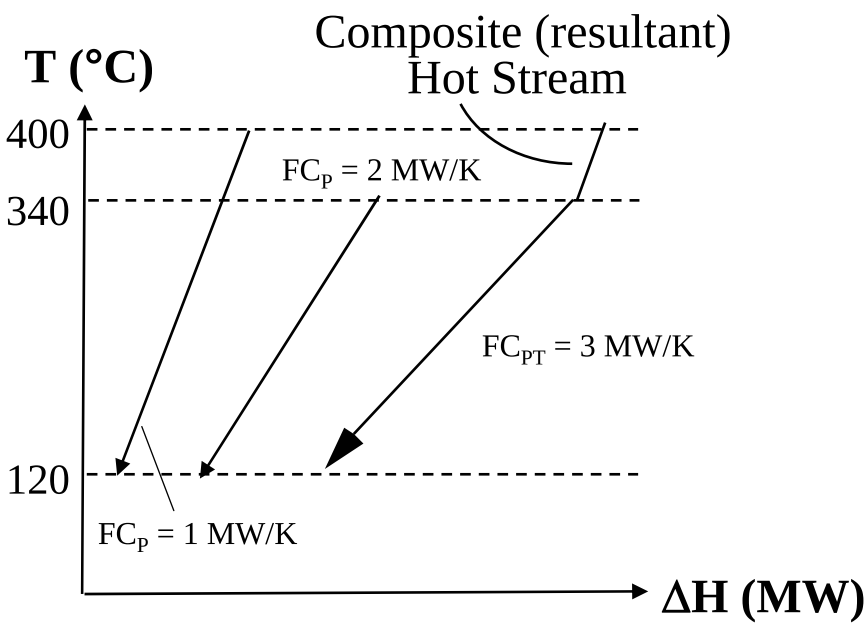


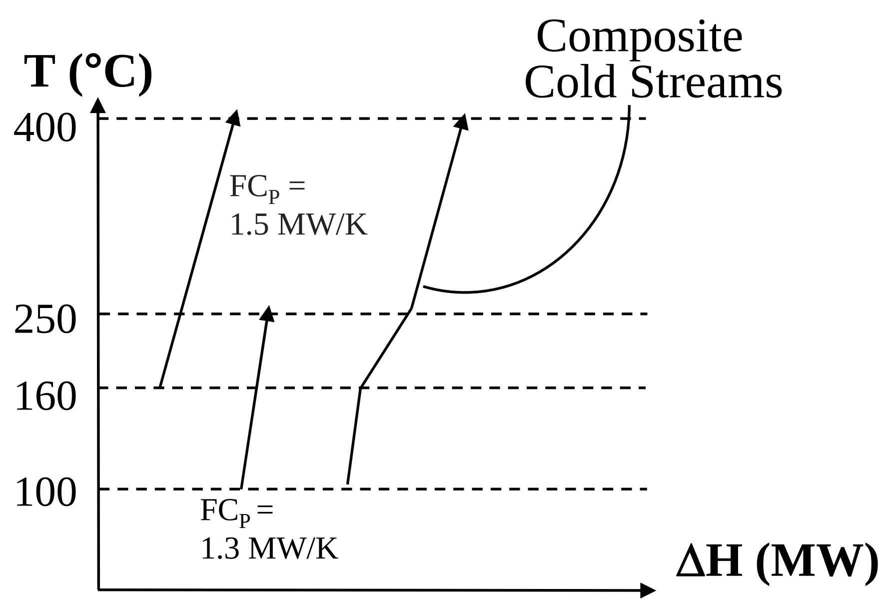
$\Delta H = FCp\Delta T \Rightarrow \Delta T/\Delta H = 1/FCp$

- ΔH is a relative quantity. Thus, the ΔT-ΔH curves can be shifted horizontally
- $1/FCp$ is the slope of the ΔT-ΔH curve

The Approach

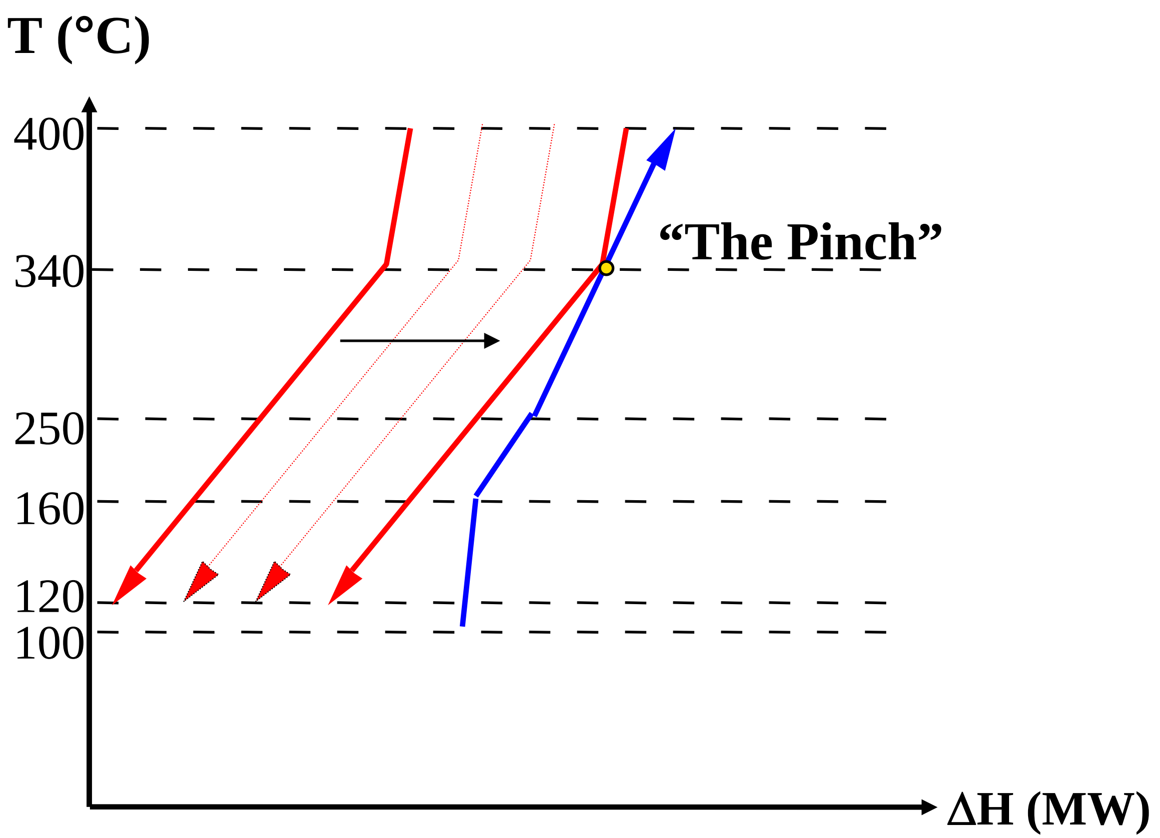
Stream Number	Stream Type	T_{supply} (°C)	T_{target} (°C)	FC_P (MW/K)	ΔH (MW)
1	Hot	400	120	1.0	-280
2	Hot	340	120	2.0	-440
3	Cold	160	400	1.5	360
4	Cold	100	250	1.3	195



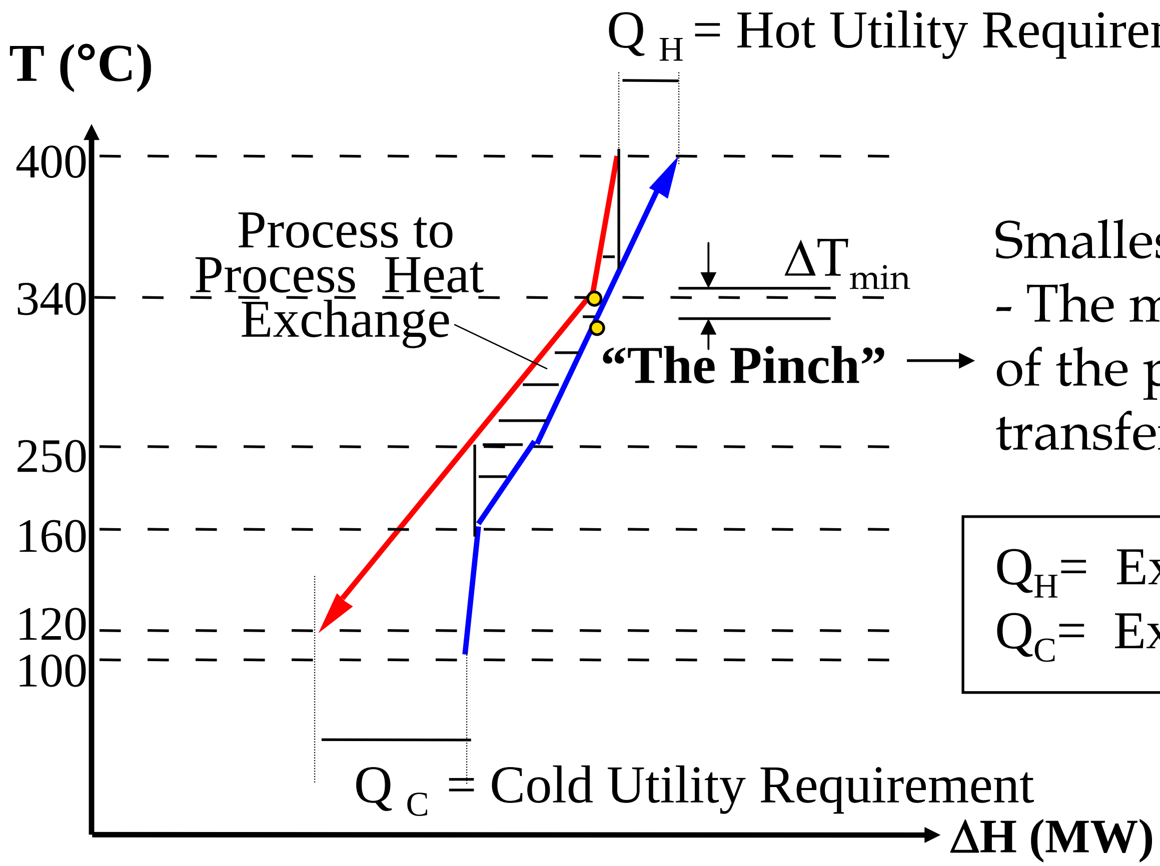


The "Pinch"

Hot and cold composites on the same ΔT-ΔH diagram

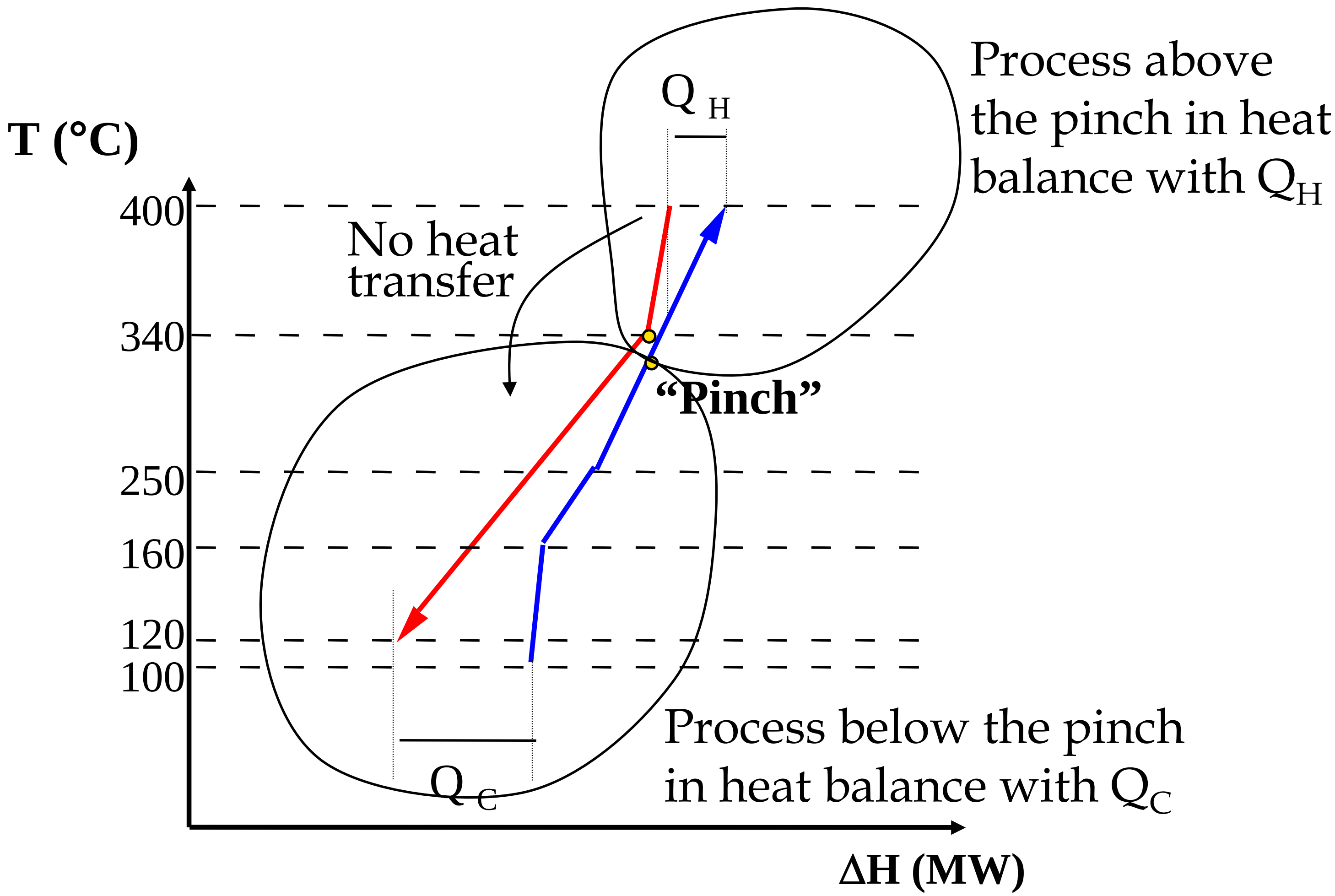


Hot and cold composites on the same ΔT-ΔH diagram



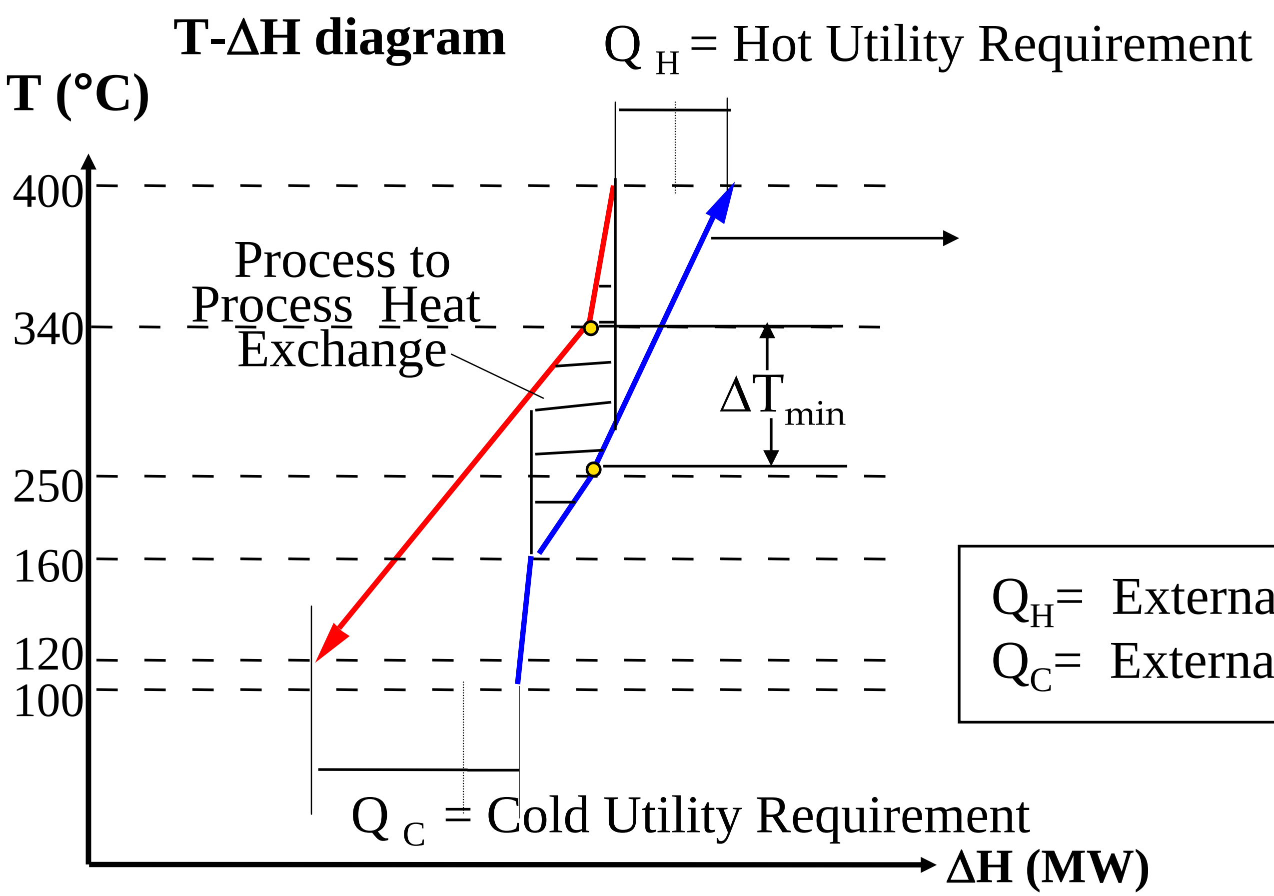
Smallest ΔT (driving force).
- The most constrained part of the process (in terms of heat transfer) is at the Pinch

Q_H= External Heating Duty
Q_C= External Cooling Duty



T (°C)
400
340
250
160
120
100
No heat
transfer
Q H
Process above
the pinch in heat
balance with Q_H
"Pinch"
Q C
Process below the pinch
in heat balance with Q_C
ΔH (MW)

Effect of ΔT_{min}

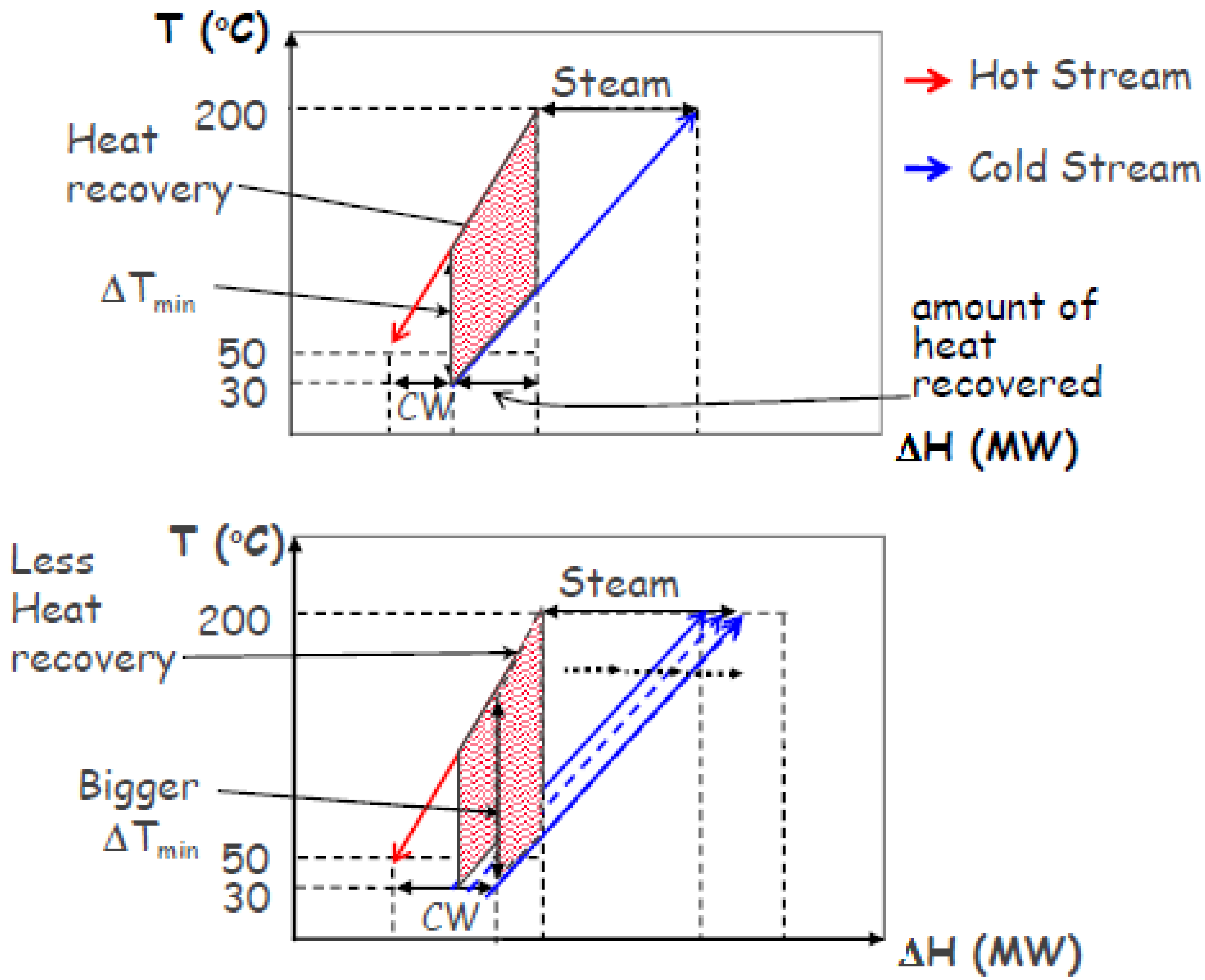


Q_H= External Heating Duty

Q_C= External Cooling Duty

Process
with integration

*ΔT_{min} =
the smallest
approach
temperature (ΔT)
for heat exchange



Significance of The "Pinch"

- The two composites can be moved horizontally to approach one another but is limited by a minimum approach temperature, ΔT_{min}

- There should be no heat transfer across the pinch.

❖ Do not heat below the pinch (no external heating)
❖ Do not cool above the pinch (external cooling)
❖ Do not transfer heat across the pinch

- Any external cooling above the pinch, or heating below the pinch will result in cross pinch heat transfer, thereby increasing the external heating requirement

Exercise

Stream data

$\Delta T_{min} = 10°C$

Stream	Type	T supply (°C)	T target (°C)	FC_P (MW/K)
C1	Cold	20	135	2
C2	Cold	80	140	4
H1	Hot	170	60	3
H2	Hot	150	30	1.5

Verify that $Q_{H,min}$=20MW; $Q_{C,min}$=60MW

Problem Table Algorithm

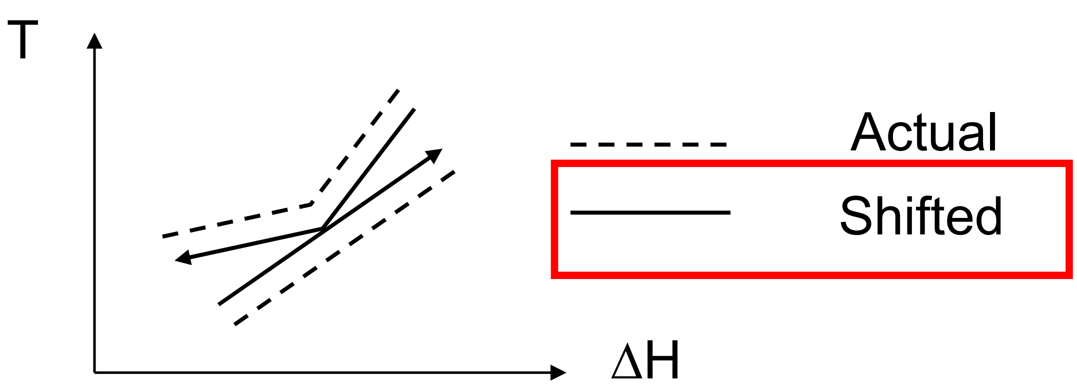
Global Temperature Interval

Actual Temperatures

	T_S	T_T
C1	60°	160°
C2	116°	260°
H1	160°	93°
H_2	249°	138°

Shifted Temperatures

	T_S	T_T
C1	65°	165°
C2	121°	265°
H1	155°	88°
H2	244°	133°

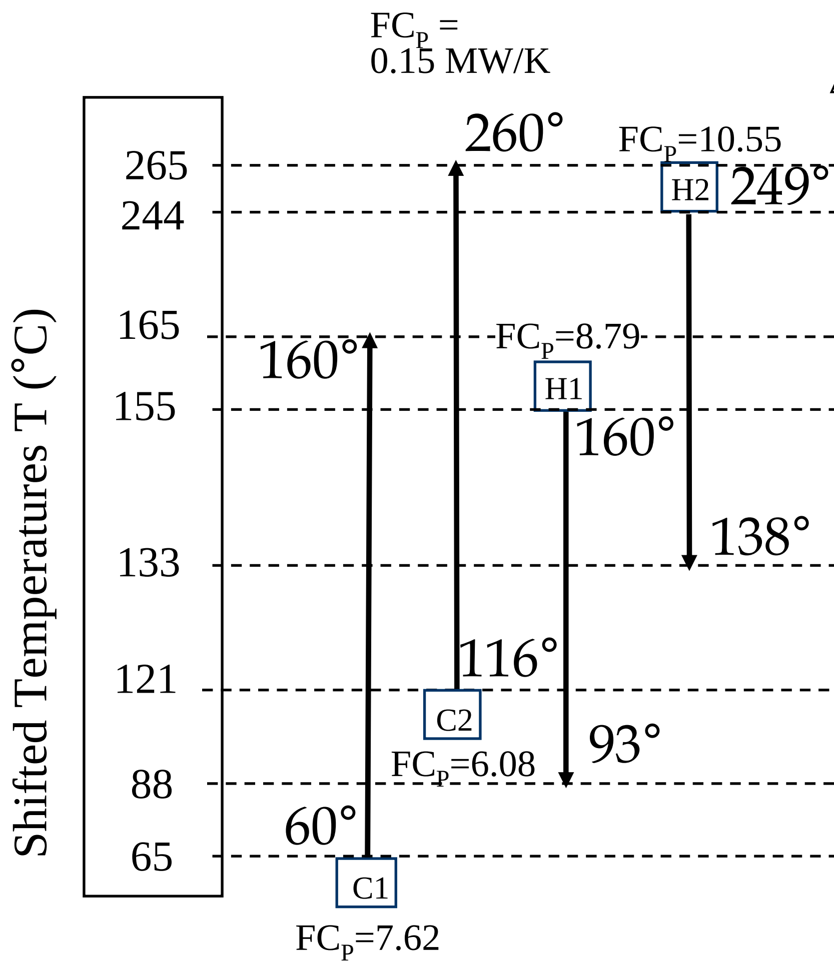


Hot: - $\Delta T_{min}/2$
Cold: + $\Delta T_{min}/2$

Remove Duplicates, and Set Up Global Temperature Intervals

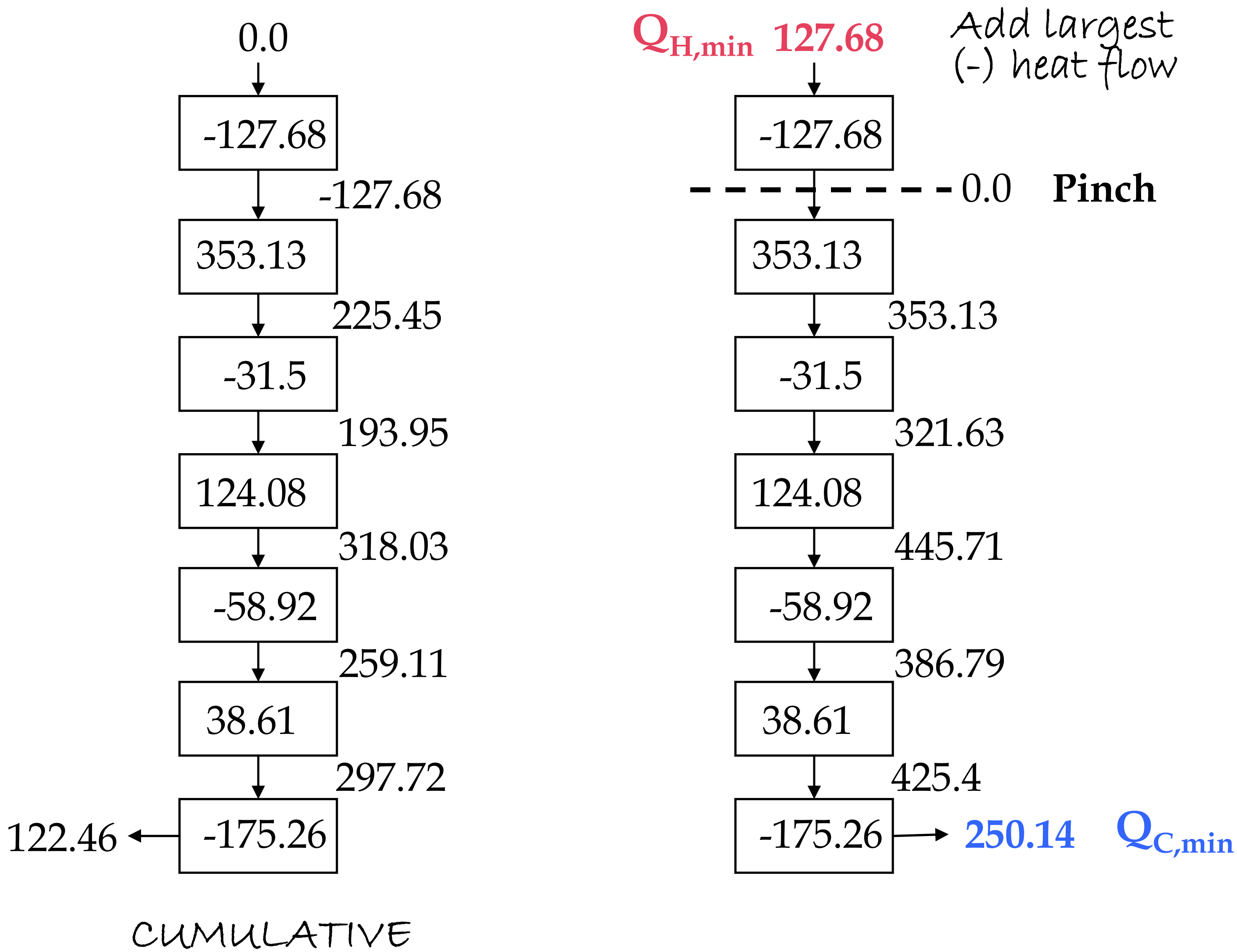
Stream	T_S / T_T	Remove Duplicates (if any)	Set up Intervals
C1	25	25	165
	140	140	145
C2	85	85	140
	145	145	85
H1	165	165	55
	55	55	25
H2	145	duplicate	
	25	duplicate	

Problem Table with Global T_{int}



$\Delta T_{interval}$	$\Sigma FC_{PH} - \Sigma FC_{PC}$	ΔH_i
21	-6.08	-127.68 (Deficit)
79	4.47	353.13 (Surplus)
10	-3.15	-31.5 (Deficit)
22	5.64	124.08 (Surplus)
12	-4.91	-58.92 (Deficit)
33	1.17	38.61 (Surplus)
23	-7.62	-175.26 (Deficit)

Heat Cascade



Problem Table - Procedure Summary

- Get shifted T_S , T_T and T_{int}
- Do interval heat balances - get int. heat surpluses and deficits
- Cascade from higher to lower Ts
- Cascade for positive heat flows between intervals
- Add the largest negative heat flow
- Find T_{Pinch}, Q_{Hmin} and Q_{Cmin}

Results Summary

- Minimum Process Heating Requirement from Hot Utility (e.g. steam) = 127.68 MW
- Minimum Process Cooling Requirement from Cold Utility (e.g. cooling water) = 250.14 MW
- Pinch (Interval) Temperature = 244 °C
- For ΔT_{min} = 10°C
- Hot Stream Pinch Temperature = 249°C
- Cold Stream Pinch Temperature = 239°C

Give yourself a TRY

Stream No.	Stream type	Supply Temperature, T_S (°C)	Target Temperature, T_T (°C)	Heat capacity flow rate, FCp (kW/°C)
1	Hot	120	86	10.99
2	Hot	260	160	6.04
3	Hot	83.3	70	13.13
4	Hot	160	50	6.56
5	Cold	50	97	11.83
6	Cold	104	124	14.89
7	Cold	86	230	5.69

References

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