

# CHEMICAL ENGINEERING DESIGN & SAFETY CHE 4253

Prof. Miguel Bagajewicz

Heat Integration  
Pinch Design Method

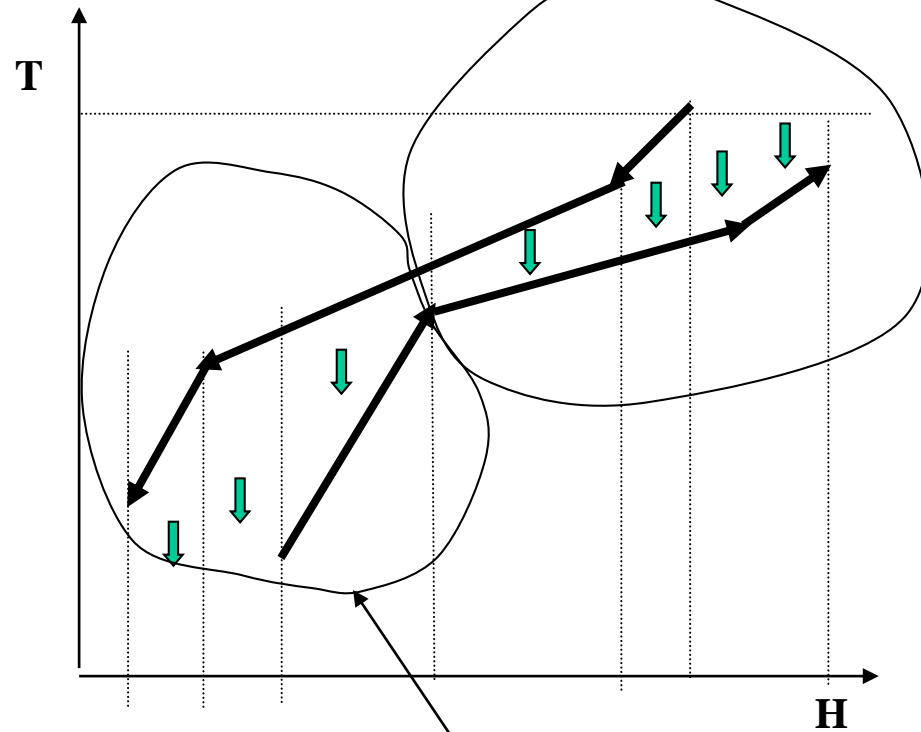
# DIVISION AT THE PINCH

## RECALL THAT

- No heat is transferred through the pinch.
- This makes the region above the pinch a HEAT SINK region and the region below the pinch a HEAT SOURCE region.

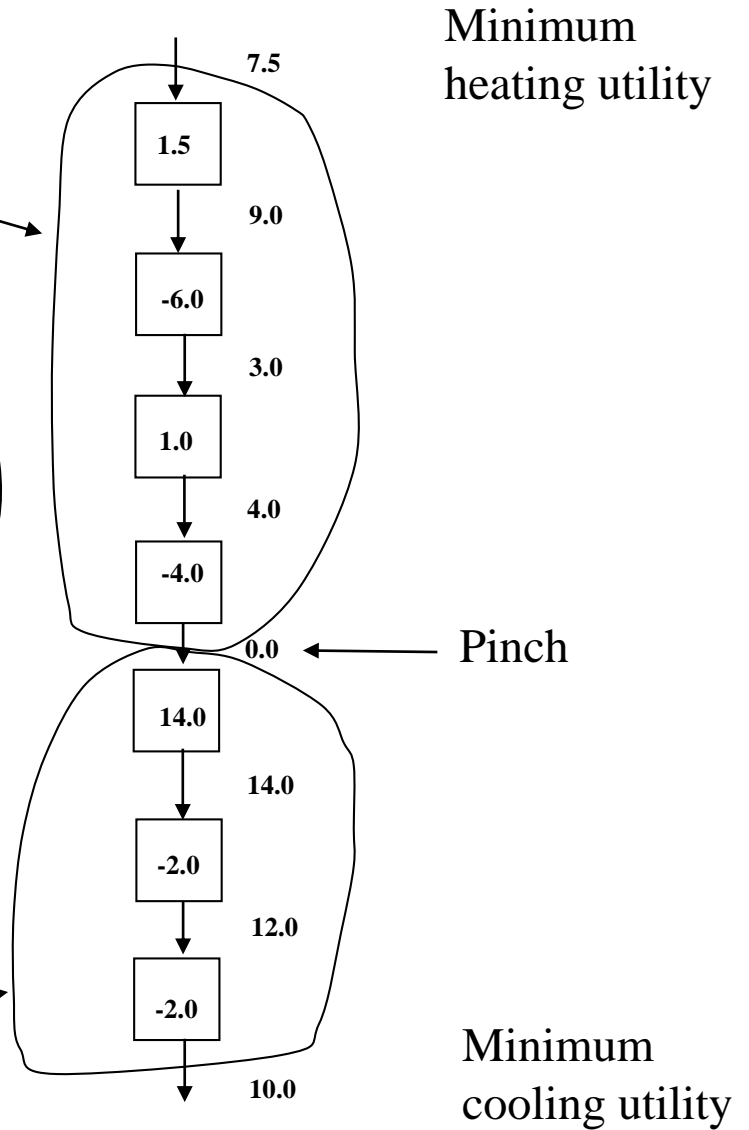
# Heat Sink

Heat is obtained from the heating utility



# Heat Source

Heat is released to cooling utility

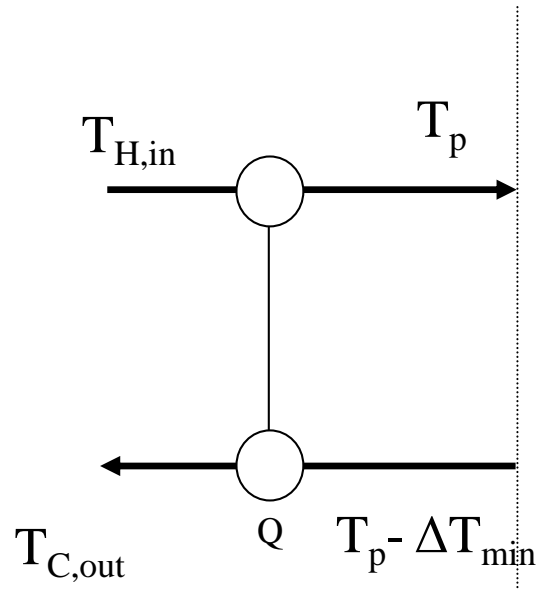


# CONCLUSION

- One can analyze the two systems separately, that is,
- Heat exchangers will not match streams above the pinch with streams below the pinch

# PINCH MATCHES

- Consider two streams above the pinch



$$T_{C,out} = T_p - \Delta T_{min} + Q/FCp_C$$

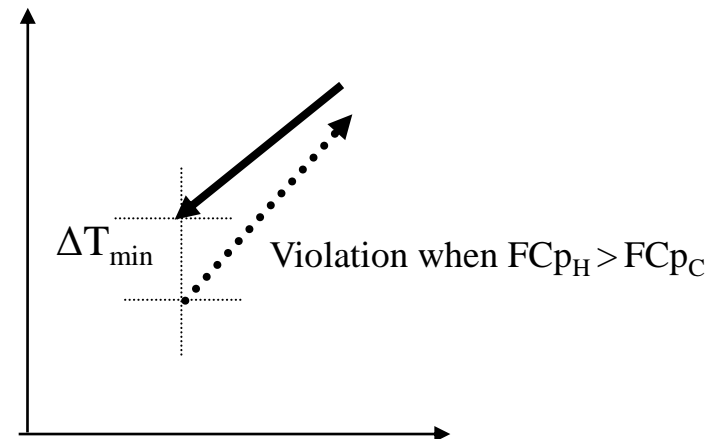
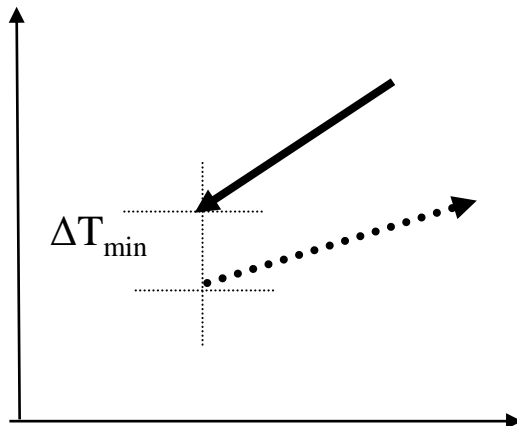
$$T_{H,in} = T_p + Q/FCp_H$$

$$\text{But } T_{H,in} > T_{C,out} + \Delta T_{min}.$$

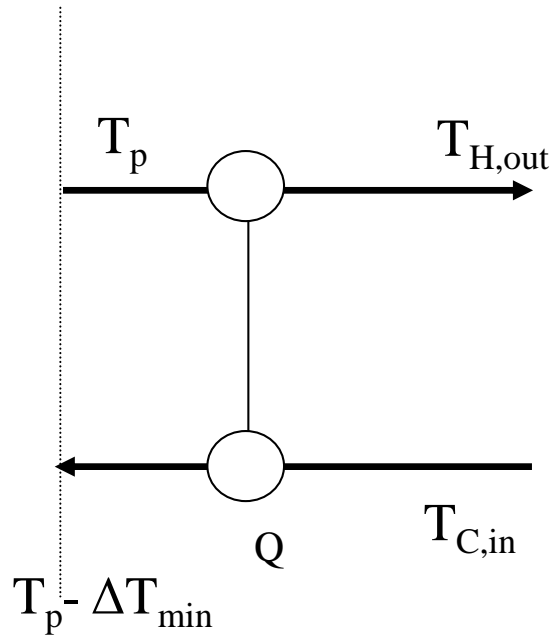
$$\text{Thus replacing one obtains } Q/FCp_H > Q/FCp_C$$

$$FCp_H < FCp_C$$

Golden rule for pinch matches above the pinch.



# Below the Pinch



$$T_{C,in} = T_p - \Delta T_{min} - Q/FCp_C$$

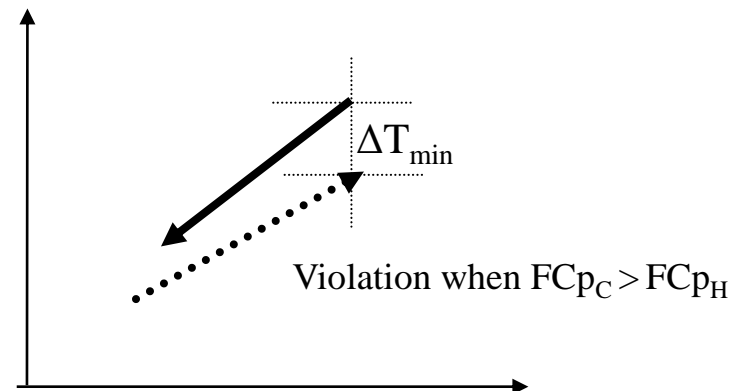
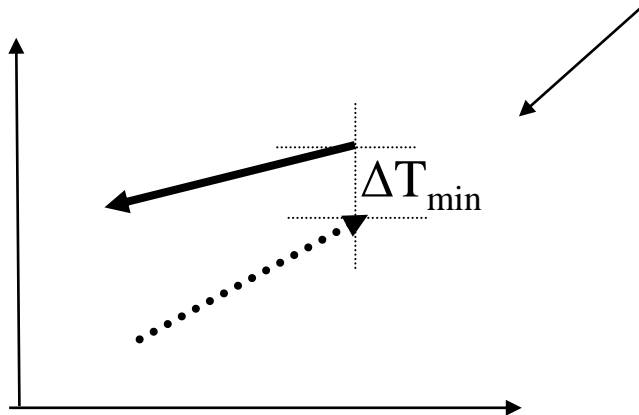
$$T_{H,out} = T_p - Q/FCp_H$$

$$\text{But } T_{H,out} > T_{C,in} + \Delta T_{min}.$$

Thus replacing one obtains

$$FCp_C < FCp_H$$

Golden rule for pinch matches below the pinch.



# CONCLUSION

- Since matches at the pinch need to satisfy these rules, one should start locating these matches first. Thus, our first design rule:

START BY MAKING PINCH  
MATCHES

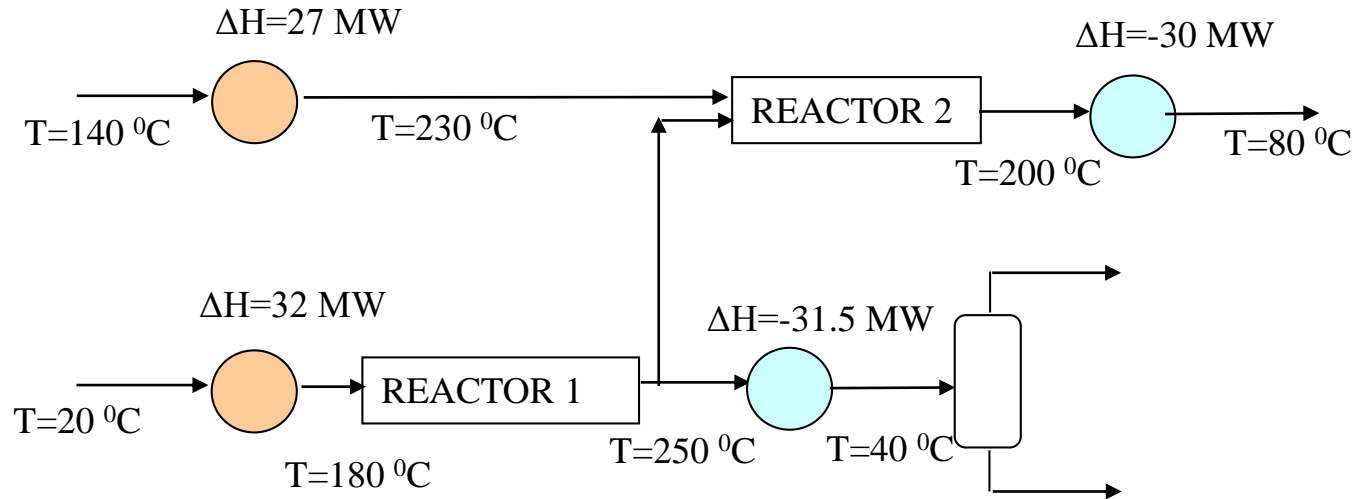
# TICK-OFF RULE

Once a match has been selected how much heat should be exchanged?

- As much as possible! (We want to minimize units, so once we have one, we make the biggest use of it possible)
- This means that one of the streams has its duty satisfied!!



# HANDS ON EXERCISE

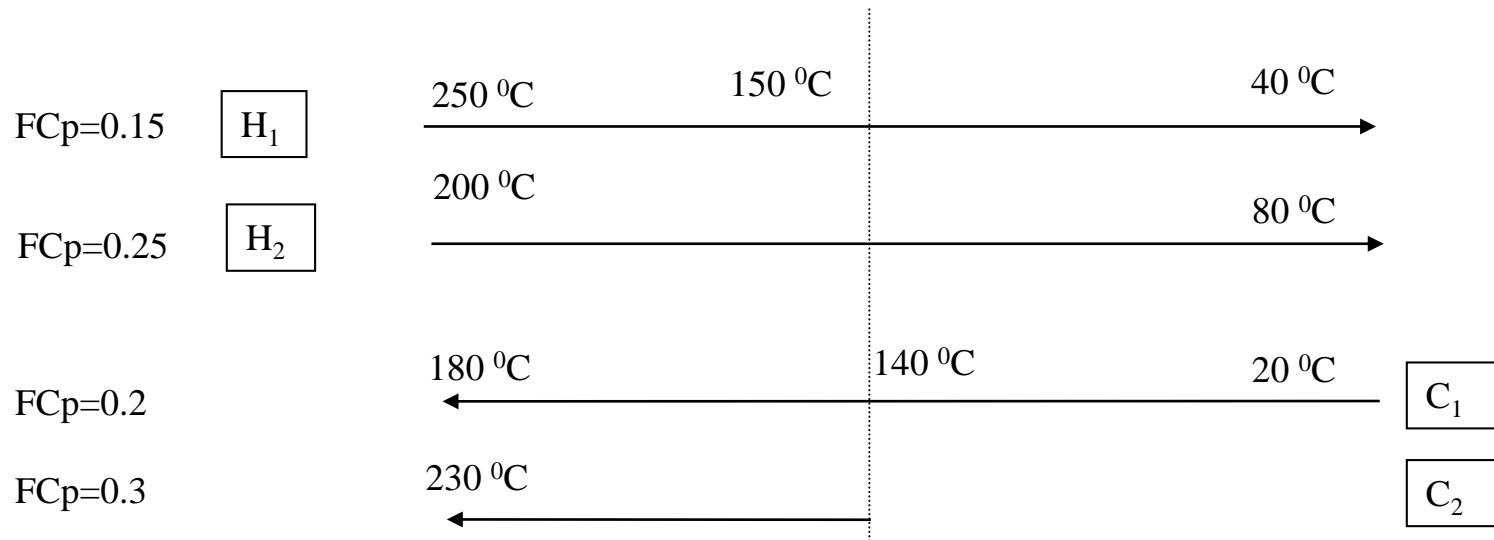


Stream	Type	Supply T ( $^{\circ}\text{C}$ )	Target T ( $^{\circ}\text{C}$ )	$\Delta H$ (MW)	$F \cdot C_p$ (MW $^{\circ}\text{C}^{-1}$ )
Reactor 1 feed	Cold	20	180	32.0	0.2
Reactor 1 product	Hot	250	40	-31.5	0.15
Reactor 2 feed	Cold	140	230	27.0	0.3
Reactor 2 product	Hot	200	80	-30.0	0.25

$$\Delta T_{\min} = 10\text{ }^{\circ}\text{C}$$

$$\text{PINCH} = 150\text{ }^{\circ}\text{C}$$

# HANDS ON EXERCISE

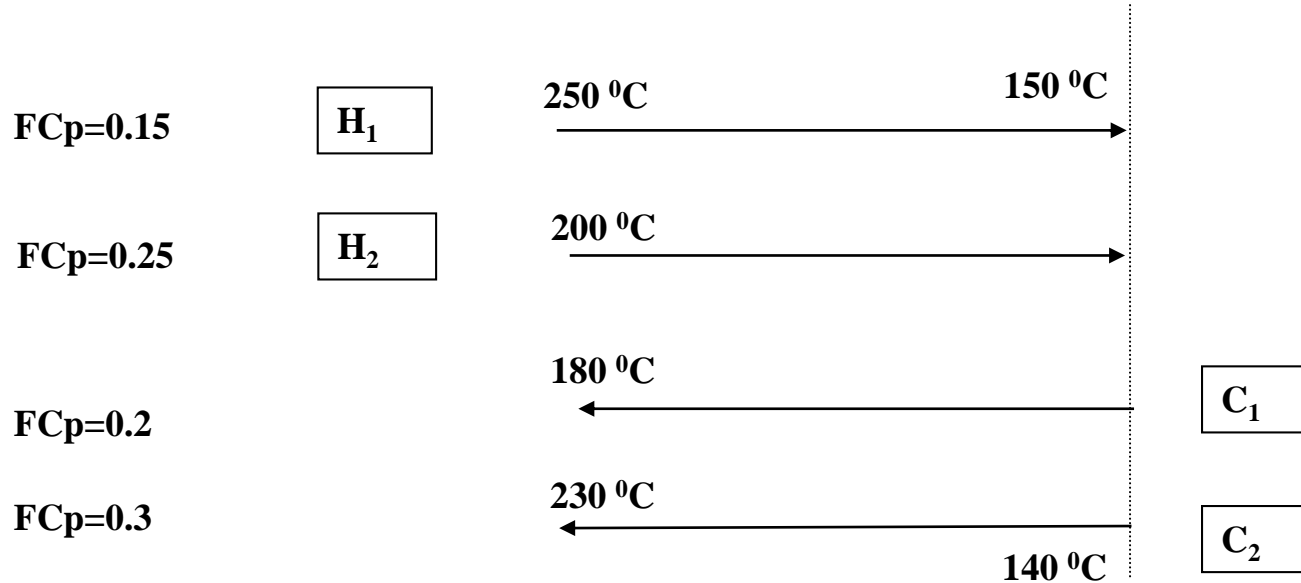


Stream	Type	Supply T (°C)	Target T (°C)	$\Delta H$ (MW)	$F \cdot C_p$ (MW °C <sup>-1</sup> )
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$$\Delta T_{\min} = 10 \text{ °C}$$

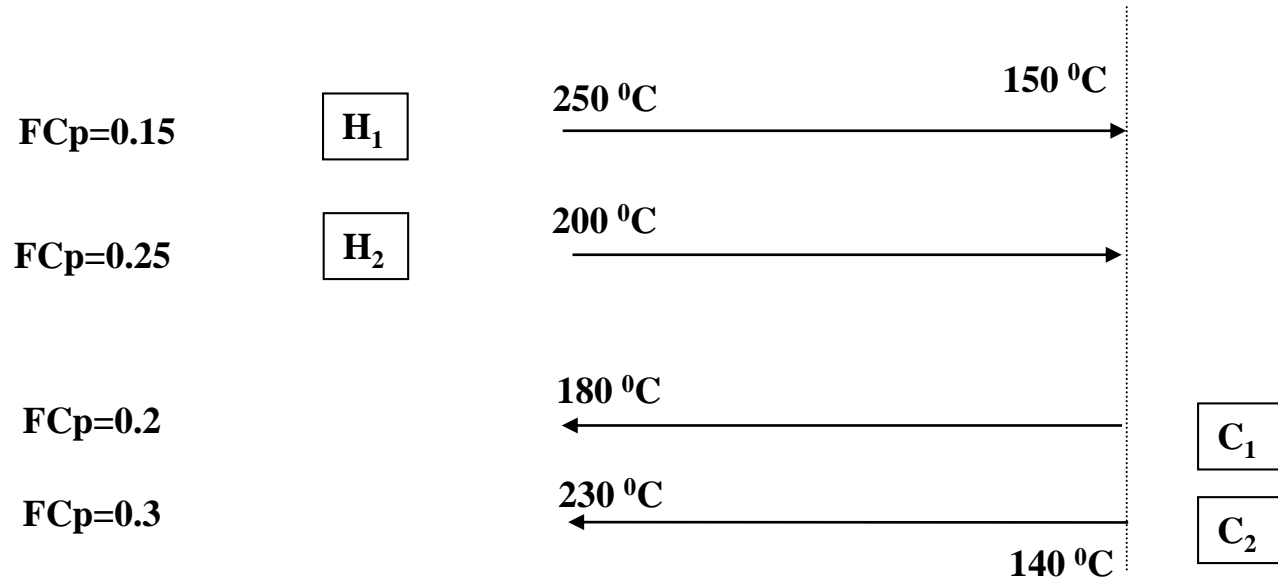
$$\text{PINCH} = 150 \text{ °C}$$

# ABOVE THE PINCH



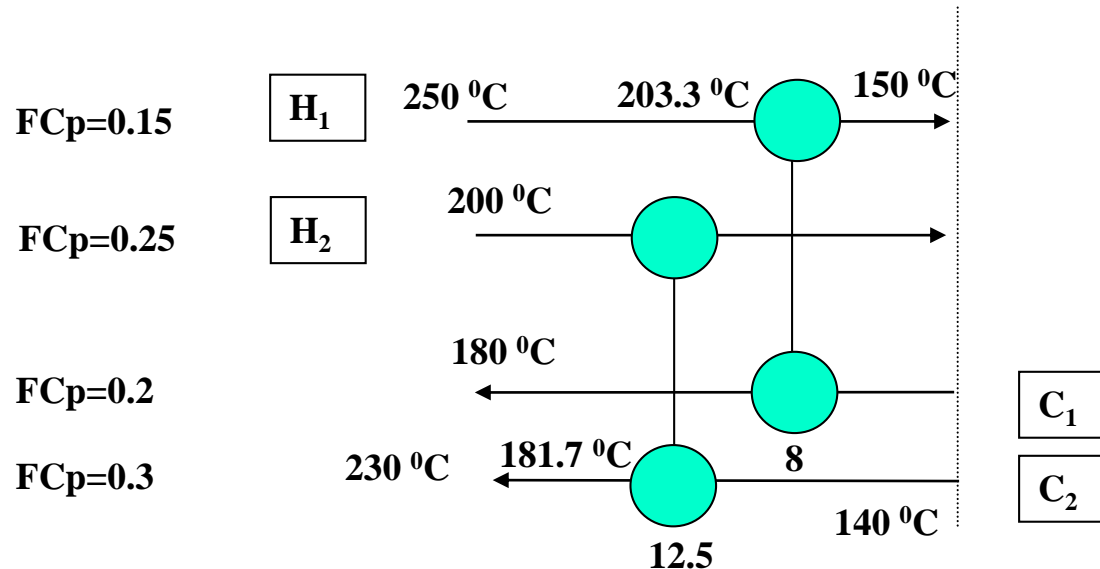
- Which matches are possible?

# Pinch matches above the Pinch



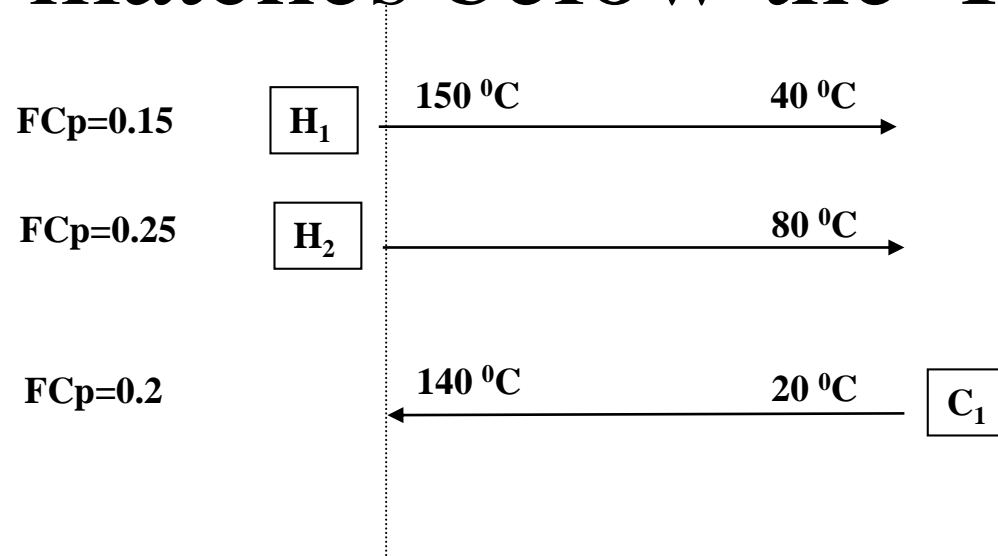
- The rule is that  $FCp_H < FCp_C$ .
- The candidates are: H1-C1, H1-C2 and H2-C2.
- Because all **hot** streams at the pinch need to participate in a pinch match, we therefore can only choose the matches H1-C1 and H2-C2.

# Pinch matches above the Pinch



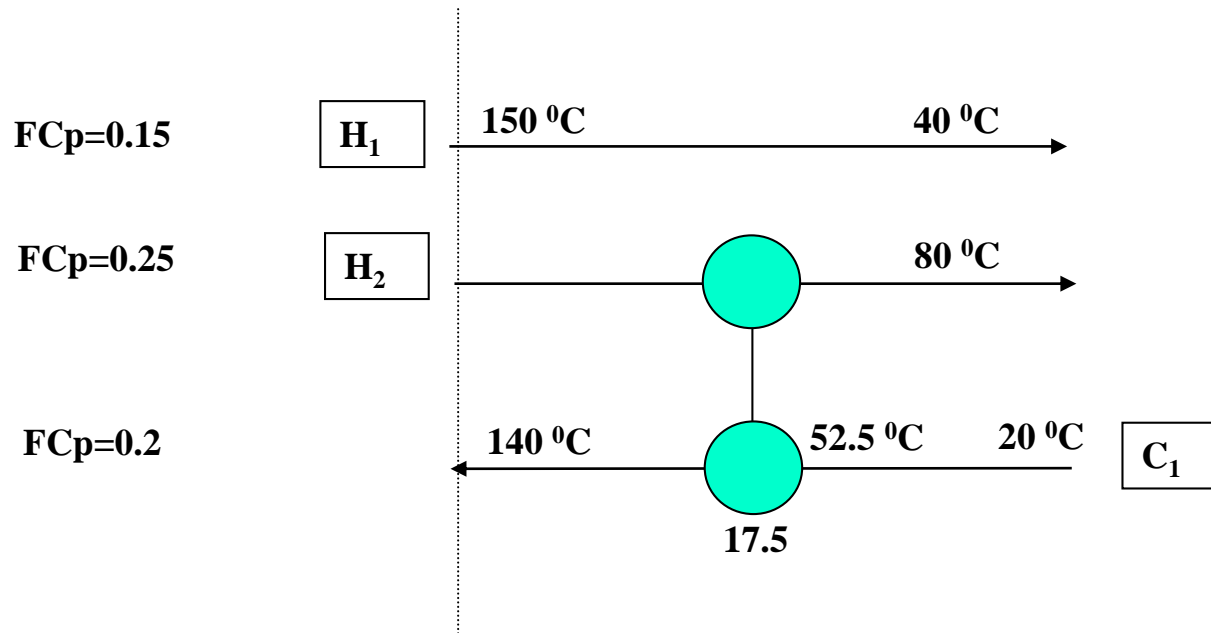
- The tick-off rule says that a maximum of 8 MW is exchanged in the match H1-C1 and as a result stream C1 reaches its target temperature.
- Similarly 12.5 MW are exchanged in the other match and the stream H2 reaches the pinch temperature.

# Pinch matches below the Pinch



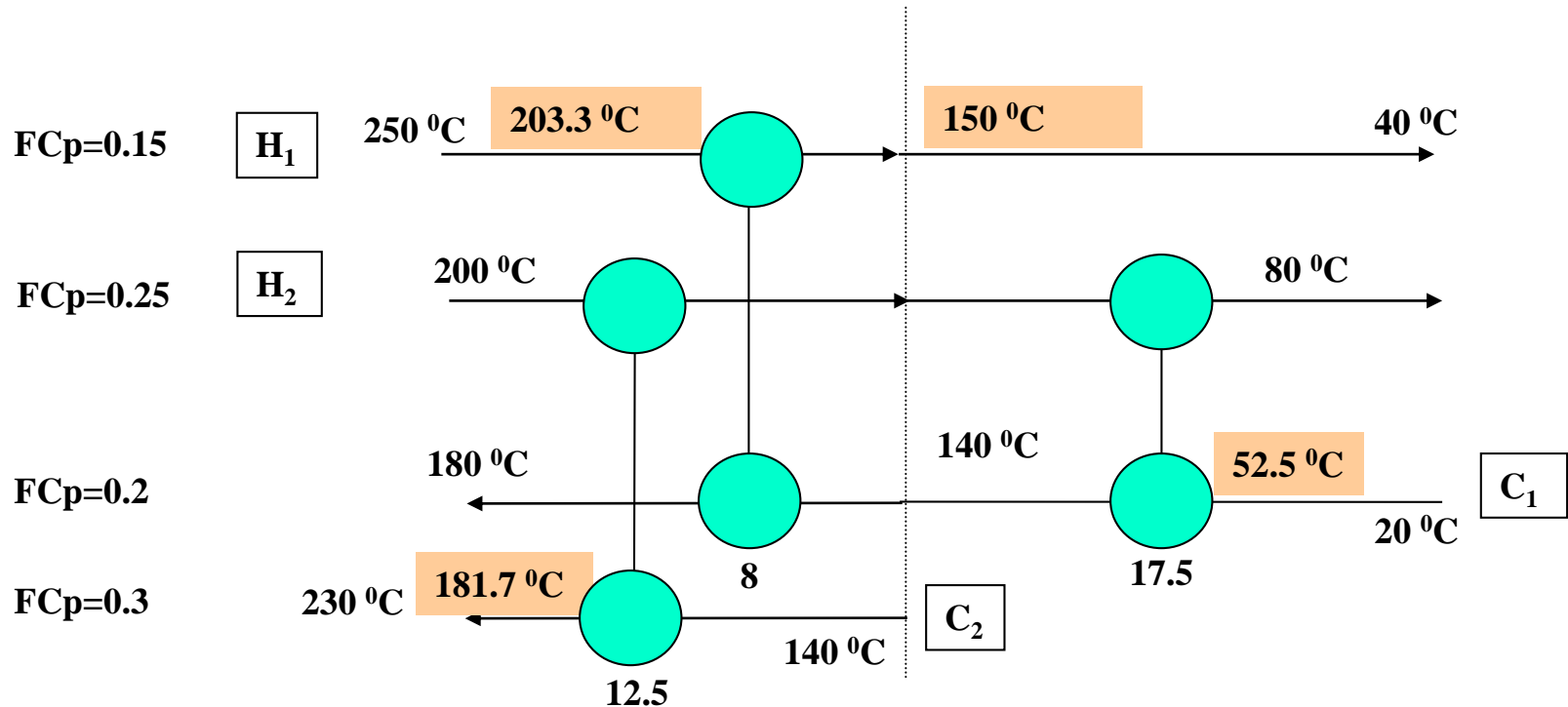
- The rule is that  $FCp_C < FCp_H$ .
- Only one match qualifies: H2-C1
- Below the pinch all **cold** streams need to participate in pinch matches

# ANSWER (below the pinch)



- The tick-off rule says that a maximum of 17.5 MW is exchanged in the match H2-C1 and as a result stream H2 reaches its target temperature.

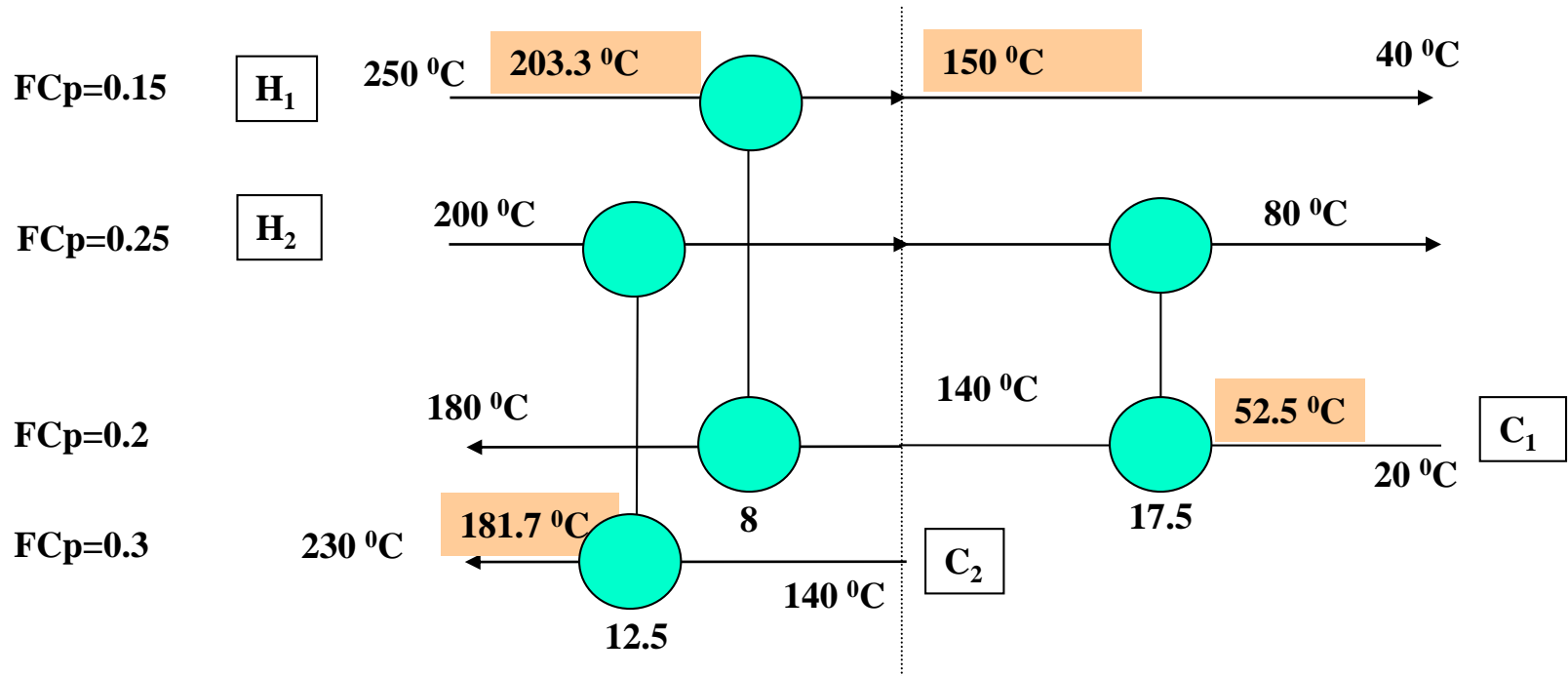
# COMPLETE NETWORK AFTER PINCH MATCHES



- Streams with unfulfilled targets are colored.

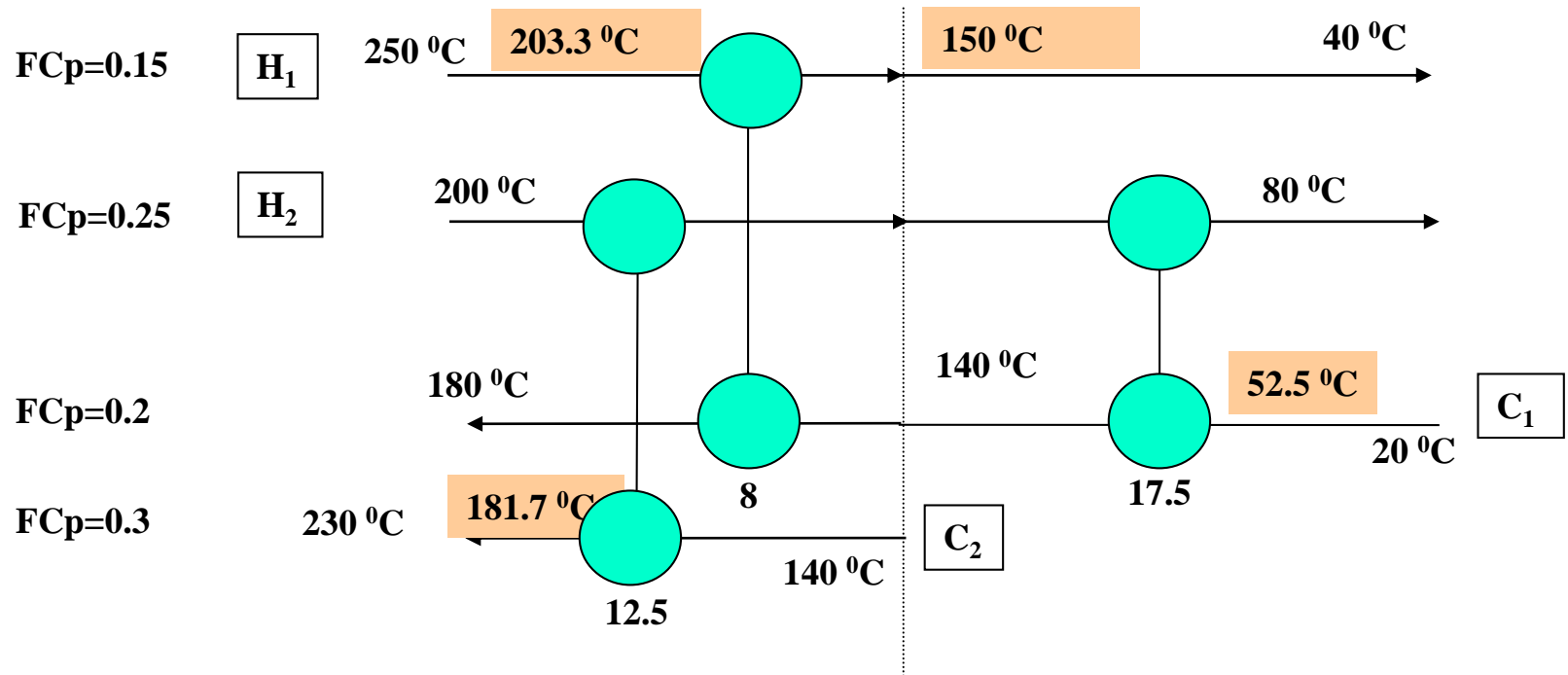


# NON-PINCH MATCHES



- Away from the pinch, there is more flexibility to make matches, so the inequalities do not have to hold.
- The pinch design method leaves you now on your own!!!!
- Therefore, use your judgment as of what matches to select!!

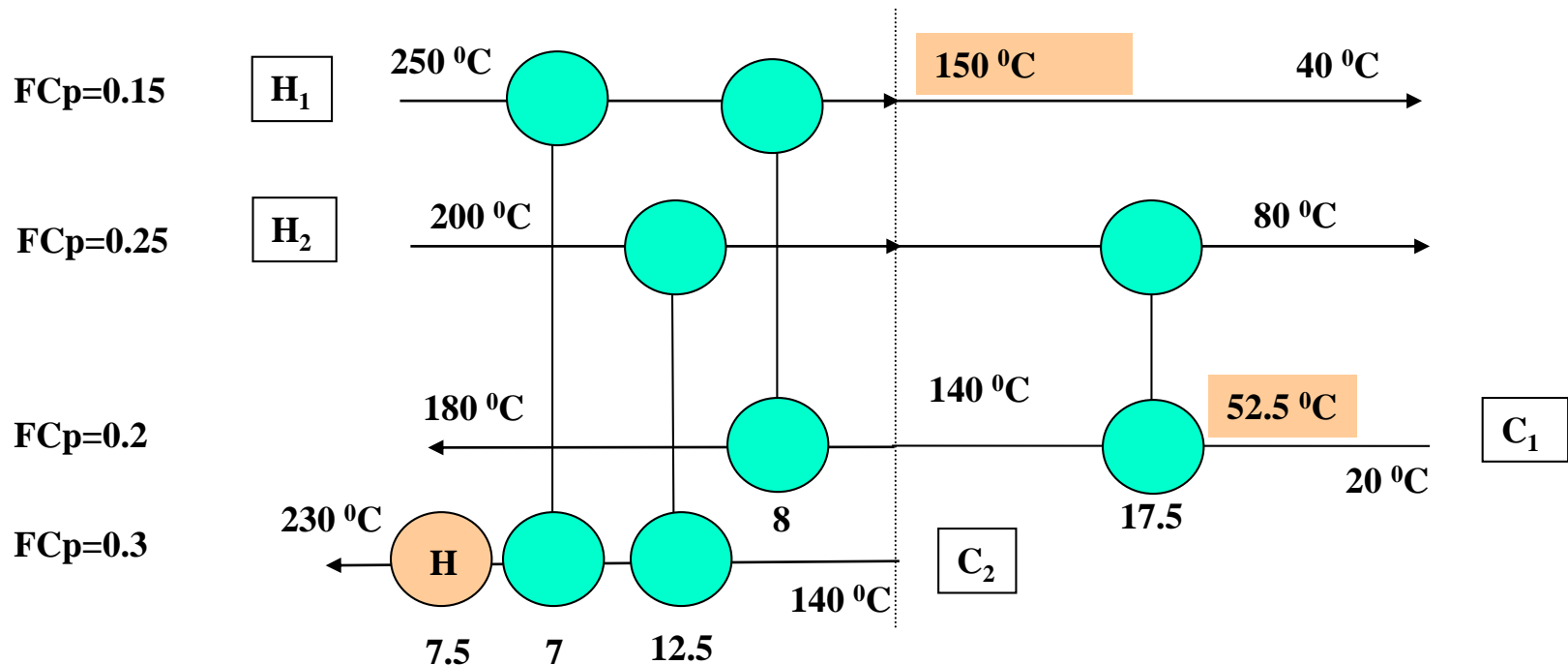
# NON-PINCH MATCHES



- We first note that we will use heating above the pinch. Thus all hot streams need to reach their inlet temperature. We are then forced to look for a match for H1.

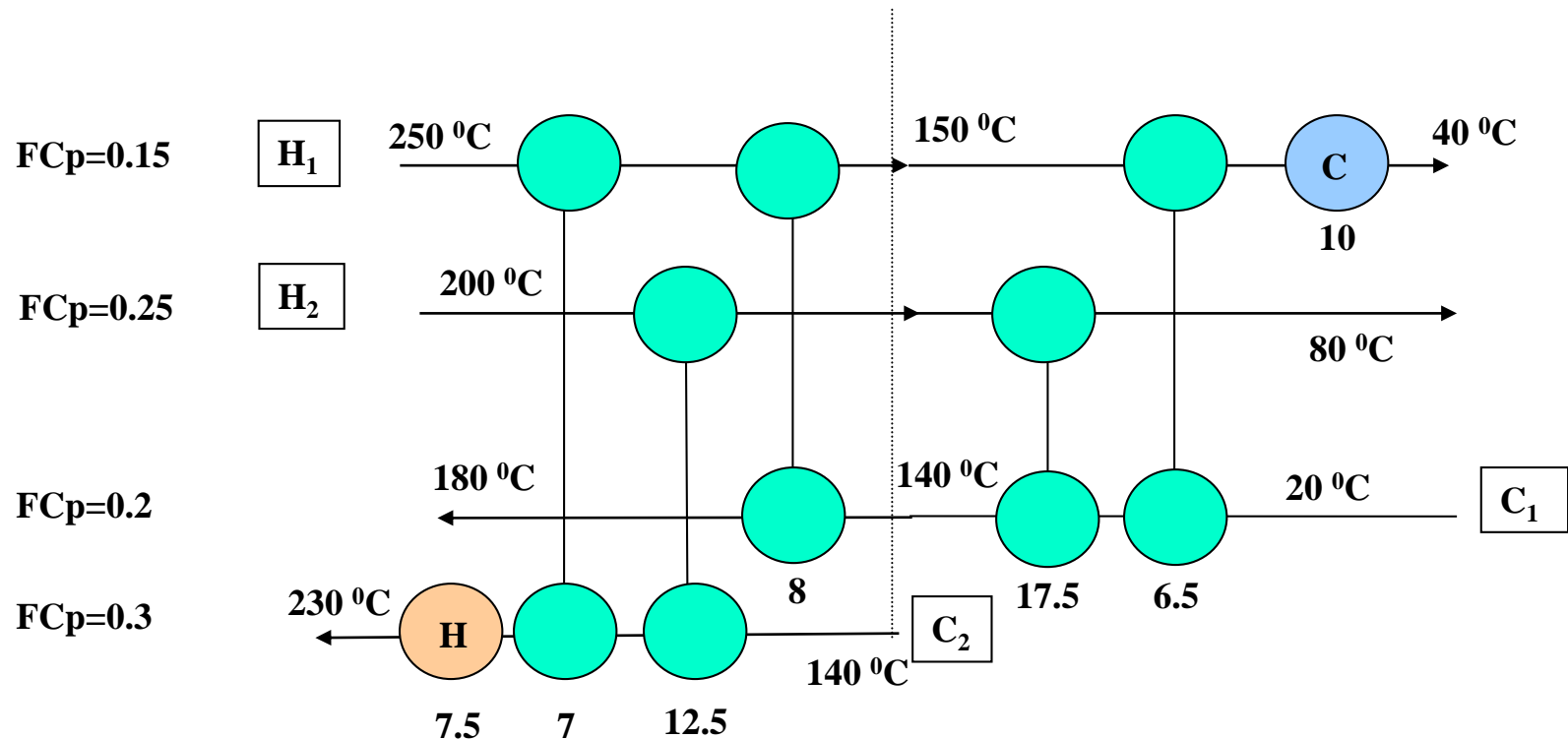
# NON-PINCH MATCHES

- The match is H1-C1. We finally put a heater on the cold stream



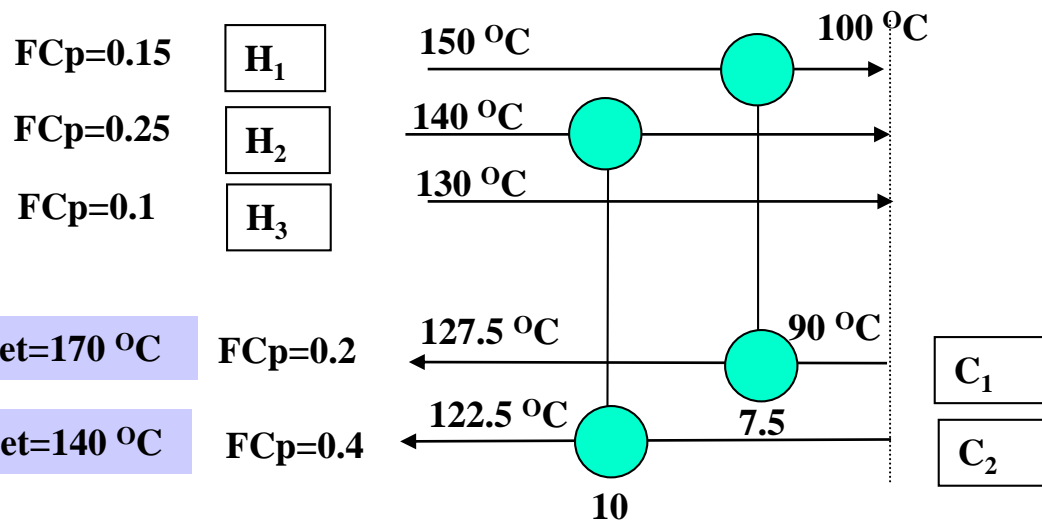
# NON-PINCH MATCHES

- Below the pinch we try to have the cold streams start at their inlet temperatures and we later locate coolers (one in this case).



# UNEQUAL NUMBER OF STREAMS AT THE PINCH

Indeed, if the number of hot streams is larger than the number of cold streams, then no pinch matches are possible. Consider this (new) example:

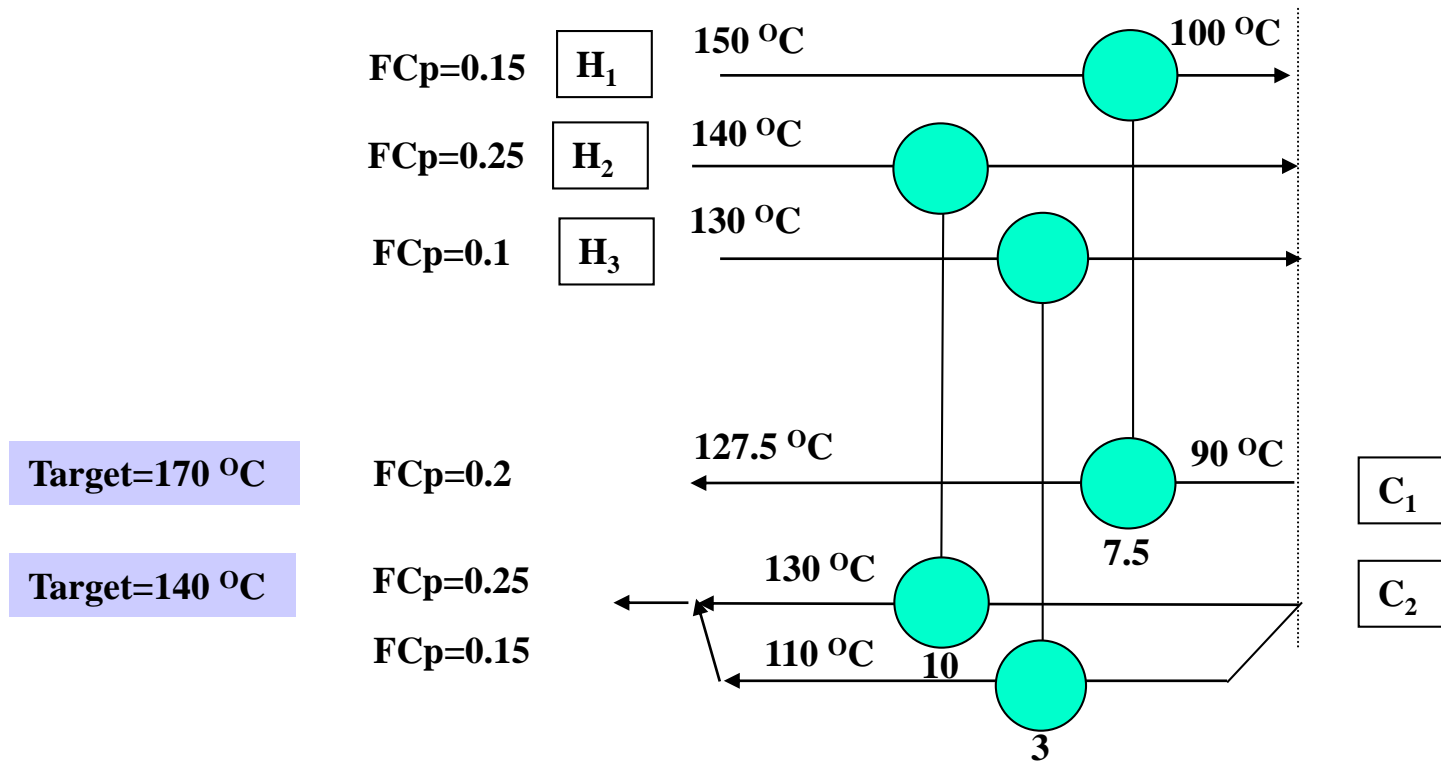


Assume the matches  $H_1$ - $C_1$  and the matches  $H_2$ - $C_2$  have been selected. Since  $H_3$  needs to go to the pinch temperature, there is no cold stream left to match, even if there is portions of  $C_1$  or  $C_2$  that are left for matching. Such matching would be infeasible.

What is then, the solution?

# UNEQUAL NUMBER OF STREAMS AT THE PINCH

**Split** cold stream until the inequality is satisfied.



Notice that different combinations of flowrates in the split satisfy the inequality.

# UNEQUAL NUMBER OF STREAMS AT THE PINCH

Above the pinch, we notice the following rule

$$S_H \leq S_C$$

If that is NOT the case, we split a cold stream until  $S_H = S_C$

A similar rule can be discussed below the pinch, that is,

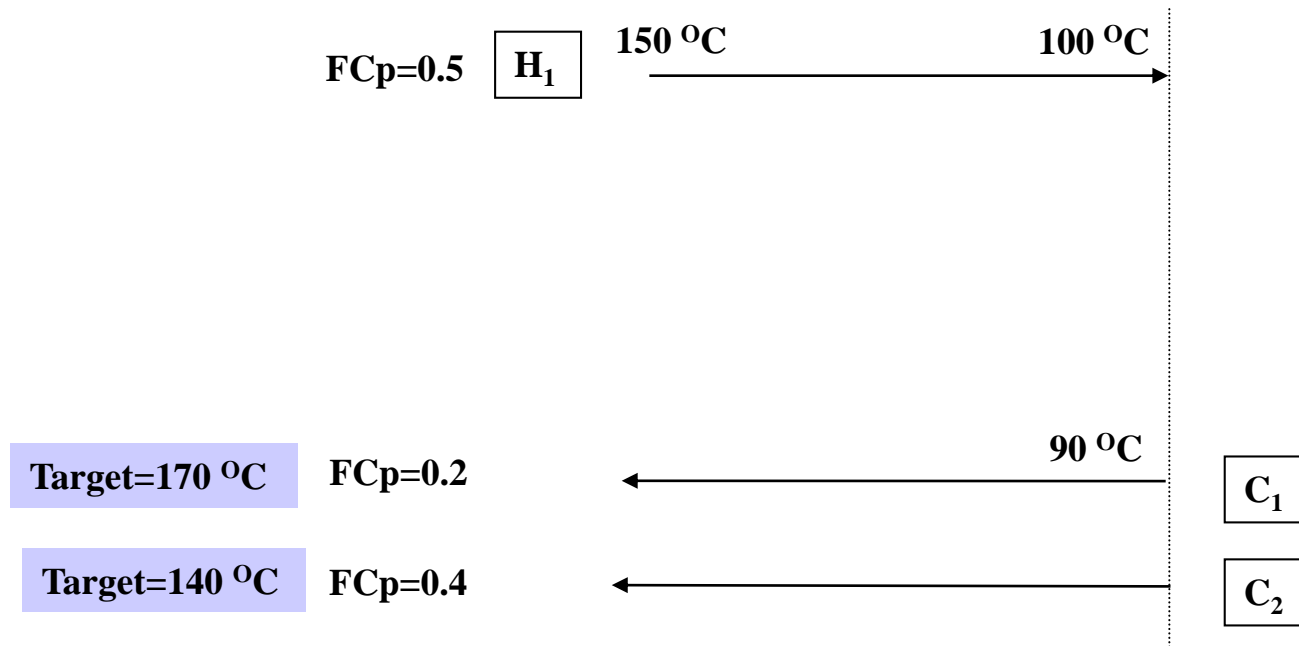
$$S_H \geq S_C$$

If that is NOT the case, we split a cold stream until  $S_H = S_C$

# INEQUALITIES NOT SATISFIED

Consider the following case above the pinch

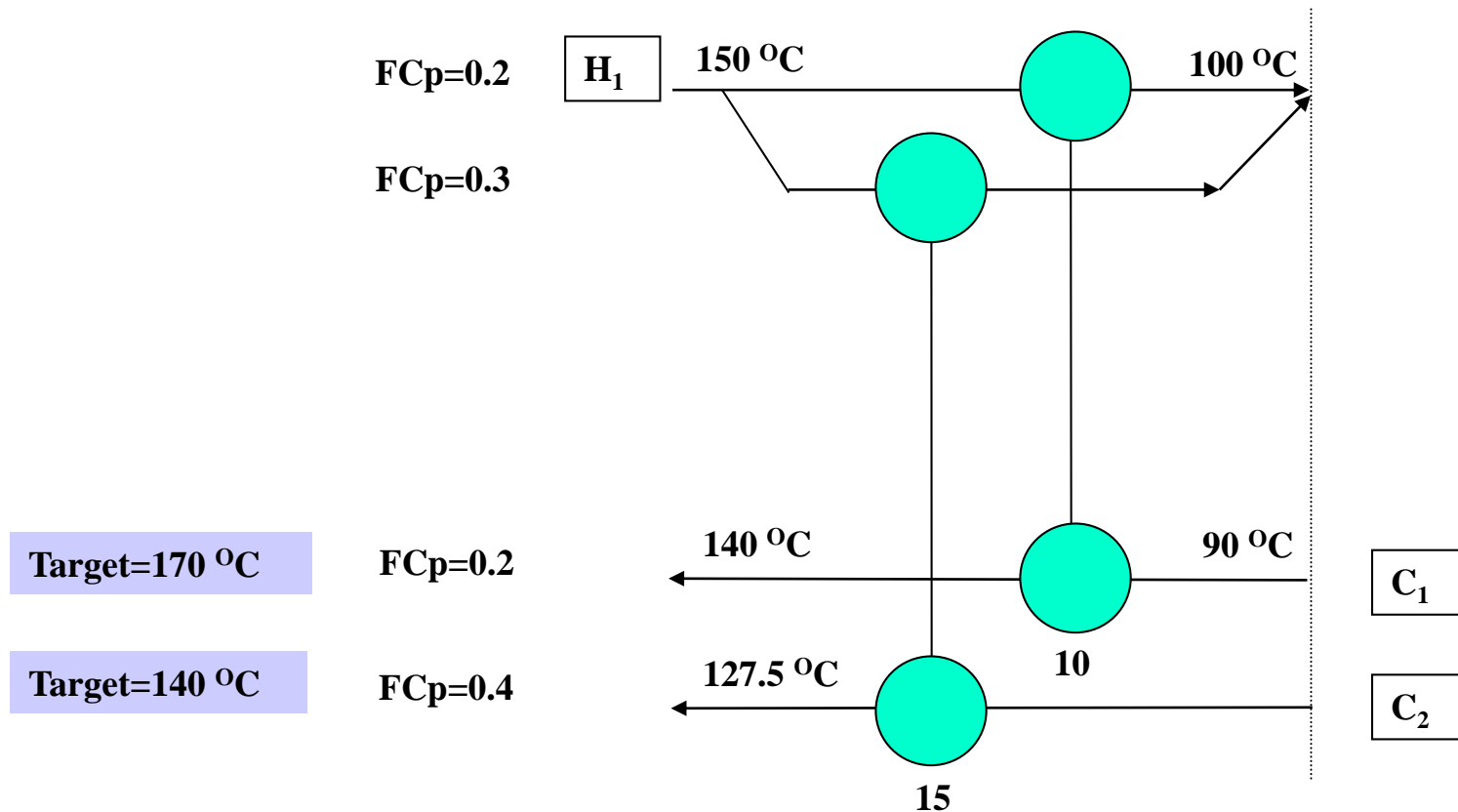
We notice that  $FCp_H > FCp_C$  (needs to be  $FCp_H \leq FCp_C$ )





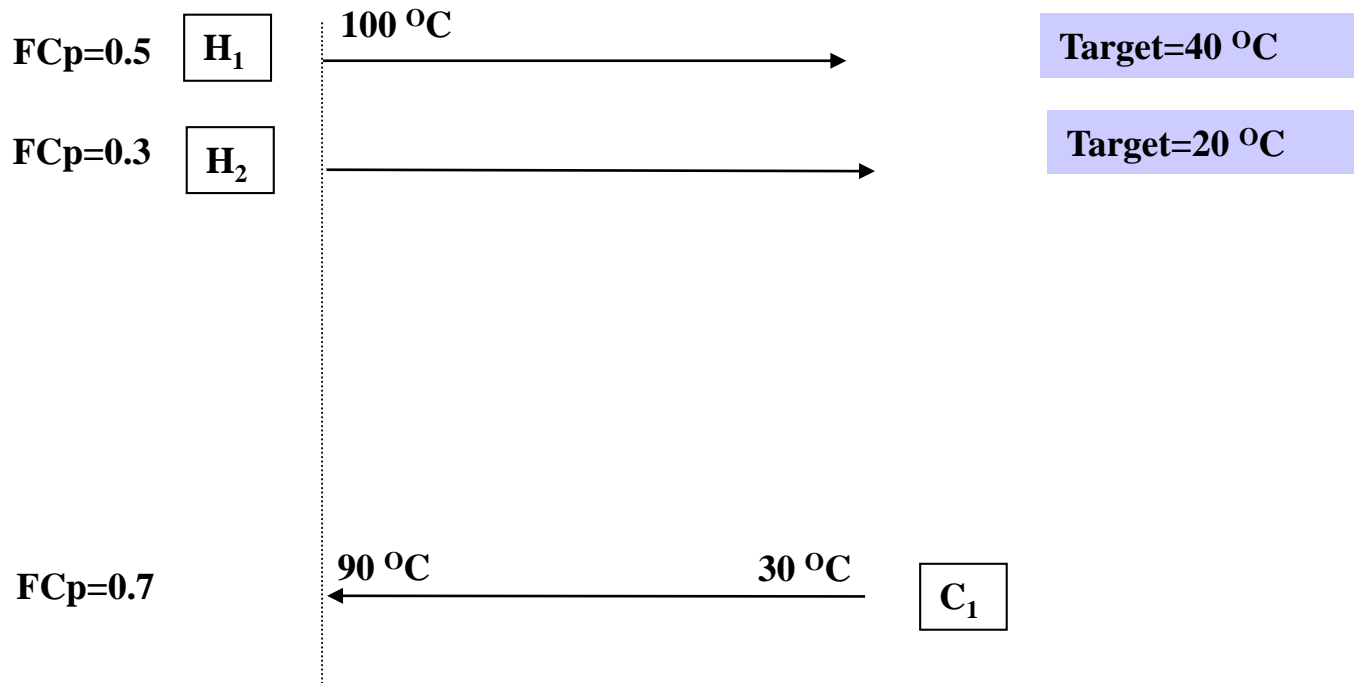
# INEQUALITIES NOT SATISFIED

The hot stream needs to be **split**



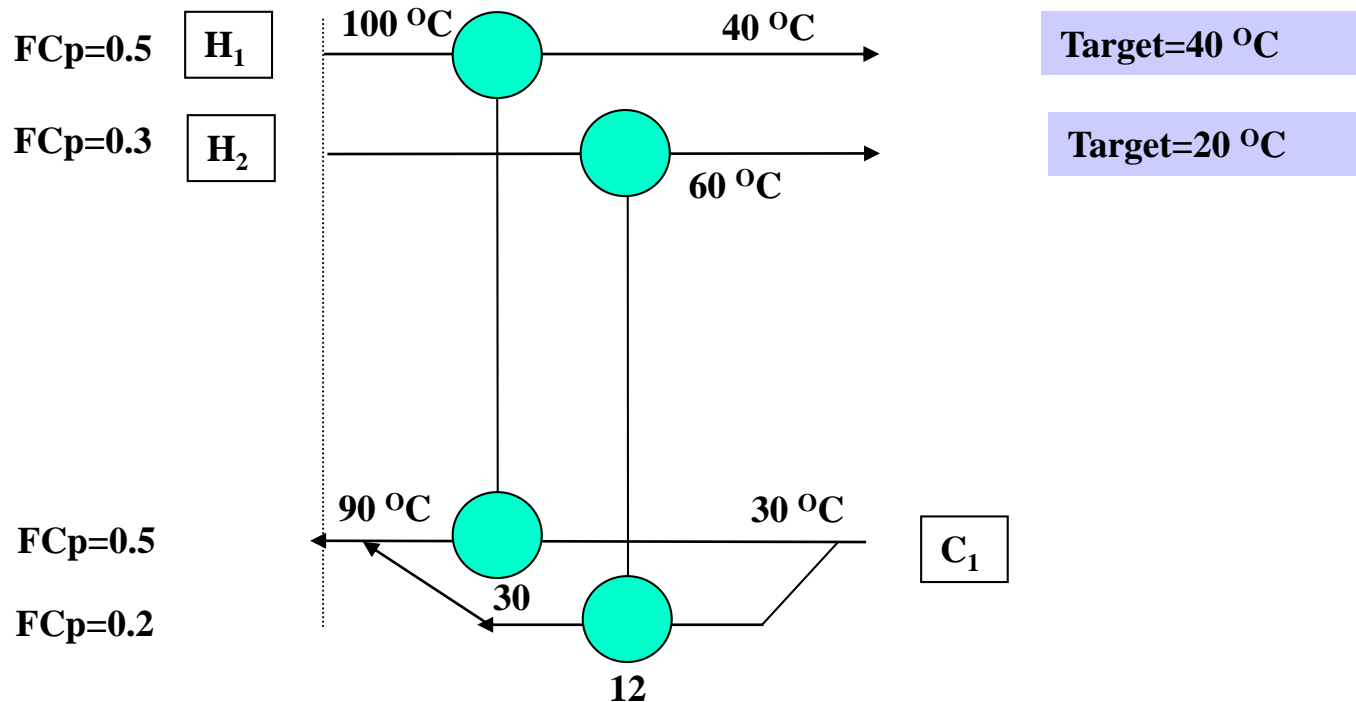
# INEQUALITIES NOT SATISFIED

Below the Pinch :



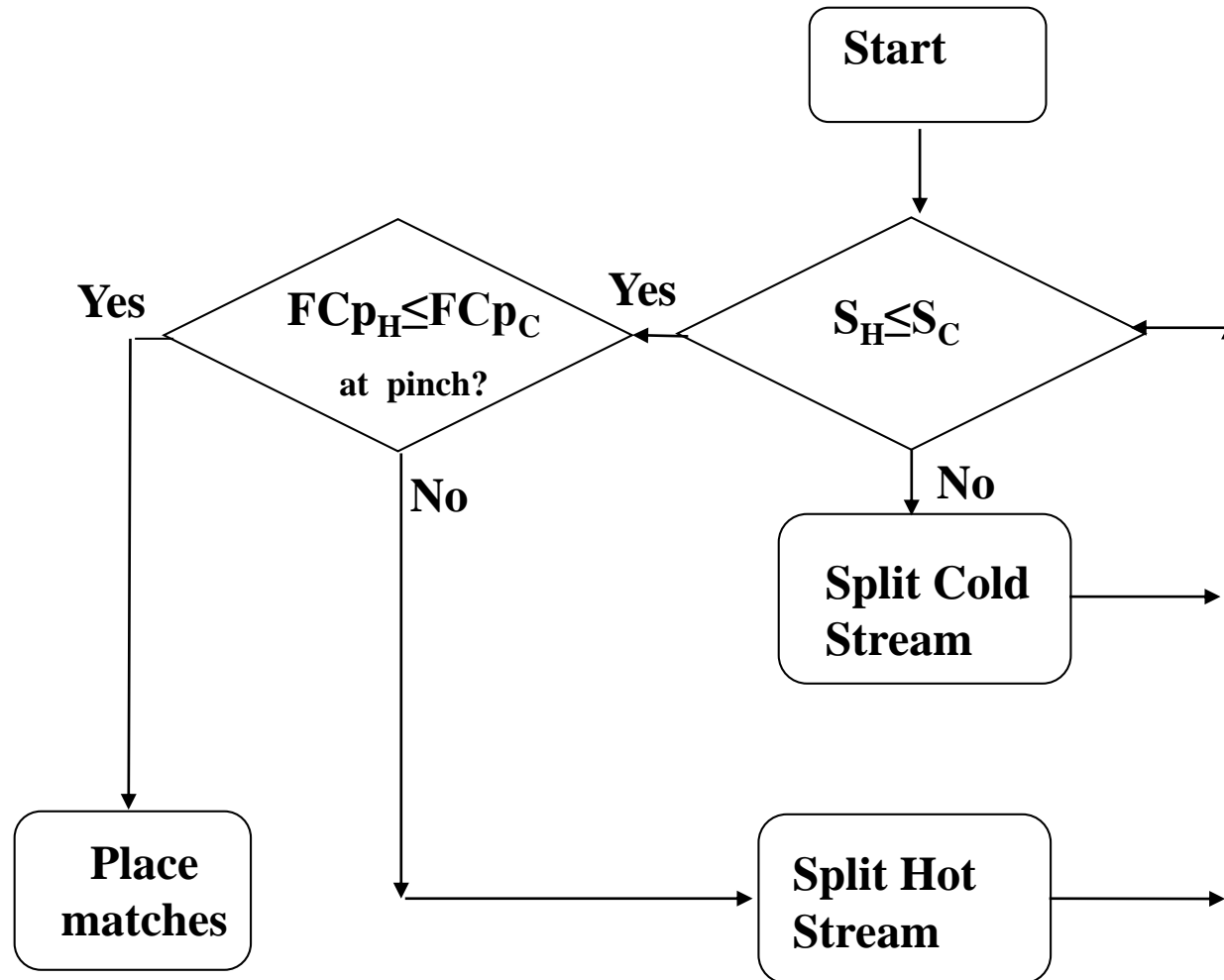
# INEQUALITIES NOT SATISFIED

The cold stream needs to be **split**



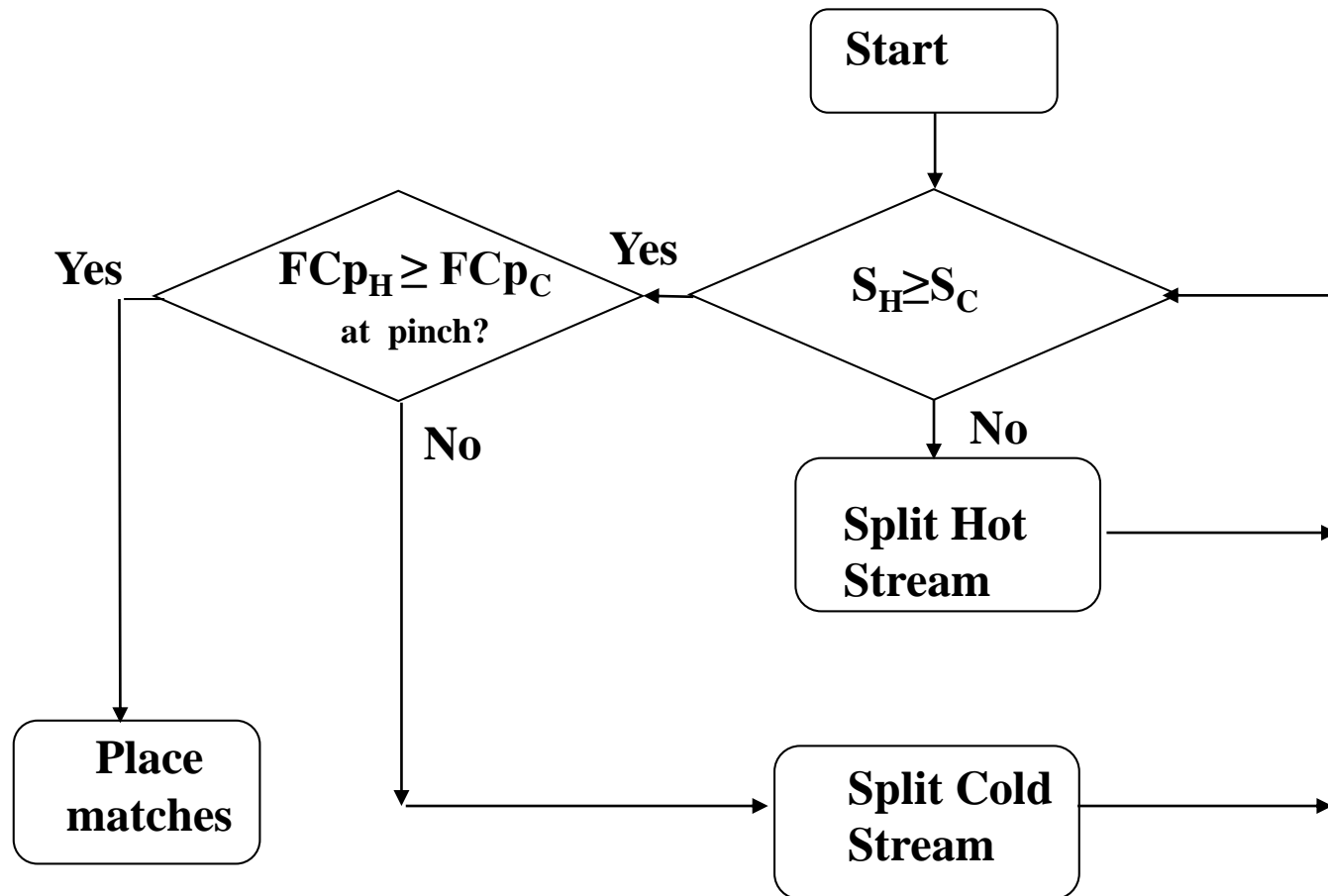
# COMPLETE PROCEDURE

## ABOVE THE PINCH



# COMPLETE PROCEDURE

## BELOW THE PINCH



# HANDS ON EXERCISE

Type	Supply T (°C)	Target T (°C)	F*Cp (MW °C <sup>-1</sup> )
Hot	750	350	0.045
Hot	550	250	0.04
Cold	300	900	0.043
Cold	200	550	0.02

$$\Delta T_{\min} = 50 \text{ °C}$$

**Minimum Heating Utility= 9.2 MW**

**Minimum Cooling Utility= 6.4 MW**

# ANSWER

