② HEN Evolution $(\Delta T)_{pinch} = 10°$ (from diagram across BB)

Consider the 4 streams, $(\Delta T)s$ can be found.

$Q_{absorbed}$ or $Q_{released}$ for each stream can be found by adding $Q_i$ + exchangers across the streams.

So $(FC_p)_1 = \dfrac{A + C + F}{180 - 40} = \dfrac{60 + 78 + 142}{140}$

$= 2 \, kW/°C$

$(FC_p)_2 = \dfrac{B + D + E + CU}{150 - 40} = 4 \, kW/°C$

$(FC_p)_3 = \dfrac{HU + A + B + E}{180 - 60} = 3 \, kW/°C$

$(FC_p)_4 = \dfrac{C + D + F}{130 - 30} = 2.6 \, kW/°C$

Step 1. Loop: D - FF - AA - BB - D : Heat exchanger with lowest Q is D (= 40kW)

Remove D. Increase F by 40 decrease A by 40, increase B by 40

TAC* 180* CU 160 kW   E  90 kW

A 20 kW   F 182 kW

B 190 kW   HU 60 kW

C 78 kW

temperatures across exchanges A, B, D, F will change

$$T_{AC} = 180 - \frac{20}{2} = 170°$$

$$T_{CF} = 170 - \frac{78}{2} = 131°$$

$$T_{BA,ent} = 131 - \frac{182}{2} = 40°$$ (emit will be same because we reallocated the heat !!)
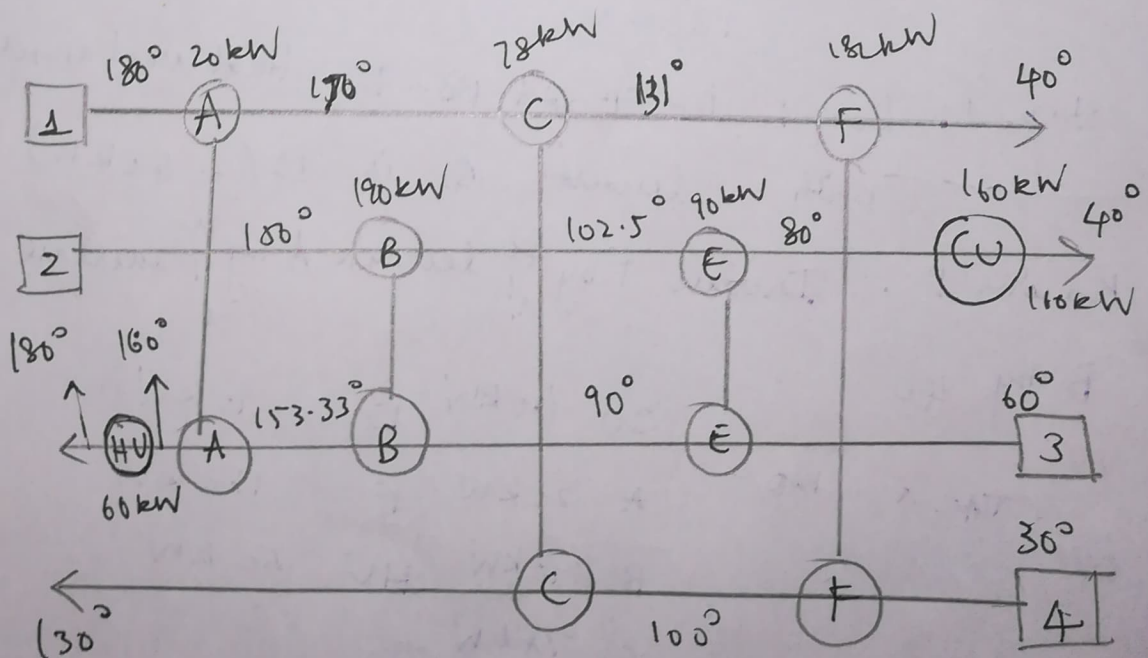
$$T_{BE} = 180 - \frac{190}{4} = 102.5°$$
(∵ no D)

$$T_{BA} = 90 + \frac{190}{3} = 153.33°$$

$$T_{FC} = 30 + \frac{182}{2.6} = 100°$$
(∵ no D)

Temperature violation across BB!!

(hot stream: 180°, cold stream: 153.3°)

To bring back to pinch level (≥10°C), need

TBA to 140°   [Step 2]
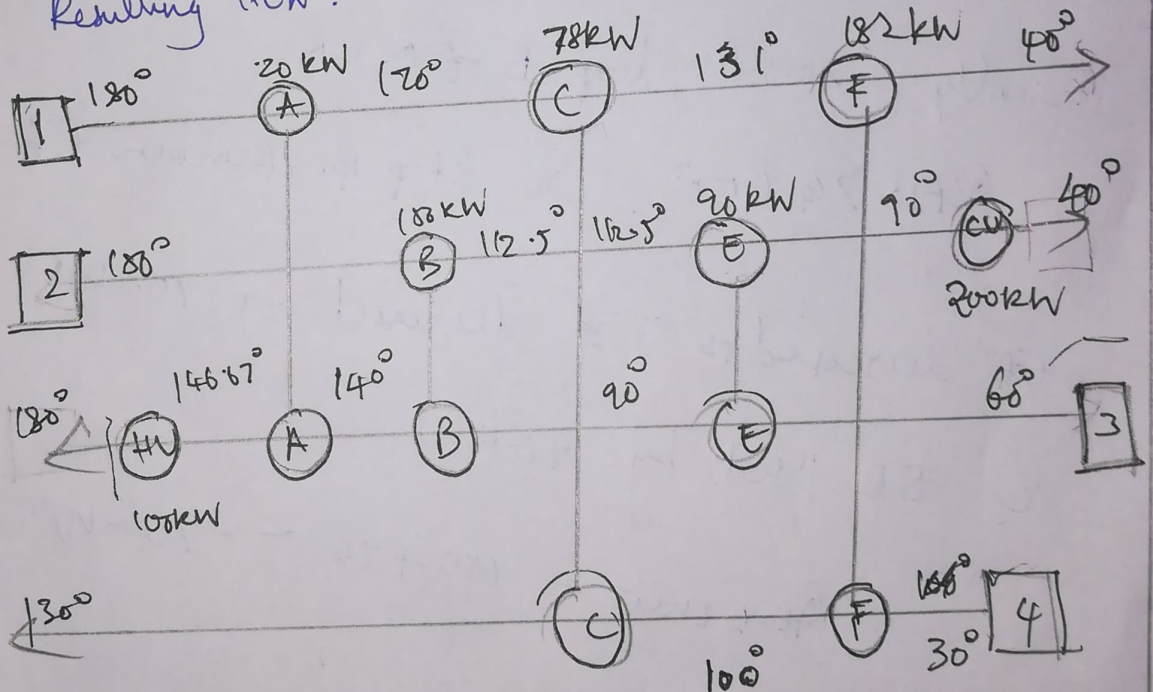
$Q_B = (140 - 90) \times 3 = 150 \text{ kW}$

Use utility path HU – BB – CU

~~Increase~~ Increase HU & CU by ~~Q~~ $\frac{190-150}{1} = 40 \text{ kW}$

decrease B by 40kW

Resulting HEN:



~~Now~~ Step 3. Remove Cc from loop C – FF – C

Reduce C to 0. Increase F by 78   ↓

$Q_{FF} = 260 \text{ kW}$   ($∵ Q_C = 78 \text{ kW}$

$∴ Q_F = 182 \text{ kW}$)

Recalculating Temperatures we get,
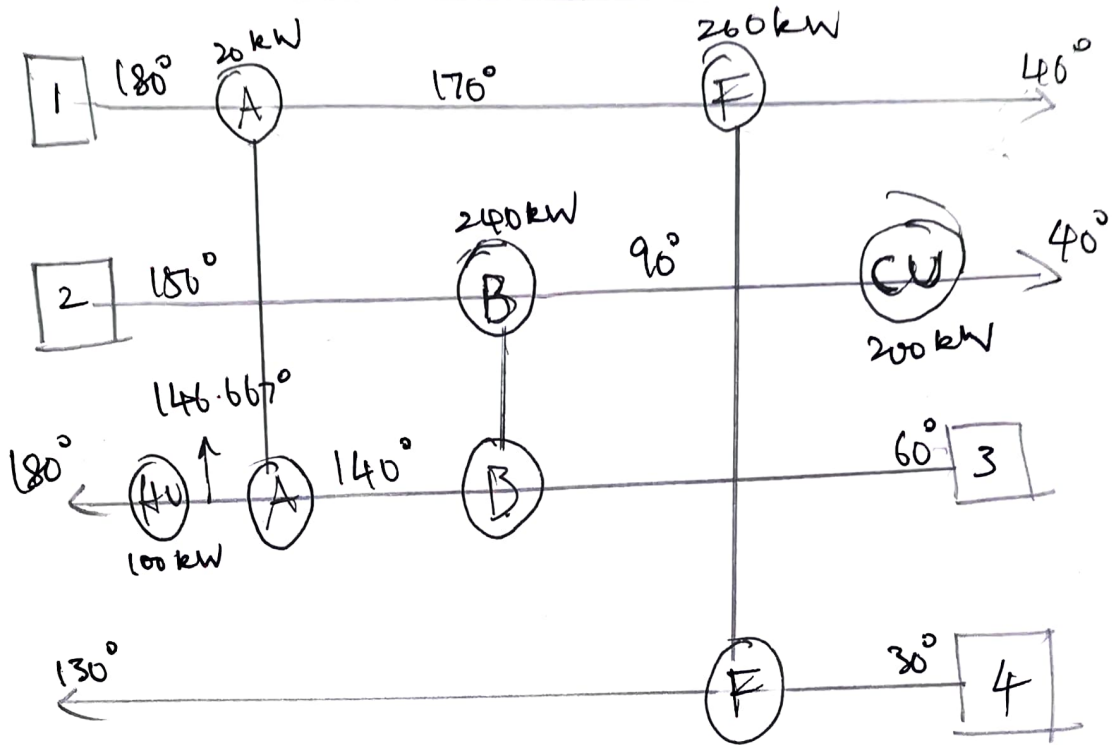(only temperatures for streams 1 & 4 change because
only they are in the loop)
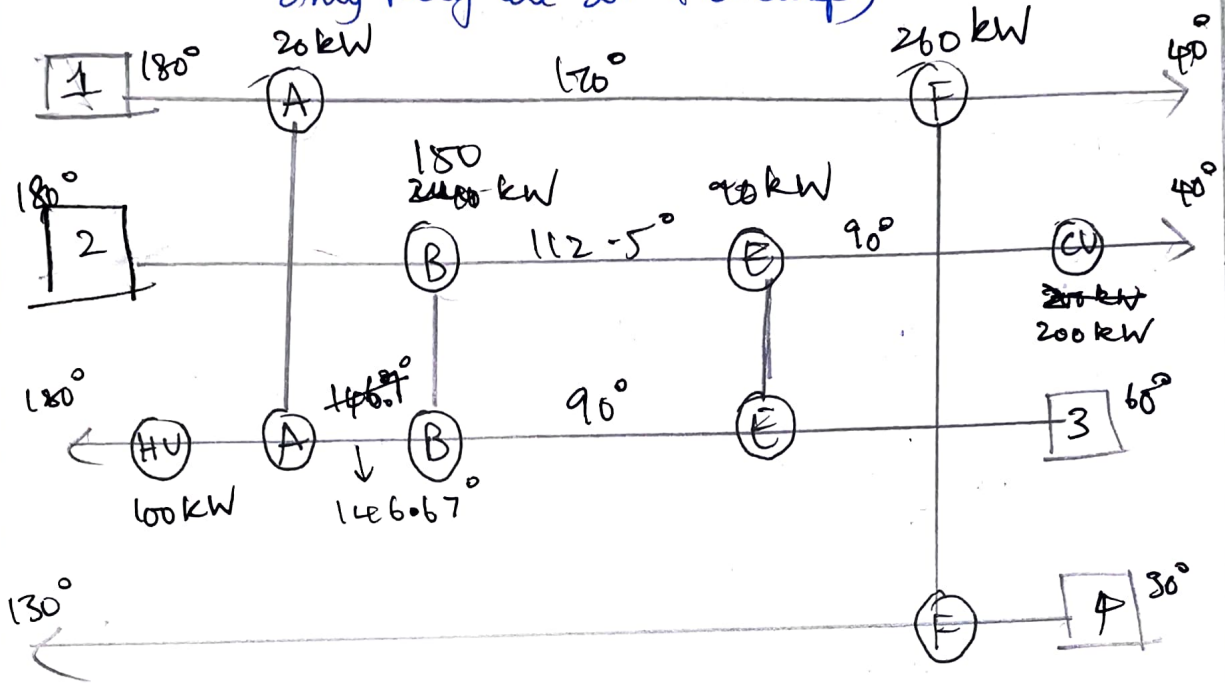


Finally, consider loop B-E & LB.

$Q_{BJB} > 4 Q_{EE}$. So Step 4. Remove EE

EE decreased to 0 & decreased by 90 kW

& BB ↑sed by 90 kW

$Q_{BB(new)} = (150 + 90 = 240 kW$

Stream grid:

- Stream 1: $180°$ — 20 kW — (A) — $176°$ — (F) 260 kW — $400°$
- Stream 2: $150°$ — (B) 240 kW — $96°$ — (CU) — $40°$, 200 kW
- Hot utility line: $180°$ ← (HU) 146.667° ↑, 100 kW — (A) $140°$ — (B) — $60°$ → 3
- $130°$ ← ... — (F) — $30°$ → 4

There are no more loops and no temperature violations.

HEN Evolution is completed and reduced to absolute minimum number of HENs

( Absolute minimum : 4 streams + 2 utilities − 1

$$= 5 \text{ exchangers}$$

( HU , AA , BB , FF , CU ) )