TUTORIAL-06: MER DESIGN AND LOOPS & PATHS

Based on
Lecture-28: MER design for single pinch problems
Lecture-32: HEN Optimization

Problem 1: For the stream data, given in Table 1, design maximum energy recovery (MER) network assuming ΔT_{min} as 20°C. Calculate the number of loops present in the network and locate them in a MER network. Also remove the heat exchanger from the network using loop breaking and restore the original ΔT_{min} throughout the network using a heat flow path.

Table 1: Heat exchanger Stream data

Streams	Type of streams	T_s °C)	T_t (°C)	CP (kW/°C)
1	Hot (H1)	260	140	18
2	Hot (H2)	230	60	23
3	Cold (C1)	60	220	21
4	Cold (C2)	150	205	46

Solution 1: The amount of hot and cold utility and the pinch temperature is required for designing of the MER network for stream data shown in Table 1. These values are computed using Problem Table Algorithm as illustrated through Problem 1 of Tutorial-02 and shown below:

Amount of hot utility : 1000 kW

Amount of cold utility : 1180 kW

Pinch point : 160 °C

Hot pinch temperature : 170 °C

Cold pinch temperature : 150 °C

Using these values the grid diagram of the network is drawn as shown in Figure 1.

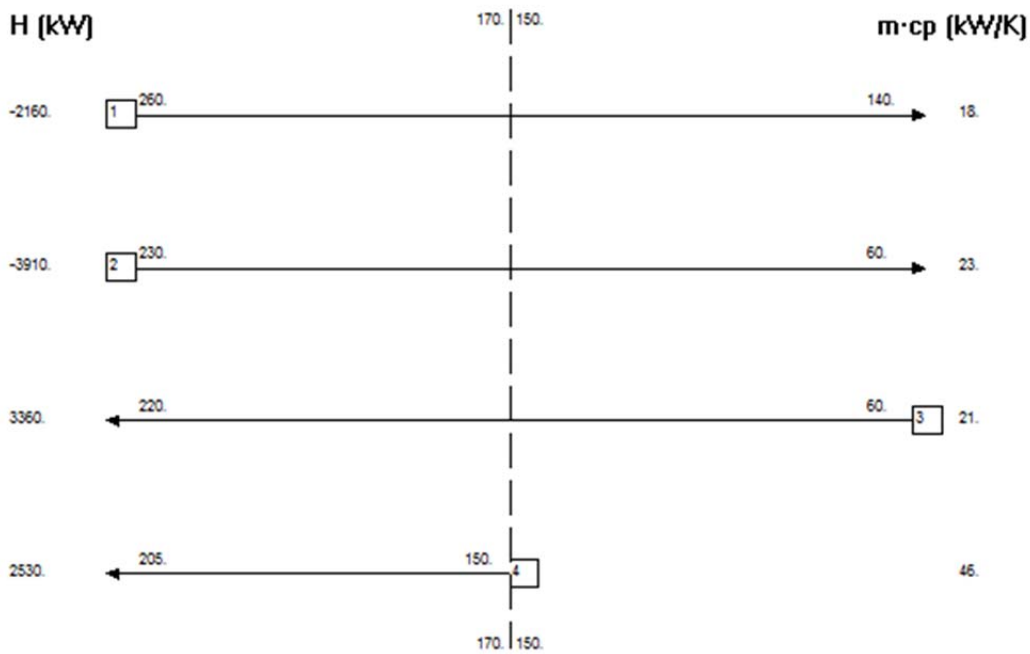

Figure 1: Grid diagram for the stream data of Problem 1

MER design

To perform MER design for the problem, the grid diagram is divided into two parts i.e. above the pinch and below the pinch. Then following the pinch design criteria placement of heat exchangers is carried out as:

For the **above pinch design** of the stream network, two criteria must be fulfilled

1) No. of stream criterion: $N_H \leq N_C$
2) CP criterion : $CP_H \leq CP_C$

So for designing the MER network for above pinch, shown in Figure 1, these rules are followed as:

1) Number of stream criterion: $2 \leq 2$
2) CP criterion: $18 < 21$
   It shows that both the criteria are satisfied between hot stream 1 and cold stream 3, shown in Figure 1, so exchanger-1 can be placed. The load of streams 1 and 3 are 1620 kW and 1470 kW, respectively, hence stream 3 can be ticked off as it has minimum load among the two streams. The placement of exchanger-1 for this match is shown in Figure 2.

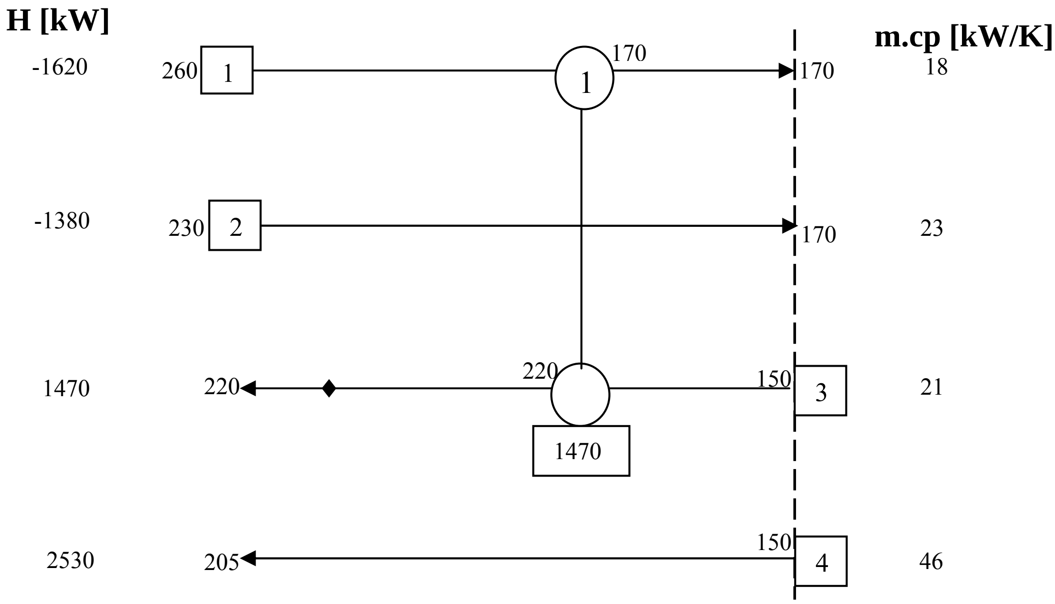

Figure 2: Design for the above pinch streams with exchanger-1

Similarly, second heat exchanger can be placed based on following rules:

- Number of stream criterion: $2 \leq 2$
- CP criterion: $23 < 46$

  Both criteria are satisfied between hot stream 2 and cold stream 4, shown in Figure 2, so exchanger-2 can be placed. The load of streams 2 and 4 are 1380 kW and 2530 kW, respectively, hence stream 2 is ticked off. The placement of heat exchanger-2 for this match is shown in Figure 3.

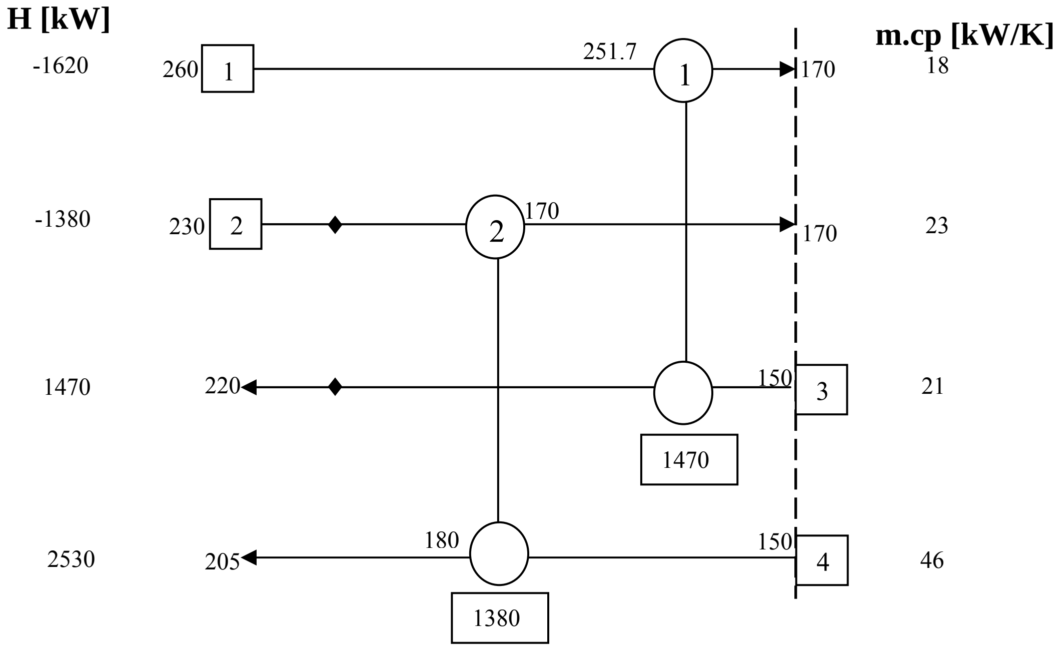

Figure 3: Design for the above pinch streams with exchanger-1 and 2

The remaining load of stream 1 is 150 kW and that of stream 4 is 1150 kW, hence stream 1 can be ticked off through placing exchanger-3 between stream 1 and stream 4. The placement of exchanger-3 for this match is shown in Figure 4.

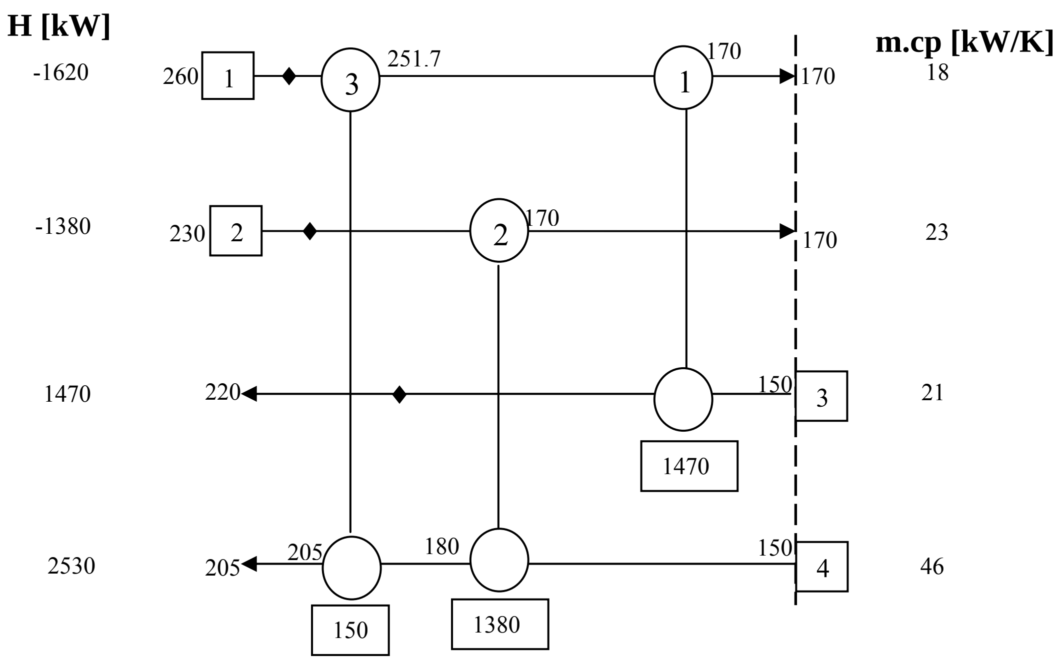

Figure 4: Design for the above pinch streams with exchanger-1, 2 and 3

The overall design for the above pinch streams is shown in Figure 5 where a heater (H) of 1000kW is placed in stream 4 which is equal to hot utility demand of the process.

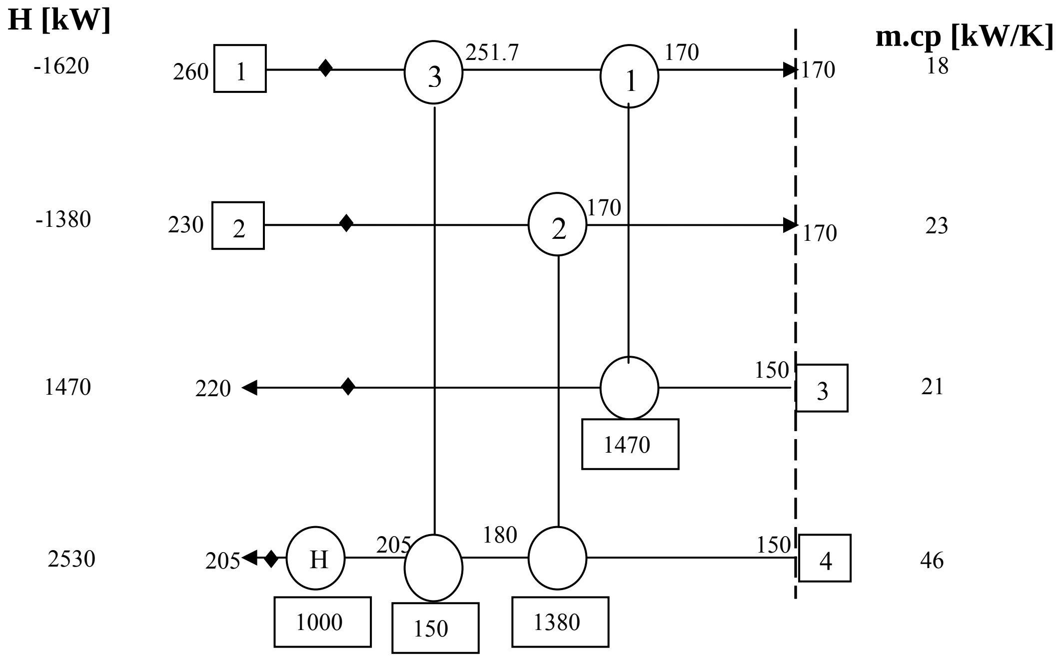

Figure 5: The overall design network for the above pinch streams

Below pinch design

The design rules are

- No. of stream criterion: $N_H \geq N_C$
- CP criterion: $CP_H > CP_C$

The grid diagram is shown in Figure 1. It is clear from the figure that number of streams criterion is satisfied as there are 2 hot streams and one cold stream. The CP criterion is also satisfied between streams 2 and 3. Thus, exchanger-4 can be placed between streams 2 and 3 with a load of 1890 kW. Consequently, stream 3 is ticked off. This placement is shown in Figure 6.

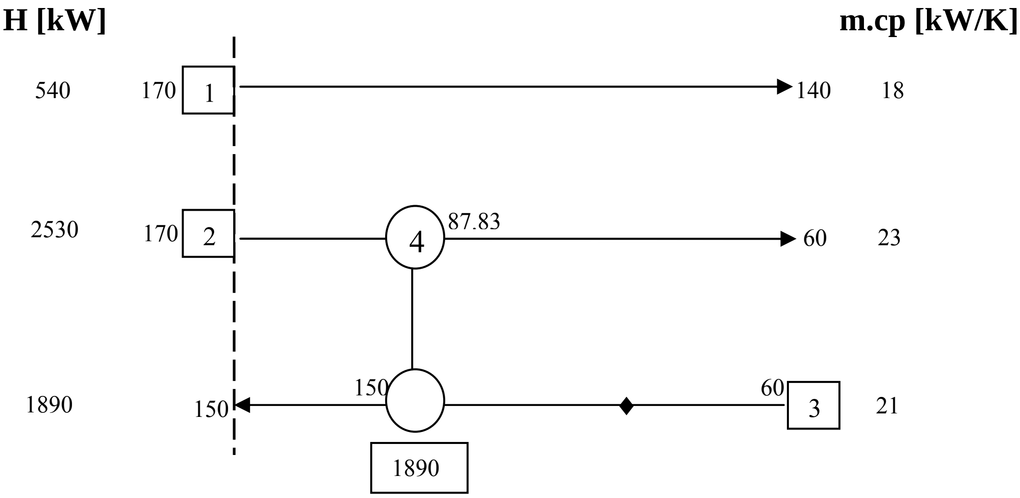

Figure 6: Design for the below pinch streams with exchanger-4

The overall design for the below pinch streams is shown in Figure 7 where two coolers of total load 1180 kW is placed which is equal to cold utility demand of the process.

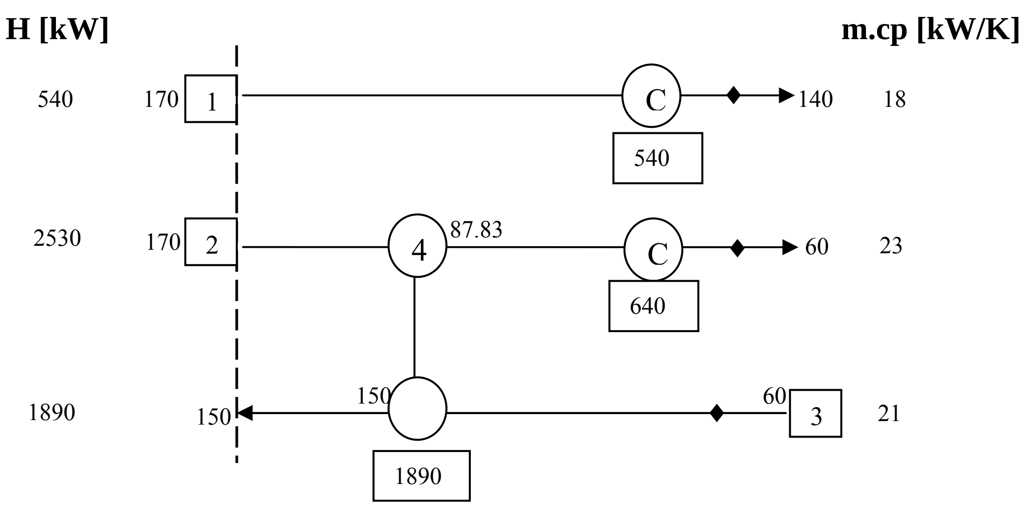

Figure 7: The overall design network for the below pinch streams

So, after combining the above pinch and below pinch design, the overall MER design network for the present problem is shown in Figure 8.

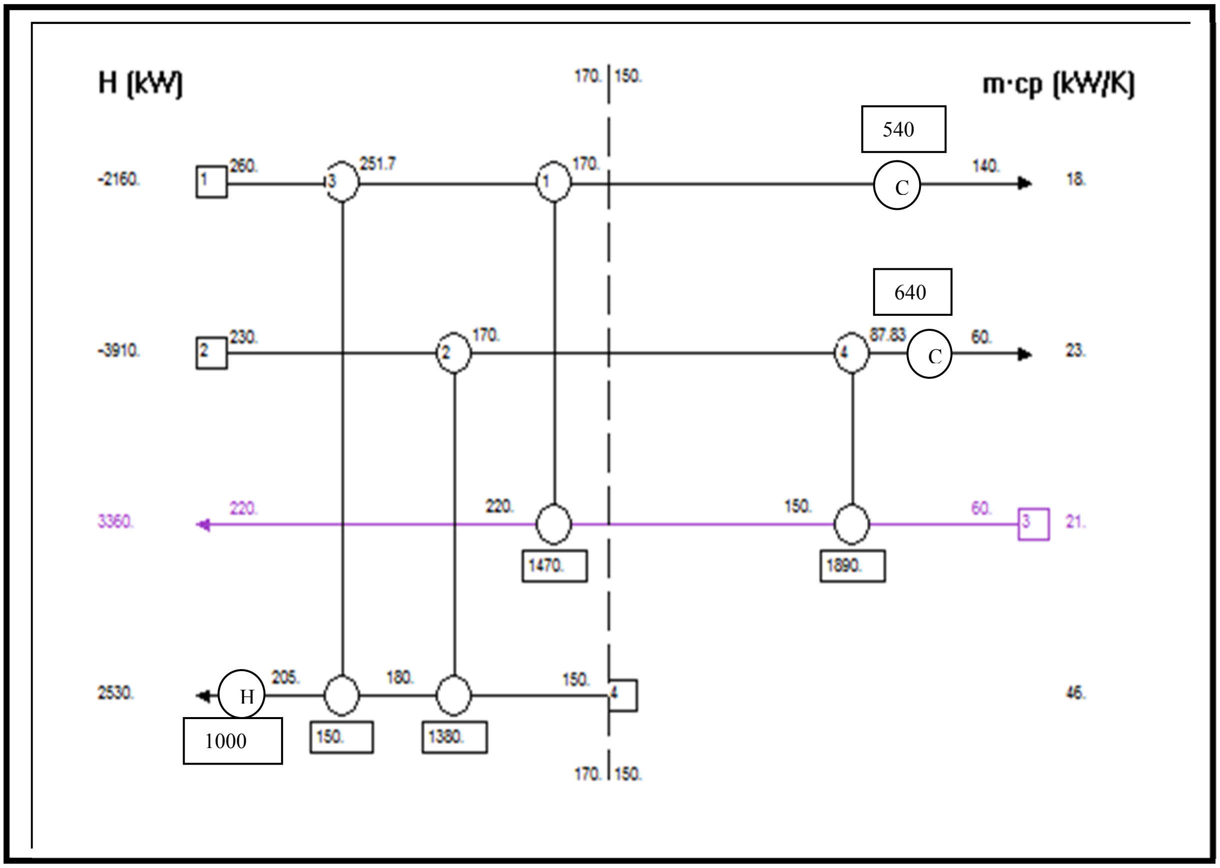

Figure 8: The MER design

Calculation of number of loops

The number of units for the overall network

$$6-1 = 5$$

The number of units above the pinch

$$5-1 = 4$$

The number of units below the pinch

$$4-1 = 3$$

So,

Total number of loops present in the network = No. of units above the pinch+ No. of units below the pinch - No. of units for the overall network

= 4 + 3 - 5
= 2

These loops are located in MER design as shown in Figure 9 and 10.

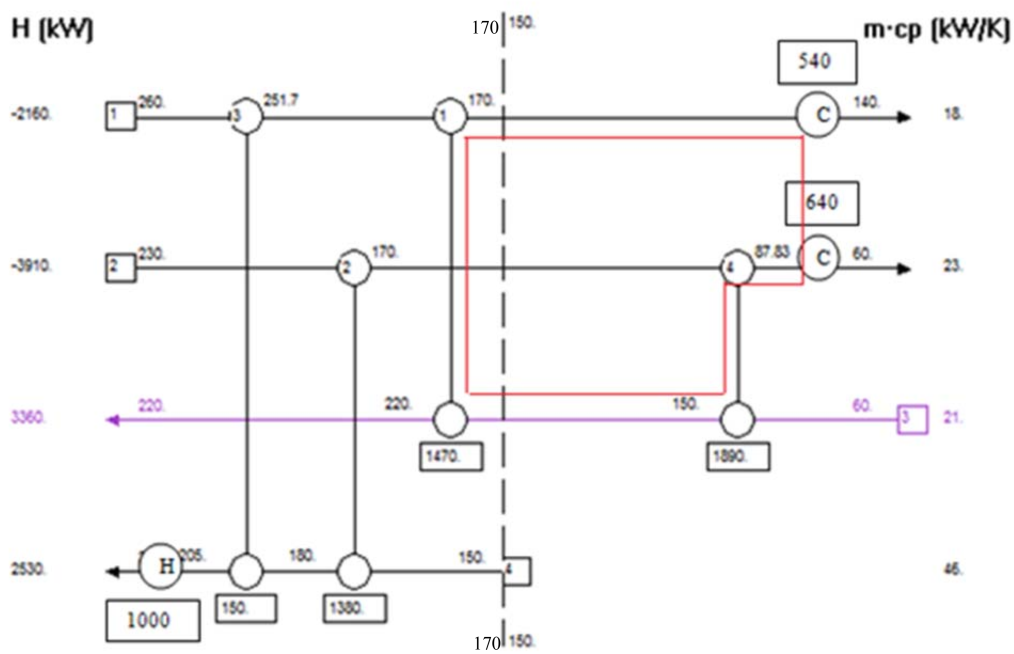

Figure 9: Loop 1 present in MER design

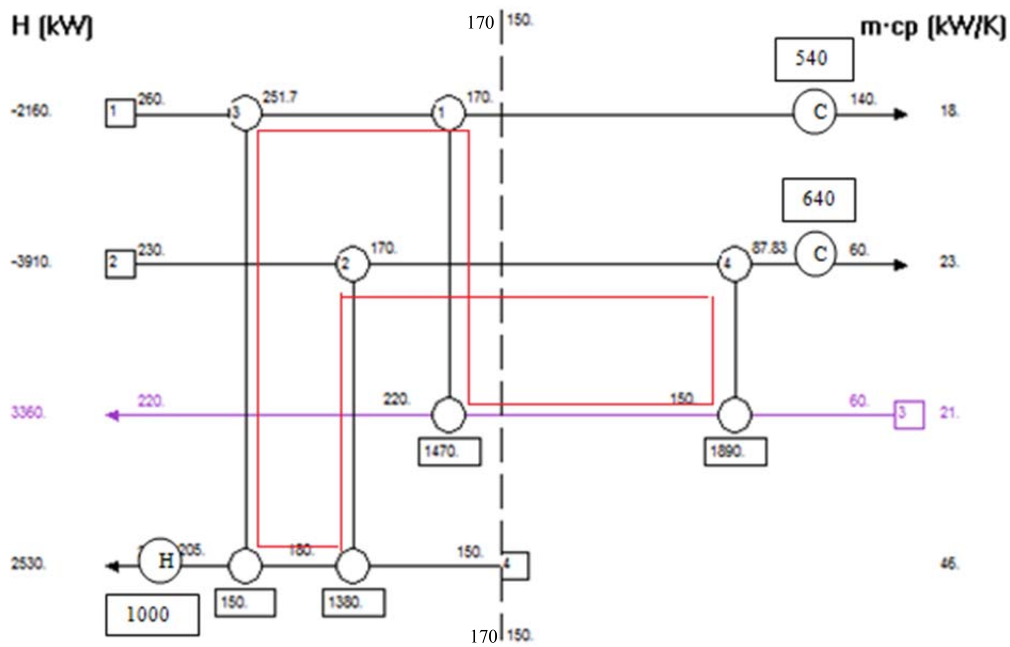

Figure 10: Loop 2 present in MER design

As two loops are independent from each other loop 2 can be broken prior to loop 1 because it has least minimum heat load exchanger i.e. 150 kW amongst all exchangers available in two loops.

Breaking of loop 2

The minimum heat load exchanger is exchanger-3 of 150 kW in Loop 2, as shown in Figure 10. So, it should be removed for breaking loop 2 and its load must be shifted to other exchangers present in Loop 2 as shown in Figure 11.

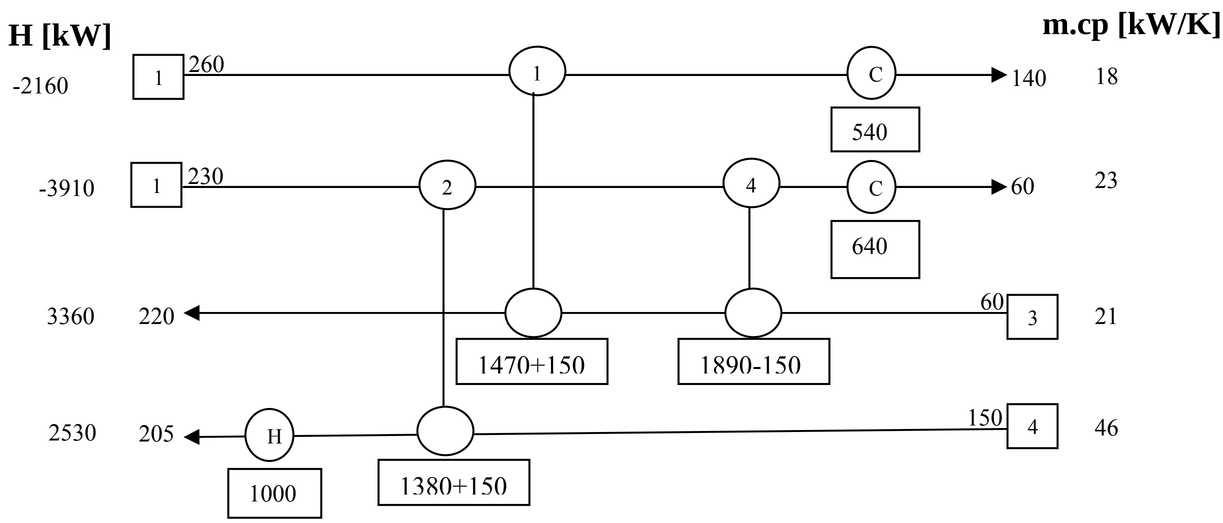

Figure 11: Shifting of minimum load for breaking of loop 2

Once the load of 150 kW is shifted the temperatures around each exchanger are computed, which are shown in Figure 12. It shows that the exchanger-2 within the red box indicates the temperature violation as ΔT_{min} is 13.5°C instead of 20°C. The ΔT_{min} can be restored through a path shown in Figure 12, which moves from hot utility to cold utility.

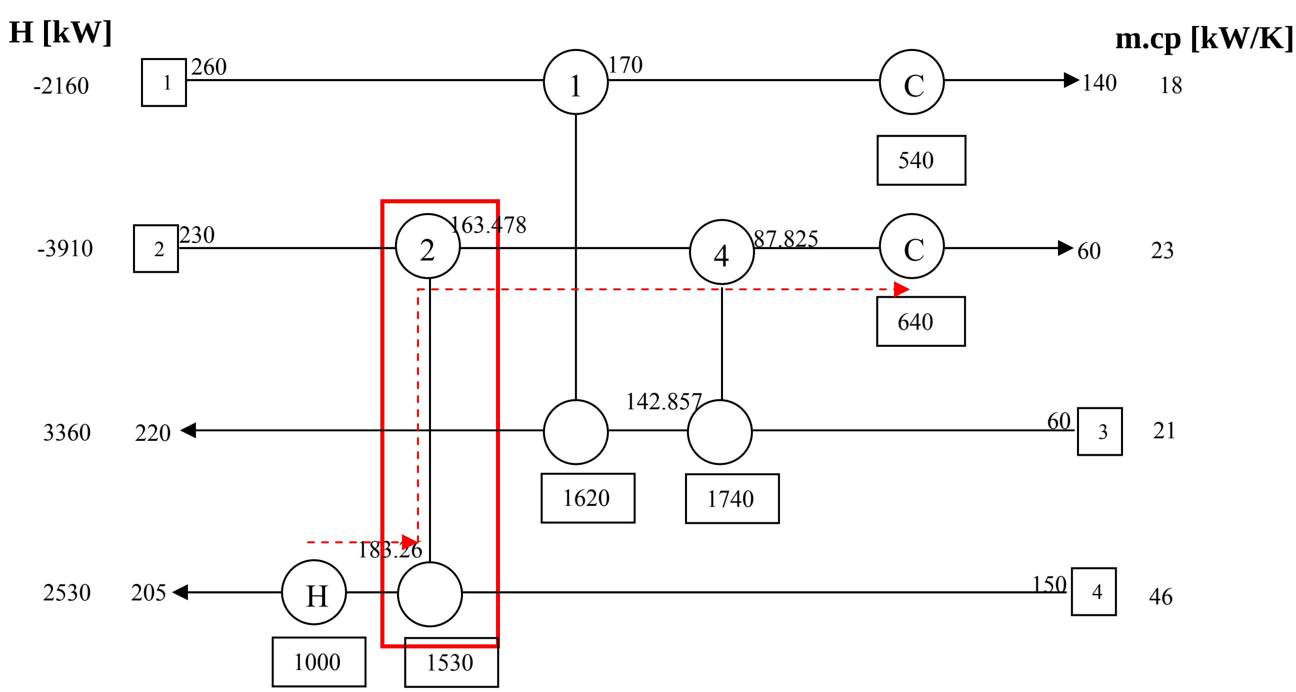

Figure 12: Heat load path after breaking loop 2

The heat duty which is shifted from exchanger-2 to maintain ΔT_{min} as 20°C is computed as

$$[230 - [(1530 - Qc)/23]] - 150 = 20$$

Qc = 150 kW

Exchanger-2 should have 150 kW less load to maintain temperature 163.478°C as 170°C. So, load on exchanger-2 has been reduced by 1380 kW (= 1530-150). Consequently, the load of 150 kW is shifted to heater and cooler as shown below:

Heater load: 1000+150 = 1150 kW

Cooler load: 640+150 = 790 kW

The final design after breaking of loop 2 and with revised values of utilities is shown in Figure 13.

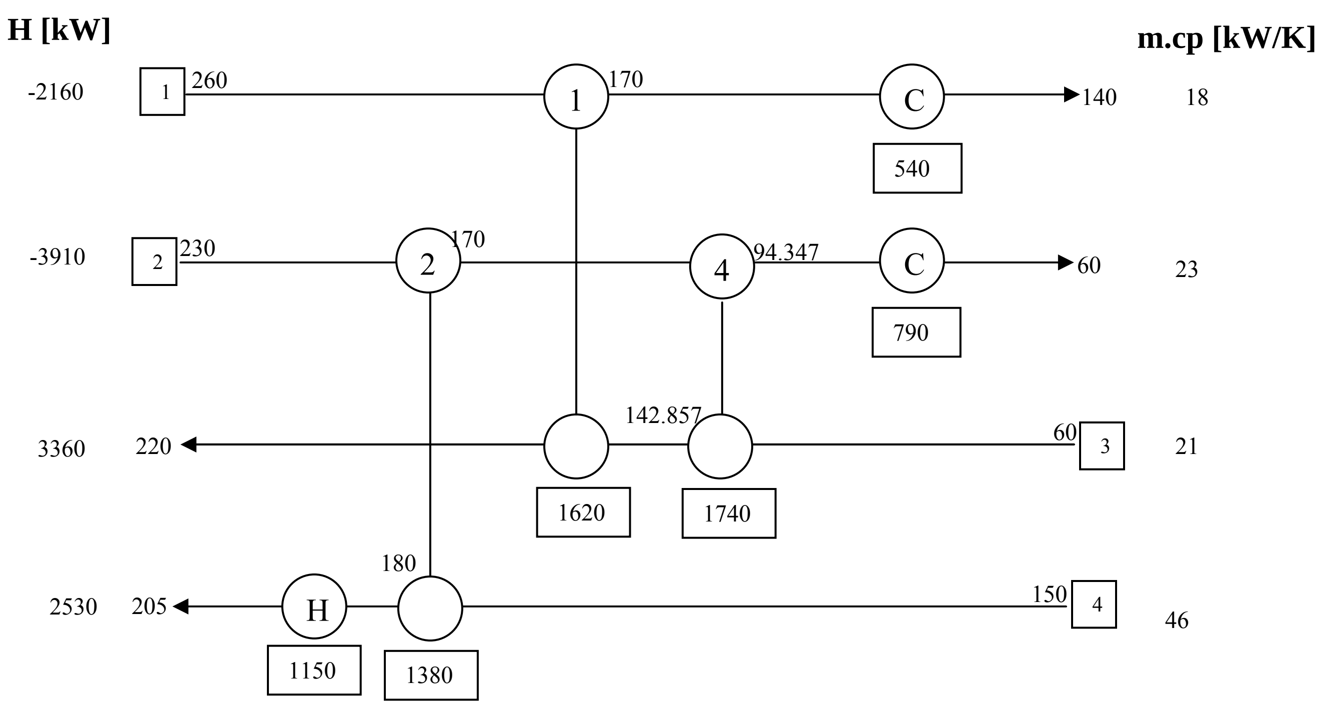

Figure 13: Final design with breaking of loop 2

Now loop 1 should be broken by taking the final design shown in Figure 13. As minimum load in Loop 1 is 540 kW, this cooler should be removed for breaking of loop 1 and this load is shifted to other heat exchanger available in the loop as shown in Figure 14.

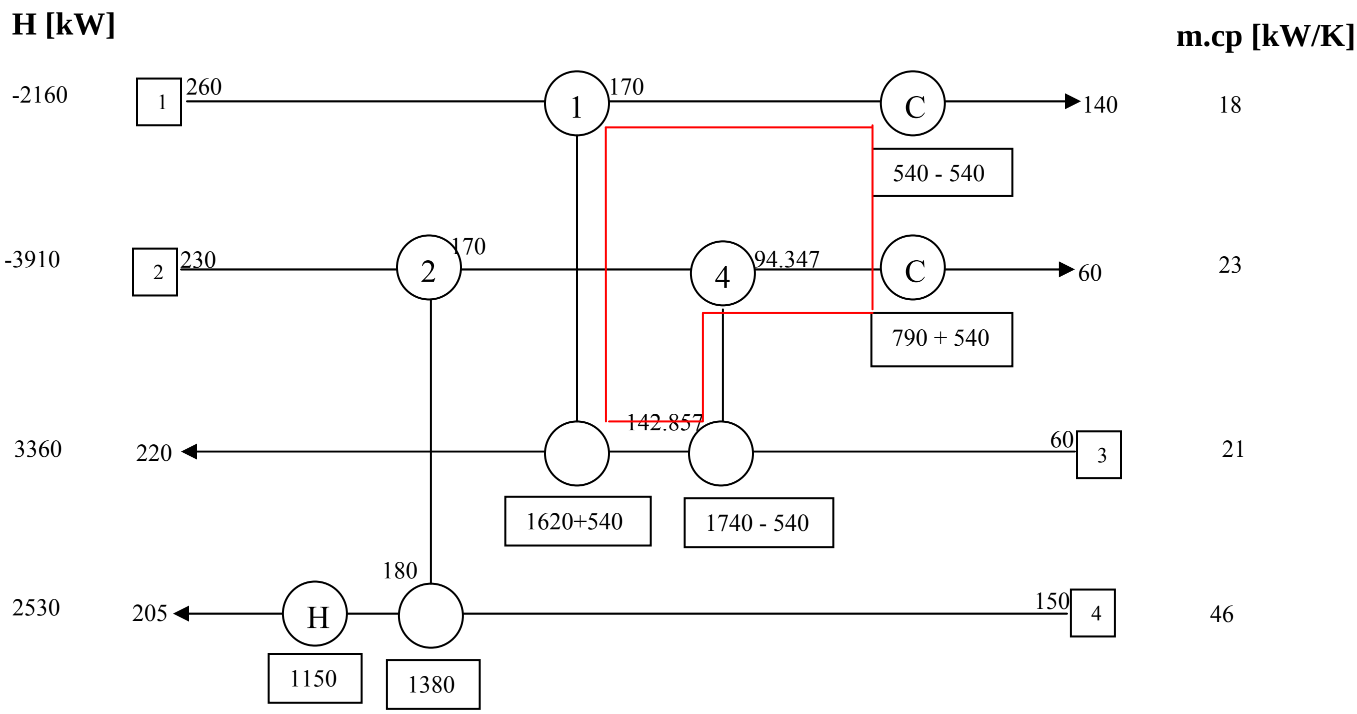

Figure 14: Breaking of loop 1

Design after breaking of loop 1 is presented in Figure 15. After breaking the loop 1, no heat exchanger violates the ΔT_{min} criteria and so there is no need to provide the path to restore the ΔT_{min} after breaking loop 1. Thus, the design shown in Figure 15 can be considered as final design.

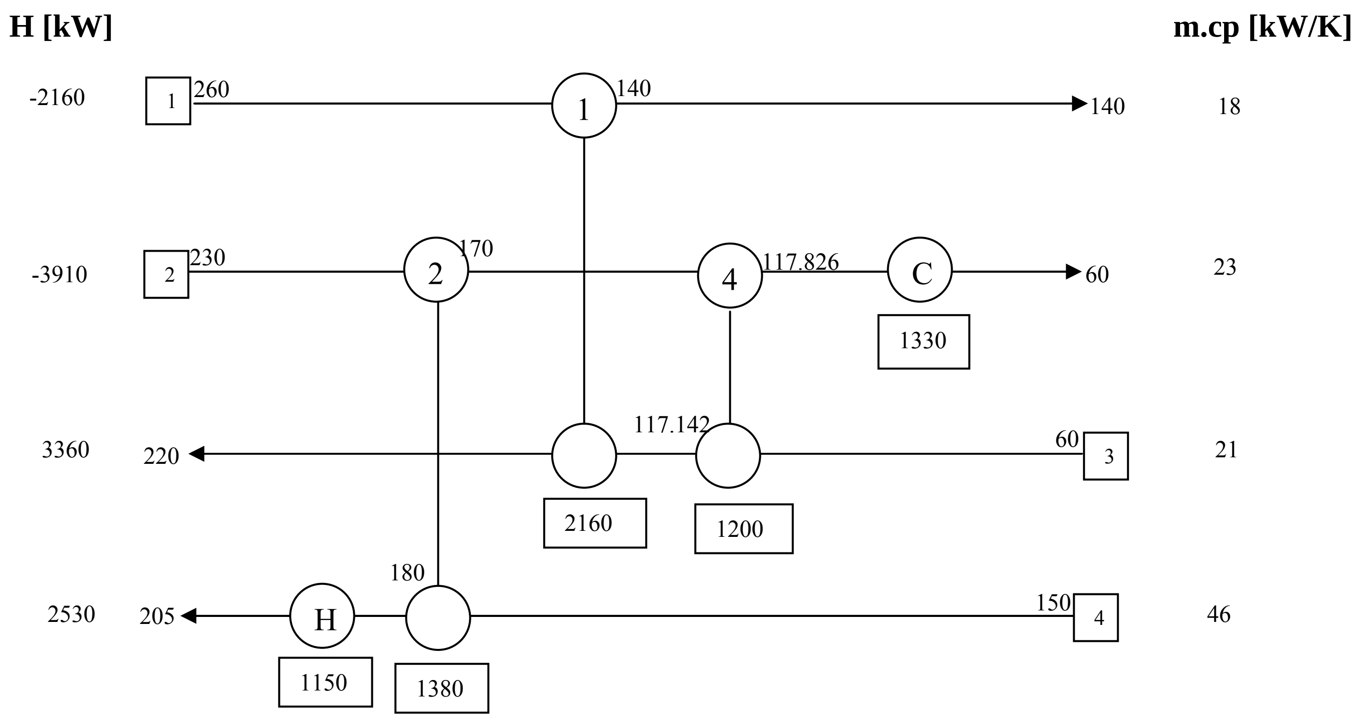

Figure 15: Design after breaking both the loops