TUTORIAL-07: DESIGN FOR MULTIPLE PINCH PROBLEM

Based on **Lecture-31: Design for Multiple Pinch Problem**

Problem 1: For a typical process, stream data is shown in Table 1. The hot and cold utilities for this process are 540 kW and 2440 kW. For this process hot utility (HU) is supplied from 210°C to 209°C whereas cold utility (CU1) is used at two stages: (1) CU1 of 590 kW from 120°C to 121°C and (2) CU2 of 1850 kW from 35°C to 50°C. The hot and cold process pinch temperatures are 160°C and 150°C, respectively. Design the heat exchanger network for this process assuming ΔT_{min} as 10°C.

Table 1: Heat exchanger Stream data

Streams	Type of streams	T_s °C)	T_t (°C)	CP (kW/°C)
1	Hot (H1)	190	50	18
2	Hot (H2)	160	50	42
3	Cold (C1)	70	190	27
4	Cold (C2)	40	140	20

Solution 1: As in the present process two cold utilities are used, so one should check whether utility pinch exists in the process or not. For this purpose the grand composite curve (GCC) is drawn as shown in Figure 1. In this curve CU1 is plotted at 125°C as it is cold utility which must be upgraded by 5°C (=120+ΔT_{min}/2). Similarly, CU2 is also upgraded in temperature while plotting it in GCC. It is clear from Figure 1 that CU1 touches the GCC at point 'a', which creates the utility pinch. Thus, Problem 1 is a case of multiple pinches.

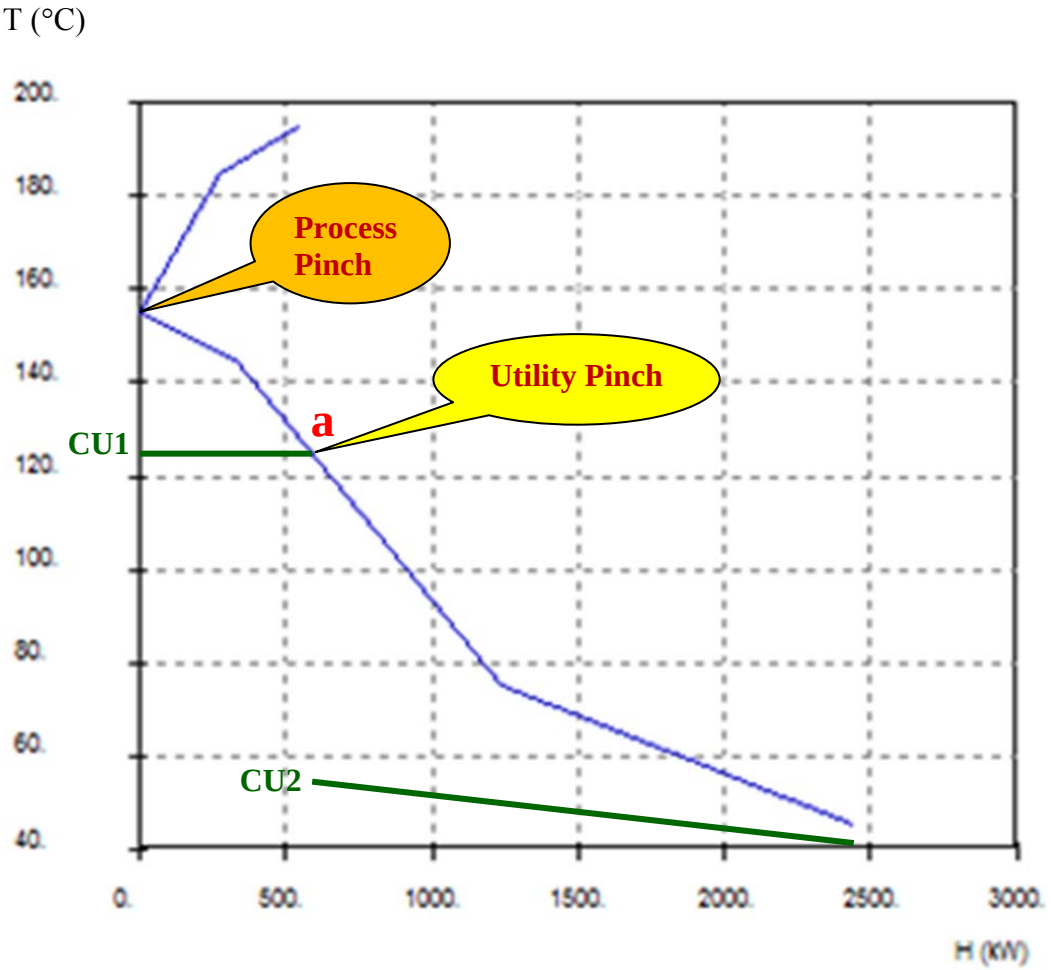

Figure 1: The grand composite curve for Problem 1

The grid diagram of the stream data, shown in Table 1, is drawn in Figure 2. It shows three different sections such as above process pinch, between process & utility pinch and below utility pinch. The design of these three sections will be carried out individually.

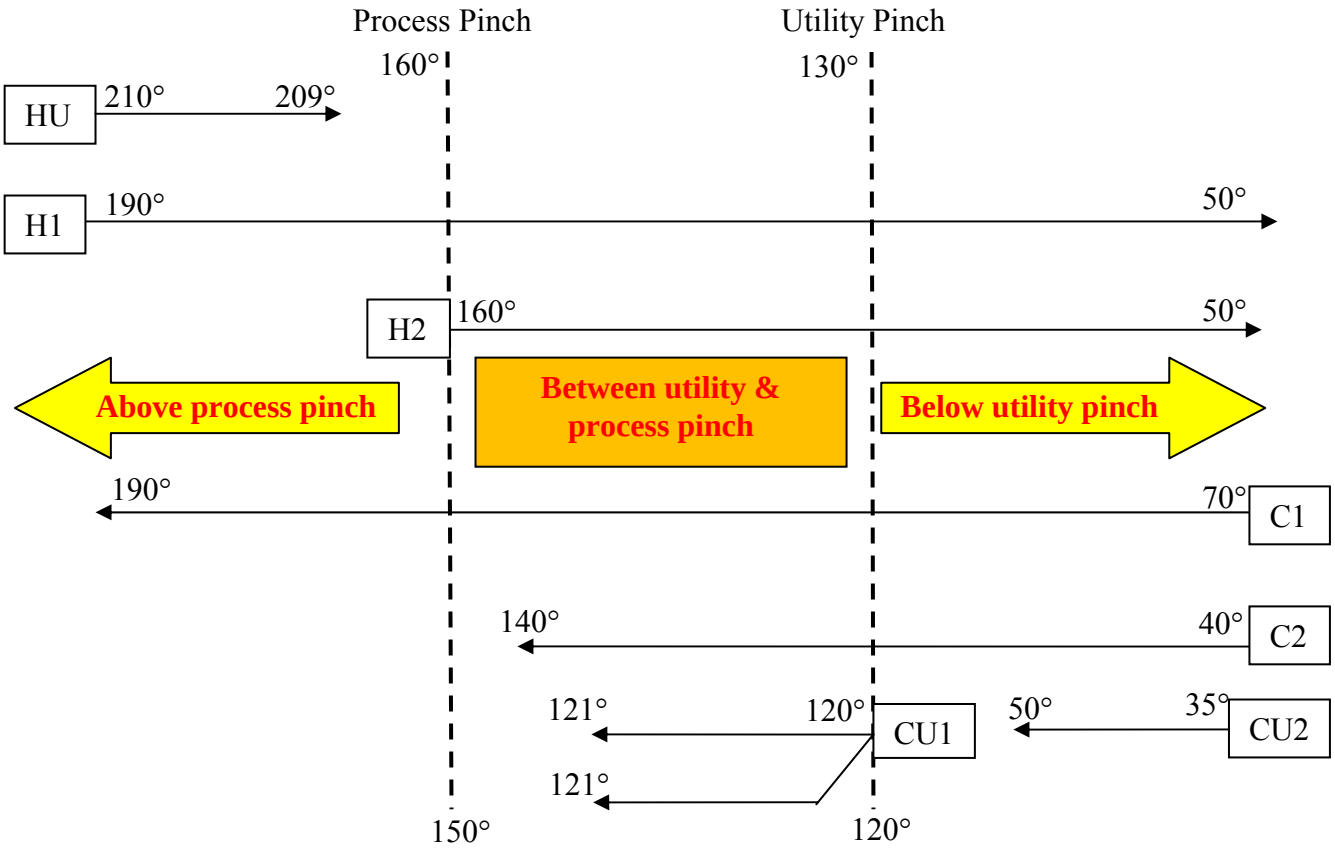

Figure 2: Grid diagram for Problem 1 having process as well as utility pinches

Design of above process pinch section

The grid diagram of above process pinch section, along with CP table, is shown in Figure 3. The pinch design rules for above pinch will be applicable in this section, which are:

- Number of stream criterion: $N_H \leq N_C$
- CP criterion: $CP_H \leq CP_C$

Figure 3 shows that number criterion is fulfilled as one hot and one cold streams exist. However, CP criterion is satisfied between hot stream, H1, and cold stream, C1, (i.e. 18 < 27) as shown in Figure 3, so exchanger-1 can be placed between these streams. The load of streams H1 and C1 are 540 kW and 1080 kW, respectively, hence stream H1 can be ticked off as it has minimum load among the two streams. The remaining load of stream C1 is satisfied through hot utility, HU, thus exchanger-2 is placed between these streams as shown in Figure 3.

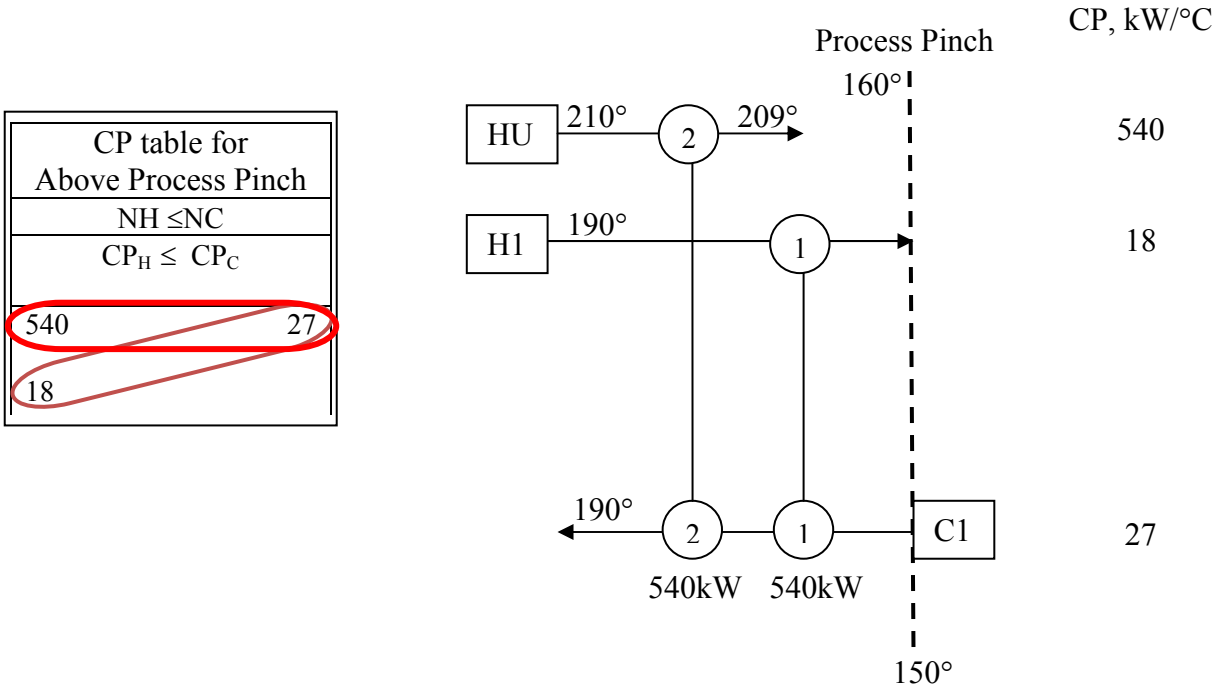

Figure 3: Design of above process pinch

Design of between process and utility pinch section

The grid diagram of section between process and utility pinch, along with CP table of this section, is shown in Figure 4. The design in this section is started from process pinch and move to utility pinch. The pinch design rules for below pinch will be applicable in this section, which are:

- Number of stream criterion: $N_H \geq N_C$
- CP criterion: $CP_H \geq CP_C$

Figure 4 shows that number criterion is fulfilled as two hot and two cold streams exist between process and utility pinch. The CP criterion is satisfied between hot stream, H2, and cold stream, C1, (i.e. 42 > 27) as shown in Figure 4. Thus, exchanger-3 can be placed between these streams. The load of streams H2 and C1 are 1260 kW and 810 kW, respectively, hence stream C1 can be ticked off. Further, it is seen from Figure 4 that CP criterion is not satisfied between streams, H1 and C2 (i.e. 18 < 20). Moreover, CP criterion can be violated between these streams as these will not cause a pinch match to be placed. Thus, exchanger-4 can be placed between streams, H1 and C2, with a load of 400 kW. Consequently, stream, C2, is ticked off. The remaining loads of streams, H1 and H2, are satisfied through cold utility, CU1. So, exchanger-5 and 6 are placed as shown in Figure 3.

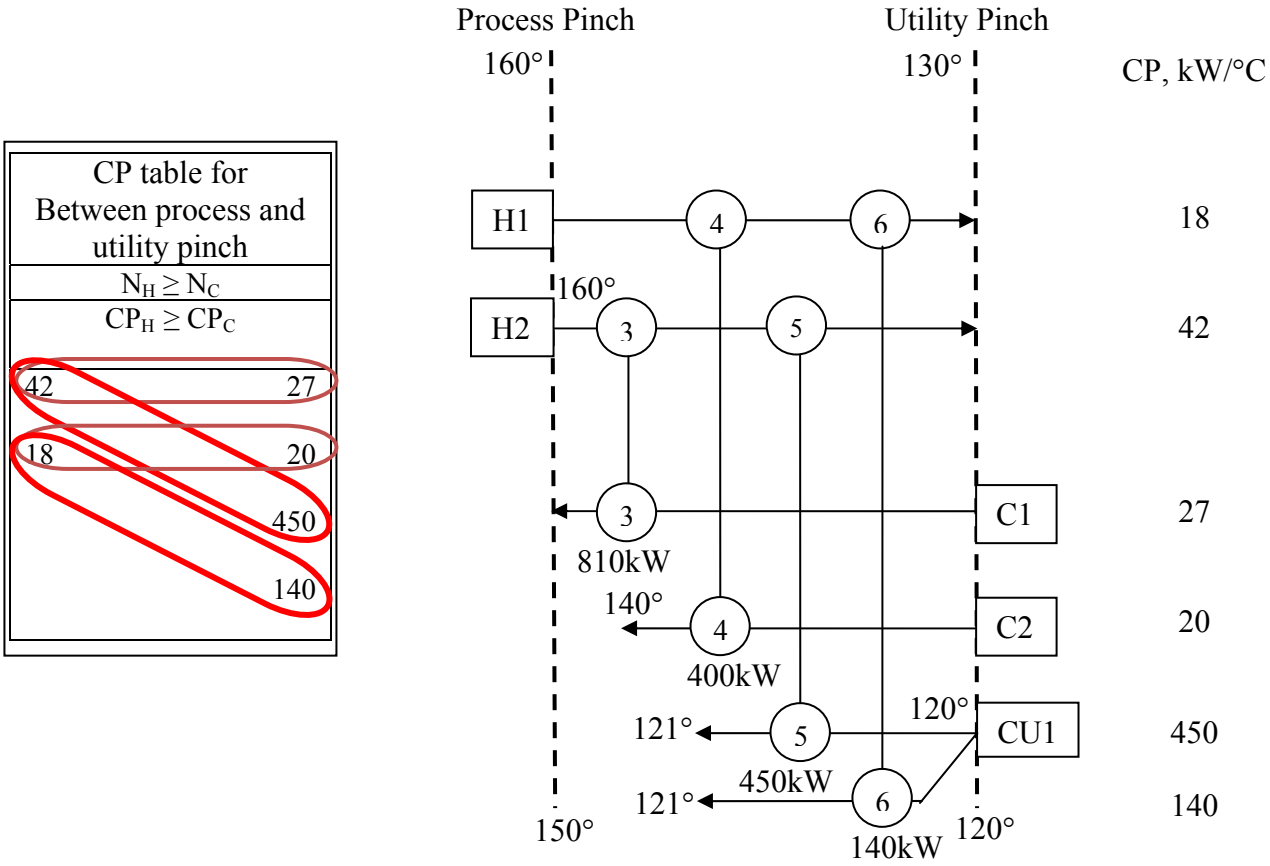

Figure 4: Design of between process and utility pinch

Design of below utility pinch section

The grid diagram of below utility pinch section, along with CP table of this section, is shown in Figure 5. The pinch design rules for below pinch will be applicable in this section, which are:

- Number of stream criterion: $N_H \geq N_C$
- CP criterion: $CP_H \geq CP_C$

Figure 5 shows that number criterion is fulfilled as two hot and two cold streams exist. The CP criterion is satisfied between hot stream, H2, and cold stream, C1, (i.e. 42 > 27) as shown in Figure 5. However, the CP criterion is not fulfilled between streams, H1 and C2, as 18 < 20. Thus, to place a pinch match between streams, H1 and C2, stream C2 must be splitted. Consequently, the number of streams criterion will violate as there will be two hot streams and three cold streams. Thus, to fulfill number of streams criterion stream, H2, must be splitted. However, stream, H2, is splitted as CP criterion between streams, H2 and C1, should not violate.

Considering these facts, exchanger-7 of 1350kW load is placed between spliited part of hot stream, H2, and cold stream, C1. Subsequently, stream, C1, is ticked off. Exchanger-8 is matched between stream, H1 and splitted part of C2 and so, stream, H1, is ticked off. Further, the splitted part of H2 as well as that of C2 are matched through exchanger-9 which is having 160kW load. Consequently, stream, C2, is ticked off. The remaining load of stream, H2, is satisfied through cold utility, CU2. So, exchanger-10 is placed between streams, H2 and CU2, as shown in Figure 5. Thus, loads of CU1 and CU2 (i.e 590+1850=2440 kW) meet the total cold utility demand of the process.

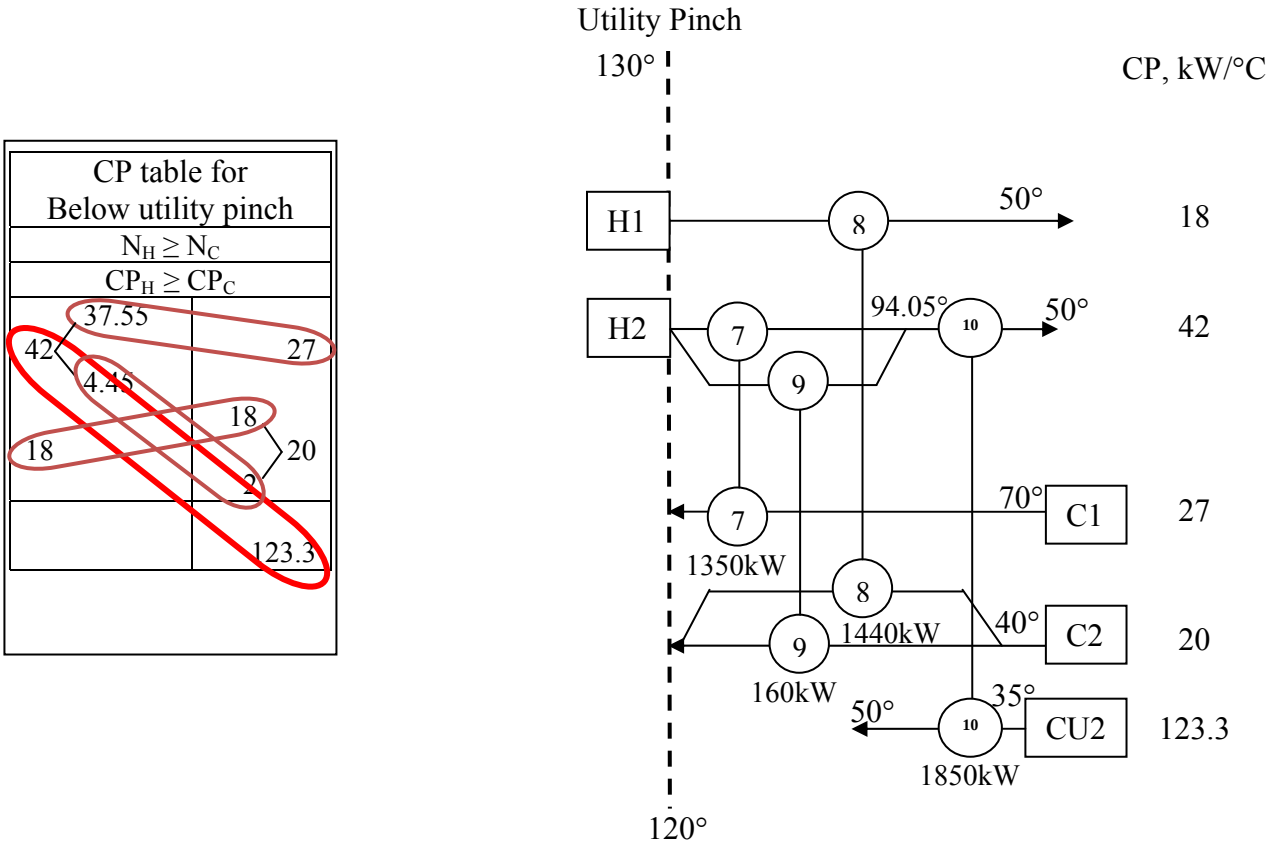

Figure 5: Design of below utility pinch

The final design of heat exchanger network is shown in Figure 6. As temperature approaches for each exchanger are more than ΔT_{min}, design is considered as feasible.

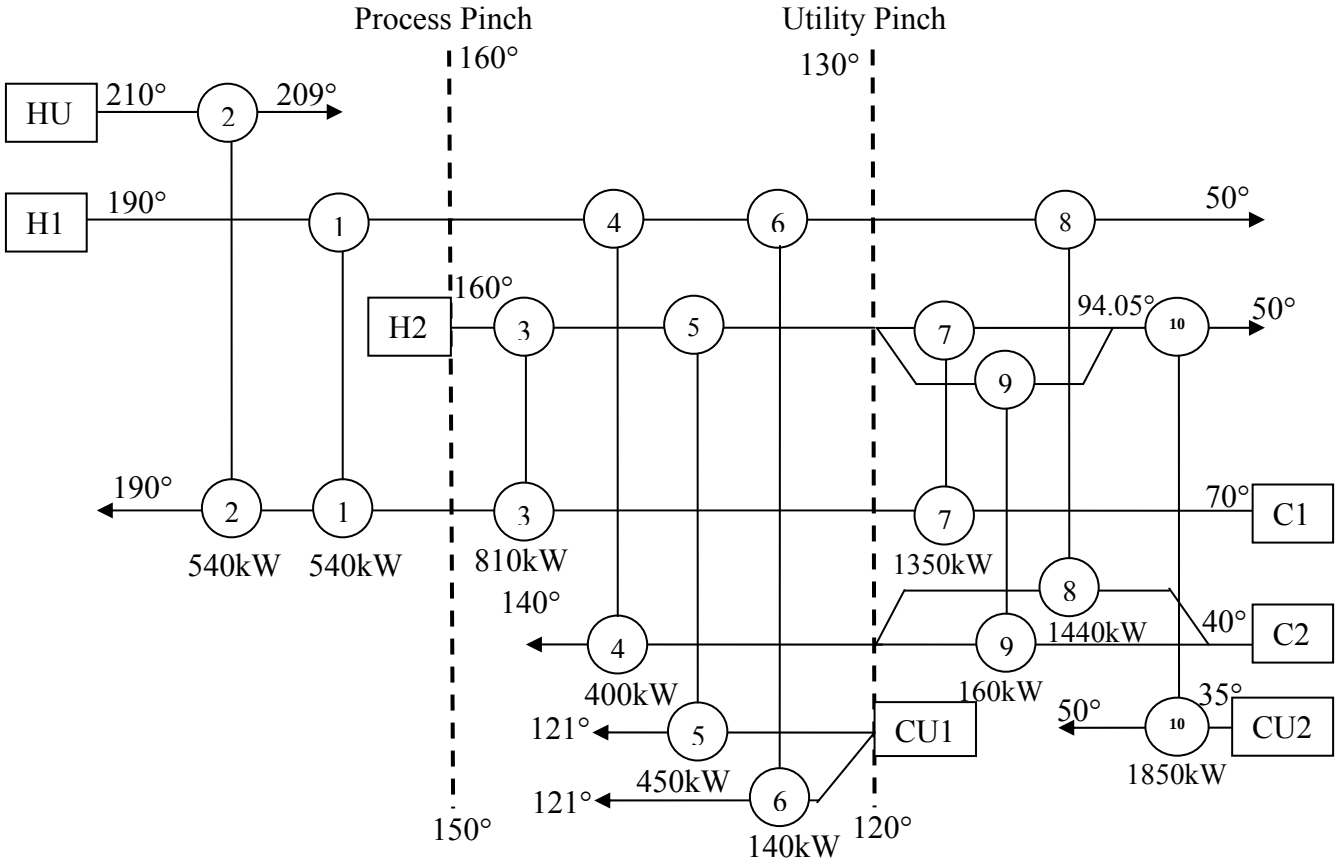

Figure 6: The final design of heat exchanger network for Problem 1