Pinch Technology Second Generation

Analysis with crisscross optimisation prior to design

Design with loop optimisation for minimum area and minimum cost

Example Case 1

Crisscross analysis - The principle.

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Case 1 - Crisscross analysis - The principle.

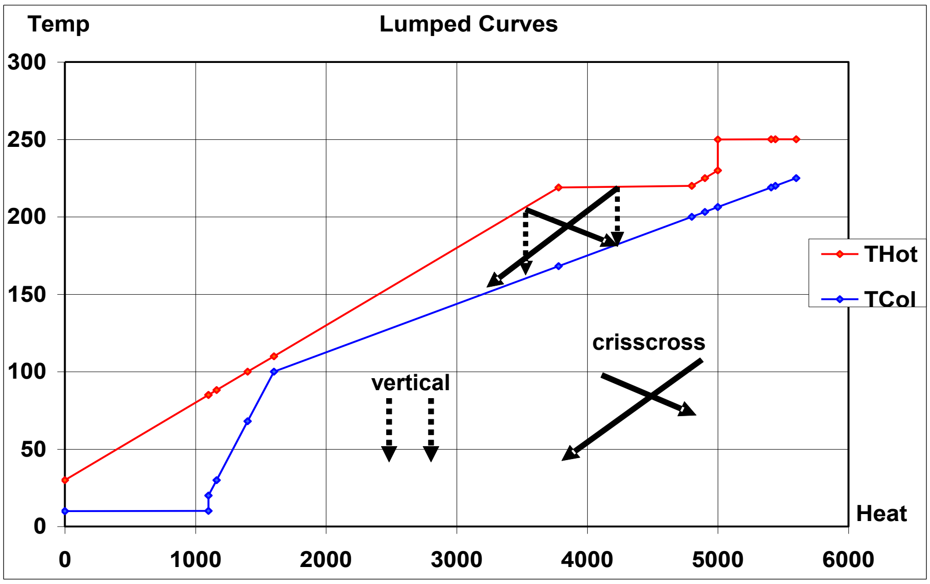
The principle of crisscross optimisation prior to design is illustrated in Case 1 with the data set of Table1.

Table 1

Tsupply °C	Ttarget °C	Heat kW	DTShift K	U*F kW/m²,K	Comment
230	30	4000	5	2	H1
220	219	1000	0 ... 100	0.1	H2
20	100	500	5	2	C1
100	200	4000	5	2	C2
250	249	600	5	2	Heating
10	15	1100	5	2	Cooling

With an overall DTMin of 10 K, energy targets are 600 kW Heating and 1100 kW Cooling with a process heat integration of 3900 kW. These energy targets are now retained and DTMin contributions will be differentiated. A shift contribution of 5 K is taken for all streams except for Hot stream H2 that has a low heat transfer coefficient. Crisscross will be applied as shown in Fig. 1.1 with the shift contribution for steam H2 varying from 0 K to 100 K.

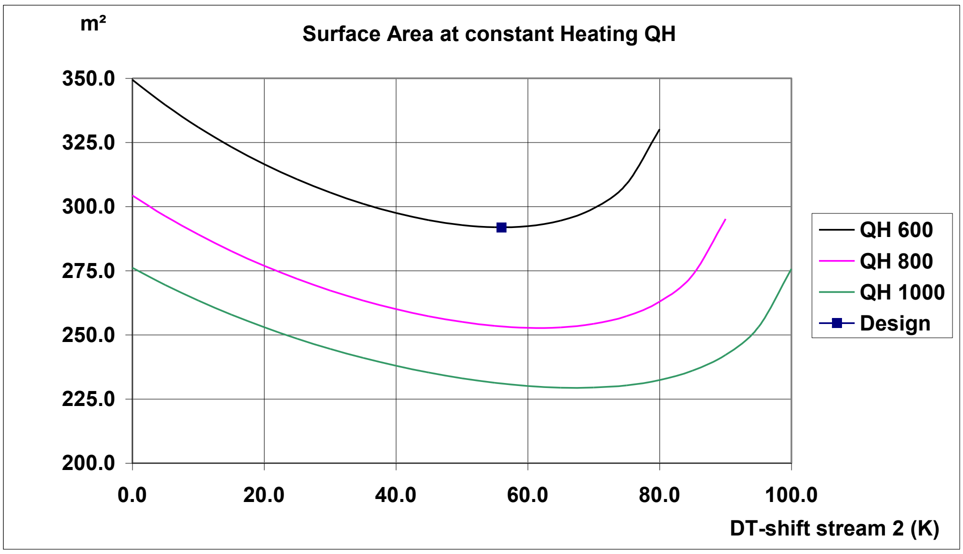
Fig.1.1



The corresponding surface area required varies as shown in Fig. 1.2 with a minimum for a shift contribution for stream H2 of 56 K. If stream H2 were shifted more than 80K, then it would start transferring heat across the pinch and it would no longer be possible to maintain the energy targets. The required area is also shown for energy targets set at 800 kW Heating, respectively 1000 kW Heating.

Fig. 1.3 shows first design(1), a classic pinch design using the tick-off procedure. It also shows design(2), a more refined design applying vertical heat exchange in the different heat integration bands without crisscross, but this design is not better than the design with the tick-off procedure.

Fig.1.2



Design(3), on the basis of the crisscross-optimised shift temperatures, however, is better; capital cost is 5.3% lower and within 0.1% of the final optimum. Obviously, cost relations depend upon the cost structures applied and in this particular case the optimum design(3) could also be derived from design(2) (no topology trap) by adjusting heat loads. There is no reason, however, for applying the vertical heat exchange instead of the tick-off procedure and adjusting heat loads in design(1) can never lead to the optimum since design(1) has a topology trap (the link that would initiate heat exchanger #3 is missing). The advantage of the crisscross procedure is that the improved data set to start from for the design leads to an initial Heat Exchanger Network (HEN) that is much closer to the final optimum than with the classic procedure.

Crisscross heat exchange is driven by the difference in shift contribution. For more streams with different heat transfer coefficients such combination of shift values can be searched that leads to minimum surface area. Temperatures of hot streams (respectively cold streams) at the pinch and at the various other temperature levels can differ from each other. The optimum shift for any particular stream depends on its heat transfer coefficient, the shape of the composite curves and the position of the stream in the heat integration grid. As shown in other examples, there is not necessarily a direct relation between a stream's heat transfer coefficient and its optimum shift value.

It is often claimed that pinch methods for HEN design suffer from improper trade-off handling, several topology traps, and are time consuming. Here, trade-off is being refined by optimising crisscross heat exchange in the analysis stage for dealing with the effects of unequal U values and an optimum data set is generated for initialising the configuration of an optimum HEN. Many examples show that topology traps are avoided. Rather than applying "pinch method" typical tick-off procedures, the concept of superstructures can successfully be applied without the need for adjusting the temperature barriers with the view to reducing surface area.

In case of retrofits, ‘pinch violations’ calculated with classic pinch analysis are not reliable since disregarding required crisscross for achieving minimum area and, consequently, proposed remedies are not optimal. By defining differentiated pinch temperatures in view of minimum surface area, resulting remedies become reliable.

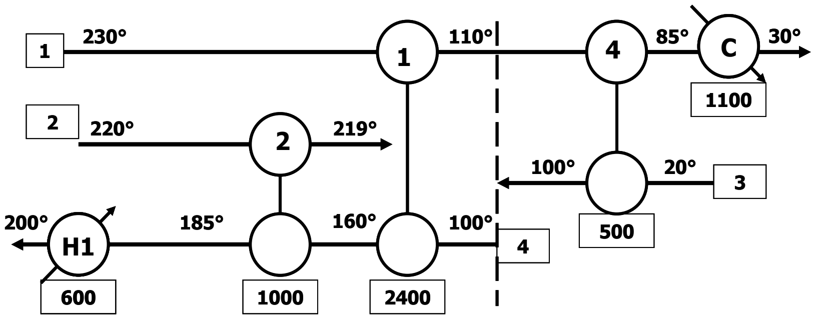
With the proposed procedure, trade-off curves frequently show a cost optimum at a higher degree of integration (lower energy consumption) than with the classic approach. This optimum is no longer driven by a global DTMin but, next to the cost parameters, by a combination of contributions that depend upon the degree of integration and the stream specific heat transfer values.

Finally, and from the point of view of pinch analysis probably most importantly, crisscross optimisation might lead to a pinch at a totally different temperature level and being caused by a different process stream than what is indicated by classic pinch analysis. The reason for this is that crisscross optimisation is targeting the economic optimum in a much more reliable way. Since design procedures start at the pinch, the proposed initial network could be completely different from the network resulting from the classic approach and might be economically feasible where the classic proposal fails.

HEX cost = 30000 + 6000 x Area $^{0.81}$

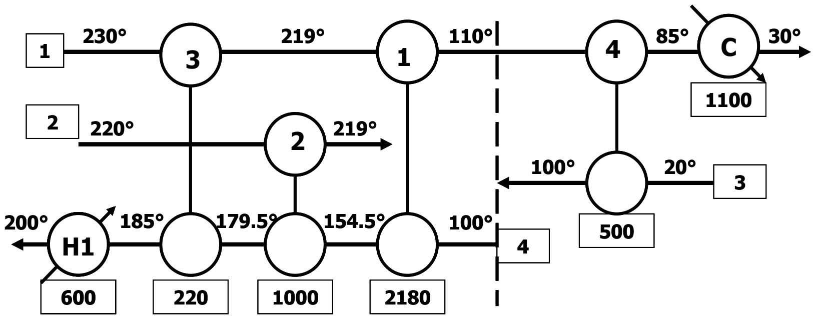
(1)

Classic pinch design – tick-off procedure
Network cost = 1030.8 kEUR



(2)

Classic pinch design - vertical heat transfer
Network cost = 1033.2 kEUR



(3)

Crisscross optimisation prior to design
Design for DT-shift of 56K on stream 2
Network cost = 975.9 kEUR

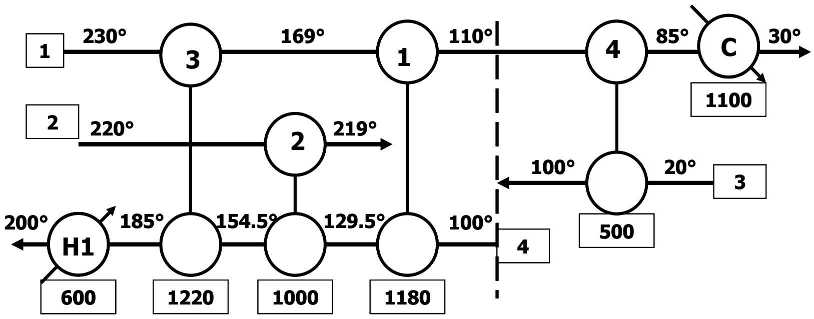


Fig.1.3