A CASE STUDY ON HEAT EXCHNAGE NETWORK

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Abstract

The requirement of energy in any processing industry is not only a need but it is indeed a most wanted utility. In a typical processing or manufacturing industry the most common utility are steam and cooling water. However the cost of these utility are no longer cheap, in fact they are expensive. Therefore saving these utility or minimizing the usage of these utilities is one of the most needed practice in a processing industry. Pinch technology is the most common method, which is aimed at minimizing the requirement of utilities by maximizing the process to process heat transfer.

In the present study temperature interval diagram or TID is used to identify the targets for minimum utility requirement and maximum process to process heat transfer in a processing facility. The targets for heat exchanger network are presented and minimization of number of heat exchangers are provided using stream splitting technique.

Keywords: *Pinch design, stream splitting, HEN synthesis, Utilities, TID*

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1. INTRODUCTION

In any processing industry there are many streams which have to be heated prior to processing or any unit process, and also there are streams which have to be cooled like products before storage and sales. In both cases energy transfer is involved. Normally heating is done using steam, heating oil etc, and for cooling purpose either cooling water or refrigerants are used depending on the need. However the cost involved in the energy transfer process has to be taken into account for any facility. Also the scarcity of natural resources also contributes to the energy crisis problem. Hence there is a need for minimizing the usage of utilities like steam and cooling water and at the same time it is required to maximize the process to process heat transfer. Pinch technology is a promising technique from which we can achieve the target of maximum process to process heat transfer and minimum utility requirement. Pinch technology involves graphical method called thermal pinch diagram and an algebraic technique namely temperature interval diagram. The latter has several advantages over the former as it can be applied when several process streams are involved in a facility.

The present study uses temperature interval diagram to maximize process to process heat transfer for a given industrial case study. Once the target for minimum utility requirements is calculated , a network of heat exchangers are designed using pinch design approach with minimum no. of heat exchangers using stream splitting technique without violating second law of thermodynamics.

2. METHODOLOGY

In the present study an algebraic approach was followed. Following thermal data on process hot streams and process cold streams were collected from a chemical fertilizer industry located in Chennai.

Stream	Heat Capacity Flow Rate, CP (KW/^{0}C)	Supply Temperature ^{o}C	Target Temperature ^{o}C	Enthalpy, ΔH (KW)
Hot	151.18	403	280	18595
Hot	146.94	280	193	12784
Hot	259.97	20	1	4939.44
Cold	422.62	214	258	18595
Cold	196.68	149	214	12784
Cold	224.52	-12	10	4939.44

Temperature interval diagram was constructed keeping a suitable temperature difference. Interval heat loads for both hot and cold streams were then tabulated in the form of TEHL. Heat balance across each interval was then carried out taking residual load to first interval as zero initially. All the negative loads were made positive in a revised cascade diagram. This gave minimum utility requirements. Once the utility targets were determined, stream splitting techniques were employed to create a network

3. RESULTS AND DISCUSSION

3.1 Temperature Interval Diagram

In the Temperature Interval Diagram (TID), 8 intervals were constructed based on data shown in Figure 1.

INTERVAL	HOT STREAM (^{0}C) 403	COLD STREAM(^{0}C) 393
1.	280	270
2.	268	258
3.	224	214
4.	193	183
5.	159	149
6	20	10
7.	1	-9
8	-2	-12

Fig 1: Temperature Interval Diagram (for 10^{0}C)

In Table of Exchangeable heat loads, total loads for each interval was summarized in Table 1 and Table 2 for both hot and cold streams respectively.

Table 1: Table of Exchangeable Heat Loads (TEHL) for Hot Side:

Interval	H1(KW)	H2(KW)	H3(KW)	HHz(KW)
1	18595.5	0	0	18595.5
2	0	1763.371	0	1763.371
3	0	6465.694	0	6465.694
4	0	4555.375	0	4555.375
5	0	0	0	0
6	0	0	0	0
7	0	0	4939.443	4939.443
8	0	0	0	0

Table 2: Table of Exchangeable Heat Loads (TEHL) for Cold Side:

Interval	C1(KW)	C2(KW)	C3(KW)	HCz(KW)
1	0	0	0	0
2	0	0	0	0
3	18595.5	0	0	18595.5
4	0	6097.19	0	6097.19
5	0	6687.2	0	6687.2
6	0	0	0	0
7	0	0	4265.8	4265.8
8	0	0	673.56	673.56

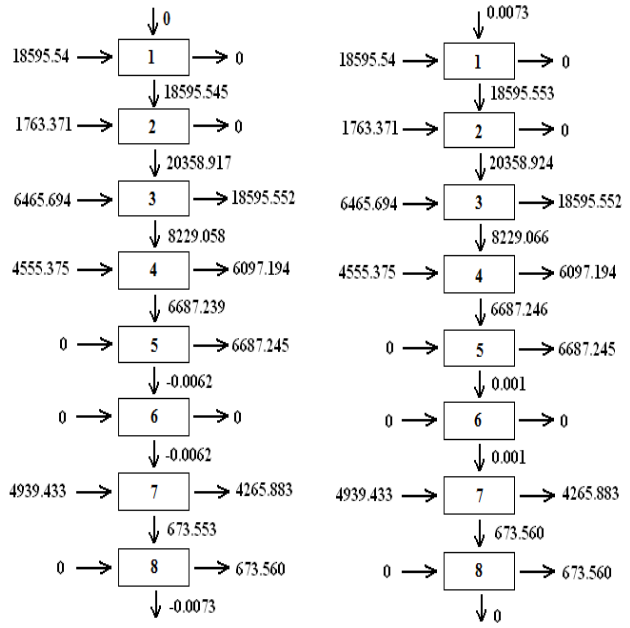

Fig 2: Cascade and Revised Cascade Diagram

From the revised cascade diagram, the minimum hot utility was found to be 0.007 KW and minimum cold utility was found to be 0 KW for ΔT_{min} 10^{0}C.

It was the case of threshold problem. An increase in ΔT_{min} overcomes the threshold problems [2]. However heat exchanger network synthesis can be done for threshold problems also. For threshold problem a capital energy trade off suggested that the optimum temperature difference was below threshold value. In order to get a pinch point in such cases, the capital energy trade off suggested that, the optimum temperature be increased such that it is at or above the threshold value.

3.2 Heat Exchange Network Synthesis

From the pinch analysis, it was found that the minimum cold utility was 0 KW. Hence the most constrained part lies in the no utility zone. This was considered to be "above the pinch" problem.

3.3 Minimum Number of Heat Exchangers

CP inequality criteria and the ΔT_{min} of 10^{0}C between the matched streams were maintained. Also the stream number criteria, $S_H \leq S_C$ (above pinch) was followed wherein 3 hot and cold streams were considered. Streams H3 and C3, H2 and C2, H3 and C3, H1 and C2, H1 and C2 were considered to be the different heat exchangers. A hot utility at C2 was found. Hence minimum number of heat exchangers was found to be 6.

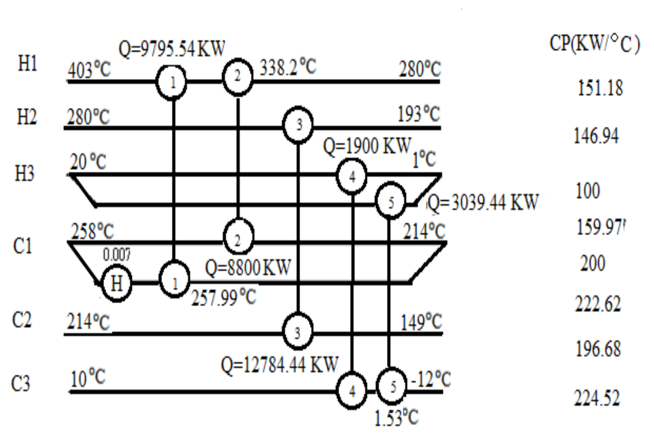

Fig 3: Pinch design (Threshold problem for ΔT_{min} 10^0C)

3.4 Temperature Interval Diagram AT $\Delta T_{MIN} = 15^0C$

In the Temperature Interval Diagram(TID), 9 intervals was constructed based on data shown in Figure 2.

INTERVAL	HOT STREAM (^{0}C)	COLD STREAM (^{0}C)
	403	388
1.	280	265
2.	273	258
3.	229	214
4.	193	178
5.	164	149
6	25	10
7.	20	5
8	3	-12
9.	1	-14

Fig 4: Temperature Interval Diagram ($\Delta T_{MIN} = 15^0C$)

In Table of Exchangeable heat loads, total loads for each interval was summarized in Table 3 and Table 4 for both hot and cold streams respectively.

Table 3: Table of Exchangeable Heat Loads (TEHL) for Hot Side:

Interval	H1(KW)	H2(KW)	H3(KW)	HHz(KW)
1	18595	0	0	18595
2	0	1028.6	0	1028.6
3	0	6465.6	0	6465.6
4	0	5290.1	0	5290.1
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	4419.5	4419.50
9	0	0	519.94	519.941

Table 4: Table of Exchangeable Heat Loads (TEHL) for Cold Side:

INTERVAL	C1(KW)	C2(KW)	C3(KW)	HCz(KW)
1	0	0	0	0
2	0	0	0	0
3	18595.5	0	0	18595.5
4	0	7080.6	0	7080.6
5	0	5703.8	0	5703.8
6	0	0	0	0
7	0	0	1122.6	1122.6
8	0	0	3816.8	3816.8
9	0	0	0	0

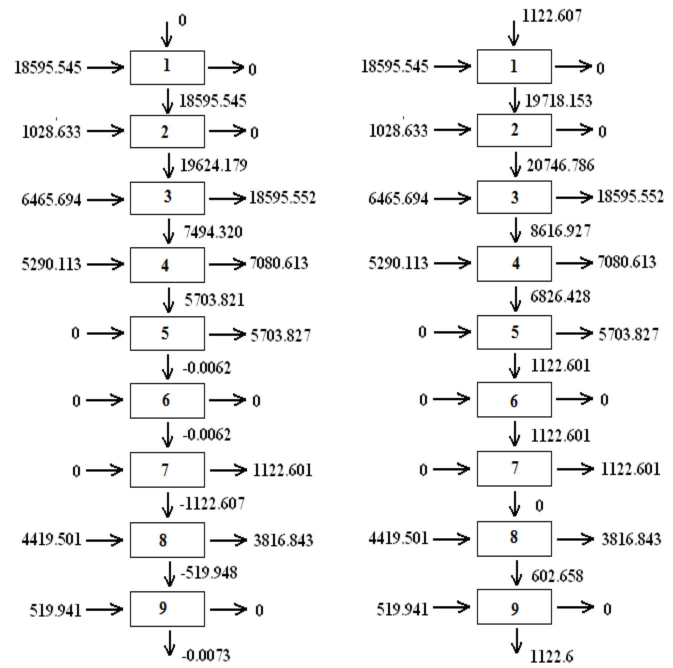

Fig 5: Cascade diagram for case study

From the revised cascade diagram, both the minimum hot utility and minimum cold utility were found to be 1122.6 KW for ΔT_{min} 15^0C. A pinch point was obtained at 20^0C hot side and 5^0C cold side.

3.5 Heat Exchange Network

From the pinch analysis, it was found that the pinch point was obtained 20^0C at hot side and 5^0C at cold side. A line was drawn at the centre representing pinch temperature and the design was divided as "above the pinch" and "below the pinch" regions, the line being the most constrained part.

Above the pinch: By using CP inequality criteria, $CP_H \leq CP_c$ (above pinch), matches were made. Below the Pinch: $CP_H \geq CP_c$ criteria was followed.

3.6 Minimum Number of Heat Exchangers

CP inequality criteria and the ΔT_{min} of 15^0C between the matched streams were maintained. Also the stream number criteria, $S_H \leq S_C$ (above pinch) was followed wherein 3 hot and cold streams were considered. Streams H3 and C3, H2 and C2, H2 and C3, H2 and C2, H1 and C1 were considered to be the different heat exchangers. A hot utility at C2 and cold utility at H3 were found. Hence minimum number of heat exchangers was found to be 7.

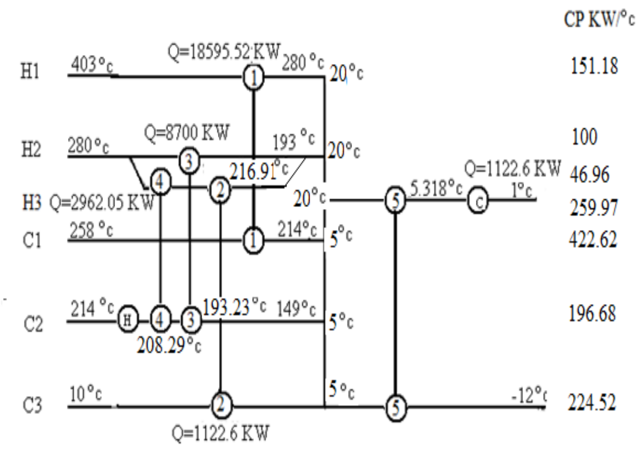

Fig 6: Pinch design (for ΔT_{min} 15^{0}C)

4. CONCLUSION

In order to overcome energy crisis in industry, heat exchange network of different industries were studied.

In this case study which was taken from chemical fertilizer industry, for ΔT_{min} equal to 10^{0}C, a threshold problem was obtained with the cold utility equal to 0 KW.

At ΔT_{min} equal to 15^{o}C, both utility requirements were found to be 1122.6KW and for this a heat exchanger network synthesis was done and it gave minimum of 7 heat exchangers.

This study gave a network of heat exchangers with maximum heat recovery among process streams there by reducing the utility consumption. Here only one type of hot utility and one type of cold utility was considered.

Even though initial ΔT_{min} gave a threshold problem, a HEN with heat recovery was synthesized. Thus an attempt was made to understand the concept of threshold problems heat exchange network synthesis and determination of minimum number of heat exchangers, for an industrial problem.

REFERENCES

[1]. Process Integration: Mahmoud M.El-Halwagi
[2]. Chemical Process Design and Integration – Robin Smith
[3]. Beabu K. Piagbo1, American Journal of Engineering Research (AJER) e-ISSN: 2320-0847 p -ISSN: 2320-0936 Volume-02, Issue-05, pp-11-18
[4]. Jackson Akpa, Journal of Emerging Trends in Engineering and Applied Science, (JETEAS) 01/2012; 3(3):475-484.
[5]. John M. Joe, Journal of Power and Energy Engineering, 2013, 1, 47-52 http://dx.doi.org/10.4236/jpee.2013.15007 Published Online October 2013
[6]. Bodo Linnhoff† and John R. Flower*, Synthesis of Cost Optimization Network, AIChE Journal Volume 24, Issue 4, pages 633– 642, July 1978
[7]. Linnhoff B, D.W. Townsend, D. Boland, G.F. Hewitt, B.E.A. Thomas, A.R.Guy, and R.H. Marsland, "User Guide on Process Integration for the Efficient Use of Energy", IChemE, Rugby, U.K. (1982).
[8]. Pinch Analysis Foundation Training Course, available from Linnhoff March Ltd, UK.
[9]. "SuperTarget" pinch analysis software suite, available from Linnhoff March Ltd, UK.
[10]. Townsend, D. W., and B. Linnhoff, "Heat and Power Networks in Process Design, Part I: Criteria for Placement of Heat Engines and Heat Pumps in Process Networks", AIChE J., 29(5), pp. 742-748 (May 1983). "Part II: Design Procedure for Equipment Selection and Process Matching", AIChE J., 29(5), pp. 748-771 (May 1983).

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