Application of Heat Integration Techniques on Extract Column Section to reduce the cold utility requirements

Deepa H A[1], Ravishankar R[2]

[1] Chemical Engineering Department, DSCE, Karnataka, India

[2] Chemical Engineering Department, DSCE, Karnataka, India

[1]deepaha@gmail.com, Ph:8762060691

Abstract: Energy is the prime mover of economic growth and is vital to the sustenance of modern economy. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible and environmental friendly. Pinch Analysis is a methodology for minimizing energy consumption of chemical plant by maximizing the utilization of hot and cold utilities available within the process, thereby reducing the use of external utilities. It is also known as heat integration, process integration, energy integration or Pinch technology. Pinch technology is applied on various process flow diagrams from chemical industries using heat integration strategies or techniques. These techniques include both graphical procedure (Thermal Pinch diagram) as well as algebraic procedure (Temperature interval diagrams) in order to compare the minimum heating and cooling utility requirement of a process with the actual requirement. In the present work, the process flow diagram of Extract column section is received from a chemical industry and block diagram is prepared for simplification. The hot and cold streams are identified and heat integration techniques are applied in order to find out the minimum cooling utility requirement. With this, the utilities available within the process can be used better and thus energy can be conserved to an extent of 20%.

Keywords*:* Graphical procedure, Algebraic procedure, Heat integration, Pinch Analysis,Cascade diagram, Thermal Pinch diagram, Temperature interval diagram, cooling utility requirement.

1. INTRODUCTION

Chemical processes should be designed as part of a sustainable industrial activity that retains the capacity of ecosystems to support both life and industrial activity into the future. Sustainable industrial activity must meet the needs of the present, without compromising the needs of future generations. For chemical process design, this means that processes should use raw materials as efficiently as it is economic and practicable, both to prevent the production of waste that can be environmentally harmful and to preserve the reserves of raw materials as much as possible. Processes should use as little energy as economic and practicable, both to prevent the build-up of carbon dioxide in the atmosphere from burning fossil fuels and to preserve the reserves of fossil fuels. [5]

In a chemical process, the heating and cooling duties that cannot be satisfied by heat recovery, dictate the need for external heating and cooling utilities (furnace heating, use of steam, steam generation, cooling water, air-cooling or refrigeration). Thus, utility selection and design follows the design of the heat recovery system.

Pinch Analysis is a methodology for minimizing energy consumption of chemical processes by calculating thermodynamically feasible energy targets and achieving them by optimizing heat recovery system, energy supply methods and process operating conditions.

1.1 Objective

In the present work the process flow diagram of Extract column section was obtained from a chemical industry and Heat integration techniques were applied in order to find the minimum cooling utility requirement. The main objective is to find the energy available and saved from the process.

1.2 Similar works

Studies similar to present work have been done by several people among which a few are listed below.

-Dr.Gavin P. Towler worked on "Integrated process design for improved energy efficiency." The concept that the efficiency with which energy and raw materials are used within the process industries depends strongly on the way in which resources are distributed within a manufacturing site were described. Most sites or processes contain several sources or sinks of the resource. For example, a chemical plant will have heat sources (hot streams) and heat sinks (cold streams). By matching these sources and sinks in the appropriate manner we can transfer heat between the streams. Thus developed a more integrated process design which makes better use of the resources available internally, and therefore reduces the amount of external resource that is required. The techniques for integrated design of processes can be applied to a range of problems, for example, recovery of process waste heat, reduction of water usage (which reduces the consumption of heat in treating fresh water and waste water), reduction of chemicals use, etc. In all cases, the overall result is a considerable saving in energy. [1]

-R.M. Mathur, B.P. Thapliyal used Pinch analysis as a tool in pulp and paper industry for setting energy targets and optimizing the heat recovery systems. Using this methodology in a bleached Kraft mill, various successful cost effective process integration and design approaches have been adopted to maximize the heat recovery. In a typical case, all process heating and cooling duties were reviewed , hot effluents being included as potential sources of additional heat. Stream data is then extracted as hot and cold streams according to analysis procedure to derive composite and Grand composite curves for a typical pulp mill. [2]

-Uday V.Shenoy worked on process integration concepts and their application to energy conservation. Heat integration Strategies such as construction of composite curves and grand composite curves for minimum energy targeting were used. The targeting methodology proposed by Shenoy etal.(1998) to determine the optimum loads for multiple utilities is based on the cheapest utility principle(CUP) ,which simply states that the temperature driving forces at the utility pinches once optimized do not change even when the minimum approach temperature at the process pinch is varied. In other words, it is optimal to increase the load of the cheapest utility and maintain the loads of the relatively expensive utilities constant while increasing the total utility consumption.[3]

2. MATERIALS AND METHODS

2.1 Heat Integration Strategies

Two techniques are available for the application of Pinch Technology on process flow diagrams from chemical industries. These include:

1) Graphical procedure (Thermal Pinch diagram)
2) Algebraic procedure (Temperature interval diagram)

The above techniques are used to find the minimum cooling utility requirement of a process.

Steps involved in Graphical Procedure:

- The given hot and cold streams must be plotted on temperature-enthalpy axes
- A constant heat capacity over the operating range is assumed
- Next, both the hot and cold streams are plotted together in a single temperature versus enthalpy plot which represents the Thermal Pinch diagram
- The point where the two composite streams touch or very close to each other is called "Thermal Pinch point".
- The region of overlap between the two streams determines the amount of heat recovery possible
- The part of the cold stream that extends beyond the start of the hot stream cannot be heated by recovery and requires steam and it is the minimum hot utility or energy target
- The part of the hot stream that extends beyond the start of the cold stream cannot be cooled by heat recovery and requires cooling water and it is the minimum cold utility

Steps involved in Algebraic Procedure:

- The first step in algebraic approach is the construction of the Temperature interval diagram(TID)
- Next, the TEHLs (Table of exchangeable heat loads) for the process hot and cold streams are to be developed
- A cascade diagram is constructed
- A Revised Cascade diagram is constructed whenever there exists a thermodynamic infeasibility.
- The results obtained from the revised cascade diagram will be identical to those obtained using the graphical pinch approach

The flow pattern of Hot and cold streams for Extract column section is as shown in Fig 1.It was observed that there were two hot streams and one cold stream with the following data.

Initial cooling utility requirement= 23750 kW

Initial heating utility requirement= 10000 kW

Minimum temperature difference, ΔT_{min}= 10^0C

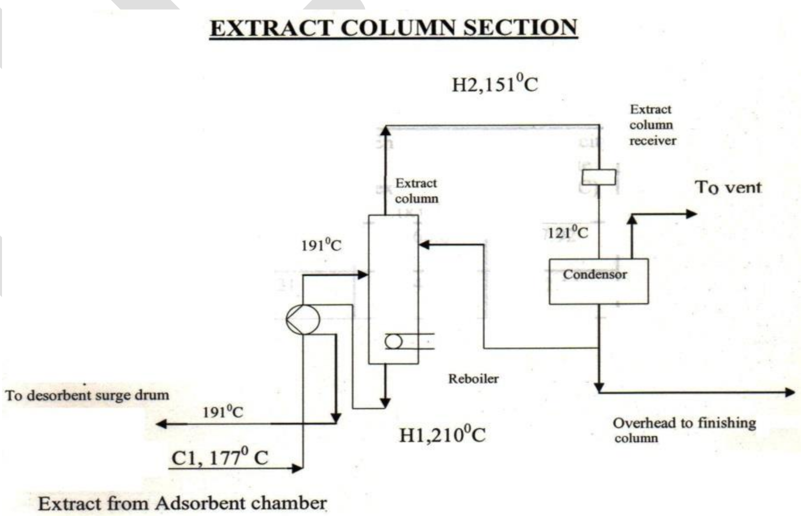

Fig.1 Block Diagram of Extract Column section

Table 1. Hot Stream Data

Sl.No	Supply Temperature (^{0}C)	Target Temperature (^{0}C)	Heat Capacity Flow Rate, m Cp (kW/^{0}C)	Heat Exchanged (kW)
H1	210	191	97.92	1860.8
H2	151	121	631.51	18945.27

Table 2. Cold Stream Data

Sl. No	Supply Temperature (^{0}C)	Target Temperature (^{0}C)	Heat Capacity Flow Rate, m Cp (kW/^{0}C)	Heat Exchanged kW
C1	177	191	132.81	1860.8

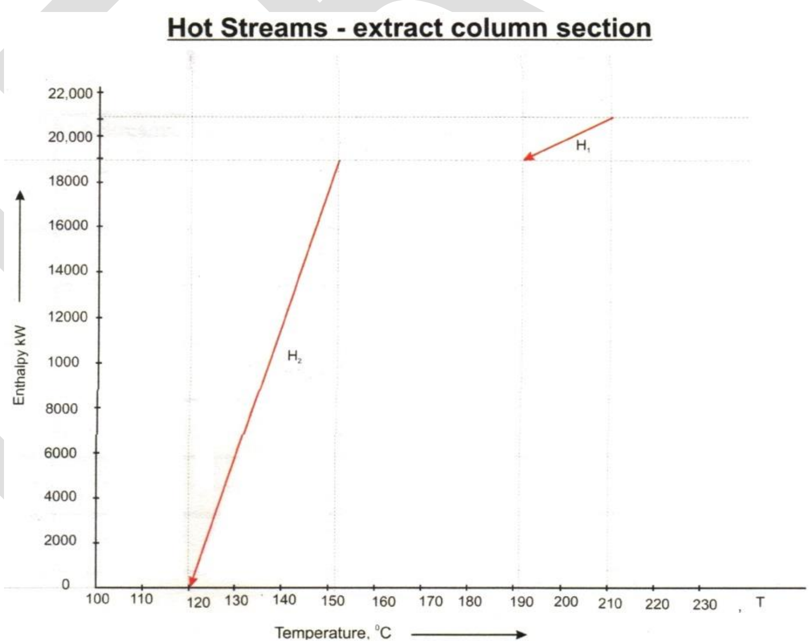

Fig 2.Representation of Hot Streams

Using the supply and target temperature data of hot streams from Table 1, they were plotted on Temperature versus Enthalpy graph as shown in Fig 2.

3. RESULTS AND DISCUSSION

Thermal Pinch diagram was constructed by plotting composite hot and cold streams on a single temperature versus enthalpy plot using graphical procedure as shown in Fig 3. From Thermal Pinch Diagram the minimum cooling utility requirement was found to be 19000 kW.

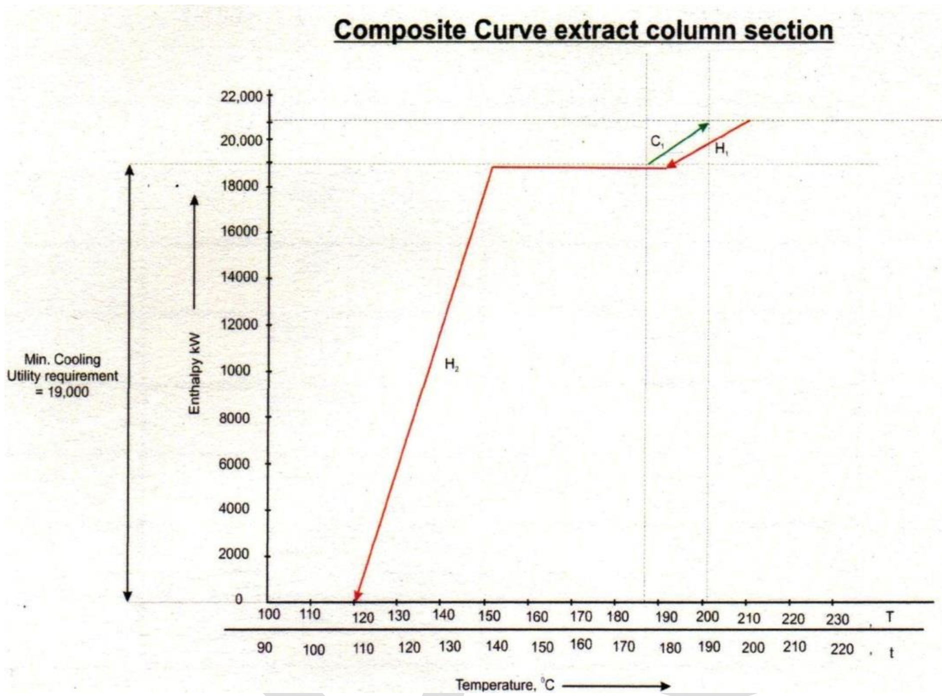

Fig3. Thermal Pinch Diagram

Temperature interval diagram (TID) was constructed using Algebraic procedure as shown in Fig 4. Considering the highest and lowest temperature of hot and cold streams the TID was constructed with seven intervals. Hot stream1,H1 was plotted from interval 1 to interval 3. H2 was plotted from interval 6 to 7 with their respective supply temperature and target temperatures as given in Table 1. Cold stream 1 was plotted from interval 4 to 2. with the supply and target temperatures as given in Table 2.

Interval	Hot Streams, T (^{0}C)	Cold Streams, t (^{0}C)
1	210	200
2	H1 201	191
3	191	181
4	187	177 C1
5	177	167
6	151	141
7	H2 121	111

Fig4. Temperature interval diagram

Using TID, the TEHL for process hot streams and process cold streams were prepared as shown in Table 3 and Table 4. A cascade diagram was constructed as shown in the Fig. 5 by plotting total load of hot streams on the left and total capacity of cold streams on the right hand side and making a heat balance across each interval.

We observed that there were no negative residual heat loads in the cascade diagram and hence there exists thermodynamic feasibility.

Table 3. TEHL for process Hot streams

Interval	Load of H1 kW	Load of H2 kW	Total Load kW
1	-	-	-
2	881.32	-	881.32
3#	979.20	-	979.20
4	-	-	-
5	-	-	-
6	-	-	-
7	-	18945.27	18945.27

#3 -Load H1: $mCp\Delta T=97.92\ (201-191)=979.2$

Table 4. TEHL for process cold streams

Interval	Capacity of C1, kW	Total Capacity of cold stream, kW
1	-	-
2	-	
3	1328.14	1328.14
4	531.258	531.258
5	-	-
6	-	-
7	-	-

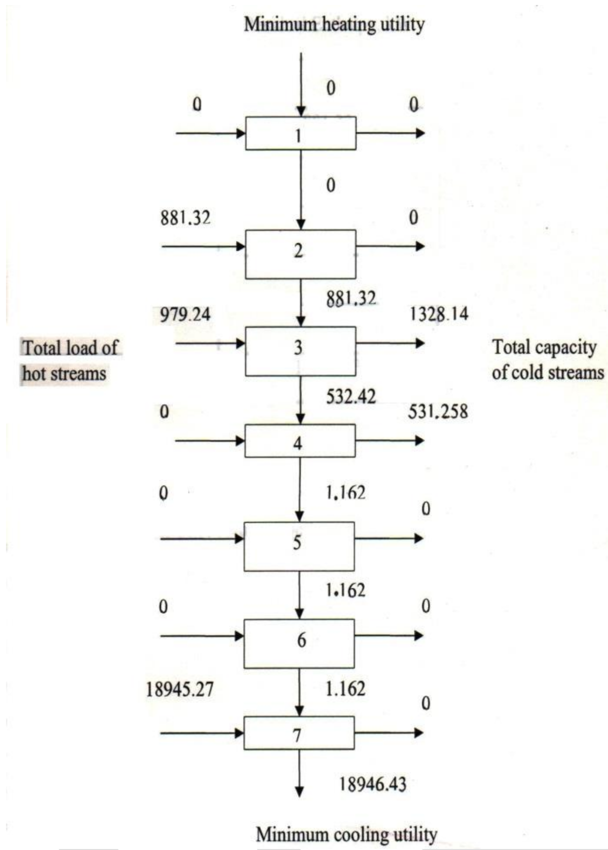

Fig 5.Cascade diagram

Table 5. Comparison of Actual and minimum cooling utility requirement

Actual cooling utility requirement, kW	Min. cooling utility requirement (Graphical procedure) kW	Min. cooling utility requirement (Algebraic procedure) kW
23750	19000	18946.43

Table 6. Percentage reduction in minimum cooling utility requirement

Actual Cooling Utility Requirement kW	% reduction from Graphical procedure kW	% reduction from Algebraic procedure kW
23750	20	20.22

4. CONCLUSION

By the application of Heat integration technique (Pinch analysis) on Extract column section the minimum cooling utility requirements were found and compared with the actual requirement which are summarized as follows:

- The minimum cooling utility requirement from graphical and algebraic procedures were found to be 19000 kW and 18946.93 kW respectively which was actually 23750 kW and hence there is a reduction in minimum cooling utility requirement by 20%
- The results obtained from graphical and algebraic procedure are identical.
- Pinch Analysis can be applied to any section in an industry.

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