Energy Efficiency Analysis Using Pinch Technology

Harshit Shukla[1], Jahanvi Chopra[2], Gaurav Salvi[3], Prof. S.C. Bandpatte[4]
[1,2,3] *Student, Bharati Vidyapeeth (Deemed To Be) University, College of Engineering, Pune, India*
[4] *Professor, Bharati Vidyapeeth (Deemed To Be) University, College of Engineering, Pune, India*

Abstract- **Energy is the prime mover of economic growth and is vital to the sustenance of a modern economy. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible and environmental friendly. 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. Pinch Technology a technique used in the realm of process engineering, is introduced. The aim of this approach is to consider all the heat transfers occurring in a large energy utilizing facility with a view to minimize the external heat transfers to or from the site. It is also known as process integration, heat integration, energy integration. Pinch technology provides a systematic methodology for energy saving in processes and total sites. The methodology is based on thermodynamic principles.**

I. INTRODUCTION

Pinch Technology provides a systematic methodology for energy saving in processes and total sites. The methodology is based on thermodynamic principles. The design of a process starts with the reactors (in the “core” of the onion). Once feeds, products, recycle concentrations and flowrates are known, the separators (the second layer of the onion) can be designed. The basic process heat and material balance is now in place, and the heat exchanger network (the third layer) can be designed. The remaining heating and cooling duties are handled by the utility system (the fourth layer). The process utility system may be a part of a centralized site-wide utility system.

A Pinch Analysis starts with the heat and material balance for the process. Using Pinch Technology, it is possible to identify appropriate changes in the core process conditions that can have an impact on energy savings (onion layers one and two). After the heat and material balance is established, targets for energy saving can be set prior to the design of the heat exchanger network. The Pinch Design Method ensures that these targets are achieved during the network design. Targets can also be set for the utility loads at various levels (e.g. steam and refrigeration levels). The utility levels supplied to the process may be a part of a centralized site-wide utility system (e.g. site steam system). Pinch Technology extends to the site level, wherein appropriate loads on the various steam mains can be identified in order to minimize the site wide energy consumption. Pinch Technology therefore provides a consistent methodology for energy saving, from the basic heat and material balance to the total site utility system. After the heat and material balance is established, targets for energy saving can be set prior to the design of the heat exchanger network. The Pinch Design Method ensures that these targets are achieved during the network design. Targets can also be set for the utility loads at various levels (e.g. steam and refrigeration levels). The utility levels supplied to the process may be a part of a centralized site-wide utility system (e.g. site steam system). Pinch Technology extends to the site level, wherein appropriate loads on the various steam mains can be identified in order to minimize the site wide energy consumption. Pinch Technology therefore provides a consistent methodology for energy saving, from the basic heat and material balance to the total site utility system. The design of the process starts with the reactors. Once feeds, products, recycle concentrations and flow rates are known, the separators can be designed. The basic process heat and material balance is now in place, and the heat exchanger network can be designed. The remaining heating and cooling duties are handled by the utility system. The process utility system may be a part of a centralized site-wide utility system. Using Pinch Technology it is possible to identify appropriate changes in the core process conditions that can have an impact on energy savings. After the heat and material balance is established, targets for energy saving can be set prior to the design of the heat exchanger network. The Pinch Design method ensures that these targets are achieves during the network design. Targets can also be set for the utility loads at various levels. Pinch Technology extends to the site level, wherein appropriate loads on the various steam mains can be identified in order to minimize the site wide energy consumption. 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 It is also known as process energy integration, heat integration, energy integration or Pinch technology. The process data is represented as a set of energy flows, or streams, as a function of heat loads (kW) against temperature (°C). These data are combined for all the streams in the plant to give composite curves, one for all hot streams (releasing heat) and one for all cold streams (requiring heat). *The point of the closest approach between the hot and the cold composite curves is the pinch point (or just pinch) with a hot stream pinch temperature and the cold stream pinch temperature.* This is where the design is most constrained. Hence, by finding this point and starting the design, the energy targets can be achieved using heat exchangers to recover heat between hot and cold streams into separate systems, one for temperature above pinch temperature and one for temperature below pinch temperature.

II. OBJECTIVE

Pinch Technology provides a discipline which allows designers to establish:

- The minimum energy to operate a process.
- A process design with the lowest energy intensity.
- An optimal investment strategy

III. METHODOLOGY

- Identification of hot, cold and utility streams in the process.
- Thermal data extraction for process and the utility streams.
- Selection of initial T_{min} value.
- Construction of Stream Population.
- Plotting of Cascade.
- Estimation of optimum T_{min} value.

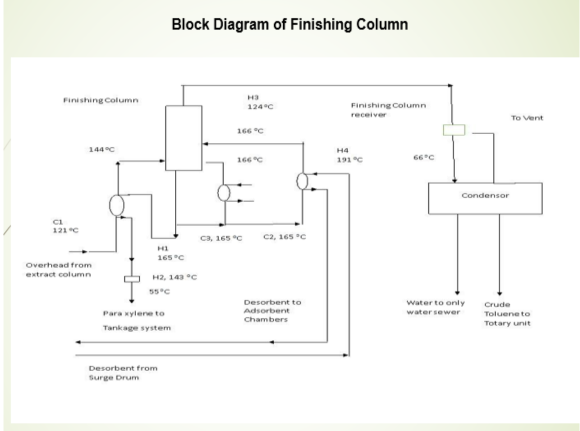

Fig.1. Finishing Column

III.1. Estimation of Hot and Cold Utility.

s.no	stream	Supply temp($T_{s)}$ (^{o}C)	Target temp(T_t) (^{o}C)	Heat capacity (Kw/^{o}C)
1	Hot	165	143	30.132
2	Hot	143	55	26.56
3	Hot	124	66	143.77
4	Hot	191	175	263.128
5	Cold	121	144	28.82
6	Cold	165	166	4210.06
7	cold	125	166	4733.41

Table 1. Thermal Data

Table shows the thermal data for Pinch Analysis. “Hot steams” are the streams that need cooling (i.e. heat sources) while “cold streams” are the streams that need heating (i.e. heat sinks). The supply temperature of the stream is denoted as Ts and target temperature as T_t.

III.2. Determing Energy Targets.

The composite curves provide a counter-current picture of heat transfer and can be used to indicate the minimum energy target for the process. This is achieved by overlapping the hot and cold composite curves, separating them by the minimum temperature difference ΔTmin (10ºC for the example process). This overlap shows the maximum process heat recovery possible indicating that the remaining heating and cooling needs are the minimum hot utility requirement.

The first step is to make adjustments in the temperatures of the composite curves as. This involves increasing the cold composite temperature by ½ ΔTmin and decreasing the hot composite temperature by ½ ΔTmin. (ΔTmin= 20 ^{o}C)

s. no	stream	Supply temp($T_{s)}$) (^{o}C)	Target temp(T_t) (^{o}C)	Heat capacity (Kw/^{o}C)
1	Hot	155	133	30.132
2	Hot	133	45	26.56
3	Hot	114	56	143.77
4	Hot	181	165	263.128
5	Cold	131	154	28.82
6	Cold	175	176	4210.06
7	cold	175	176	4733.41

Table 2. Shifted Thermal Data

III.3. Stream Population

Arranging temperature in decreasing order and doing stream population.

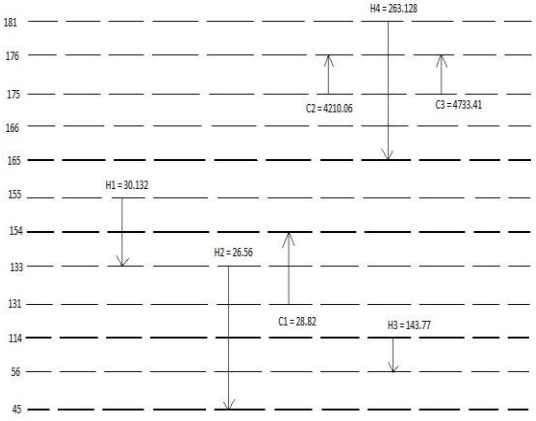

Fig.2. Stream Population

III.4. Calculation of Heat Balance.

In each shifted temperature, calculate a simple energy balance from:

$\Delta H_i = [\sum CP_c - \sum CP_h] \Delta T_i$

Where: ΔH_i = Heat Energy for the shifted temperature.

ΔT_i = the temperature difference across it.

$\Delta T_{interval}$	$\sum C_{pc} - \sum C_{ph}$ (kW/°C)	ΔH (kW)
5	-263.126	-1315.64
1	8680.342	8680.342
9	-263.128	-2368.15
1	-263.128	-263.128
10	0	0
1	-30.132	-30.132
21	-1.312	-27.552
2	2.26	4.52
17	-26.56	-451.52
58	-170.33	-9879.14
11	26.56	-292.16

Table 3. Heat Balance.

A heat balance is carried out within each shifted temperature interval according to Equation. The result is given in which some of the shifted intervals are seen to have a surplus of heat and some have a deficit. The heat balance within each shifted interval allows maximum heat recovery within each interval. However, recovery must also be allowed between intervals.

III.5. Cascading Construction

Assumption that at the start there is 0 MW.

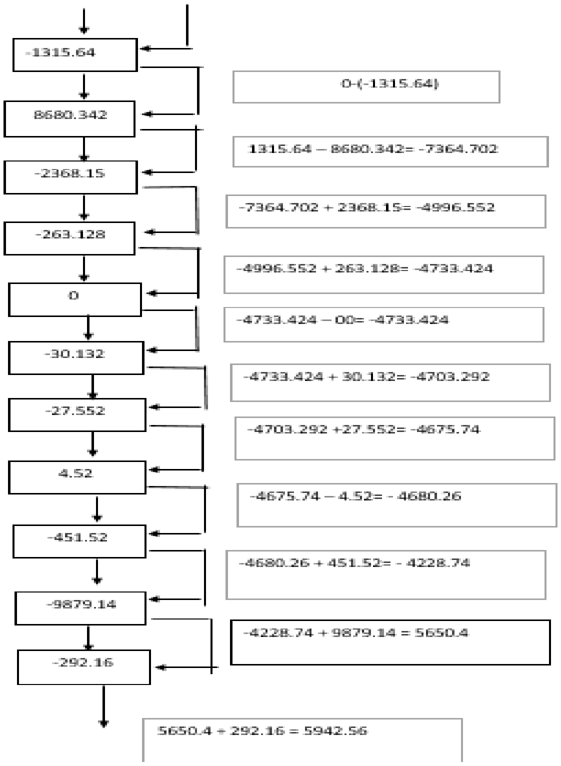

Fig.3. Cascade Diagram

Now, cascade any surplus heat down the temperature scale from interval to interval. This is possible because any excess heat available from the hot streams in an interval is hot enough to supply a deficit in the cold streams in the next interval down. First, assume no heat is supplied to the first interval from hot utility. The first interval has -1315.64 kW, which is cascaded to the next interval. This second interval has an 8680.342 kW, which leaves the heat cascaded from this interval to be−7364.702 kW. In the third interval, the process has -2368.15 kW, which leaves−4996.552 Kw to be cascaded and some of the heat flows are negative, which is infeasible. Heat cannot be transferred up the temperature scale. To make the cascade feasible, sufficient heat must be added from hot utility to make the heat flows to be at least zero. The smallest amount of heat needed from hot utility is the largest negative heat flow from the cascade that is -7364.702 kW. 7364.702 kW is added from hot utility to the first interval. This does not change the heat balance within each interval, but increases all of the heat flows between intervals by 7364.702 kW, giving one heat flow of just zero at an interval temperature of 175°C.

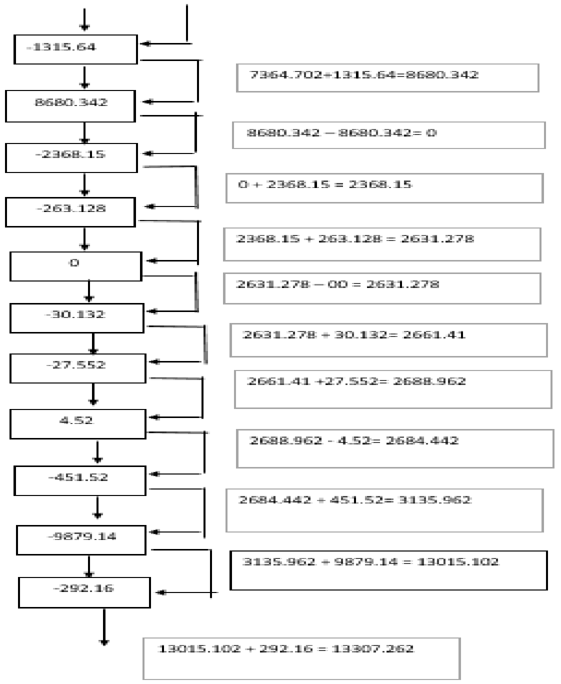

Fig.4. Revised Cascade Diagram

The process data is represented as a set of energy flows, or streams, as a function of heat loads (kW) against temperature (°C). These data are combined for all the streams in the plant to give composite curves, one for all hot streams (releasing heat) and one for all cold streams (requiring heat). The point of the closest approach between the hot and the cold composite curves is the pinch point (or just pinch) with a hot stream pinch temperature and the cold stream pinch temperature. This is where the design is most constrained. Hence, by finding this point and starting the design, the energy targets can be achieved using heat exchangers to recover heat between hot and cold streams into separate systems, one for temperature above pinch temperature and one for temperature below pinch temperature.

III.6. For (ΔTmin= 10°C)

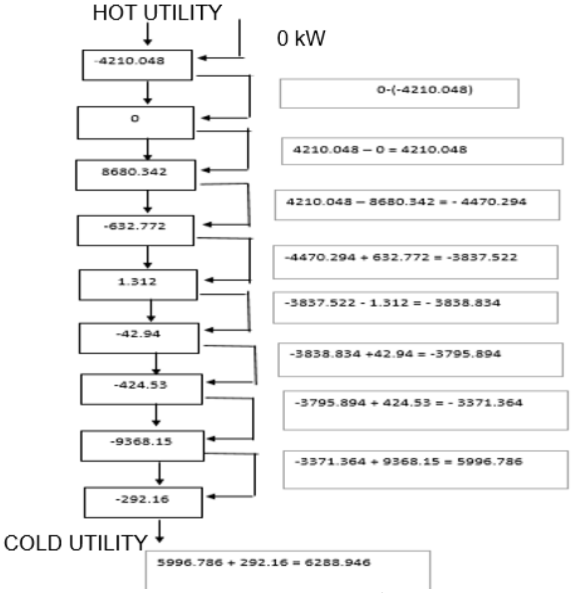

Fig.5.For T_{min} =10°C

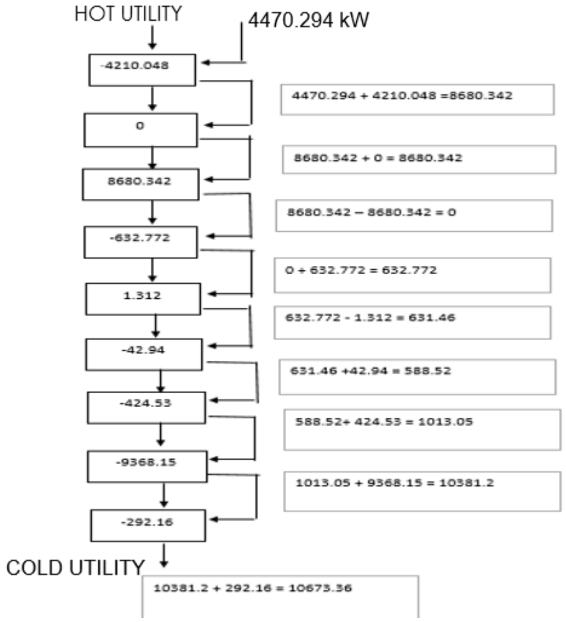

Fig.6. Revised Cascade for T_{min} =10°C

IV. RESULTS.

(For T_{min} = 20 °C)
HOT UTILITY: -7364.702 kW
COLD UTILITY: 13307.23 kW
AT PINCH POINT:

HOT TEMP: 185 °C
COLD TEMP: 165 °C
(For T_{min} = 10 °C)
HOT UTILITY: -4470.294 kW
COLD UTILITY: 10673.36 kW
AT PINCH POINT:
HOT TEMP: 170 °C
COLD TEMP: 160 °C

V. CONCLUSION

Pinch analysis has become a mature tool for the design of heat exchanger networks. Moreover, it has developed from a specialist tool for heat recovery into a broader based methodology for the conceptual design of process and energy systems. The major contribution of Pinch Analysis is in analysis rather than network design. Targets are analyzed prior to design. This allows the designer to scope and screen design strategies. The scoping and screening considers overall economics (not just energy costs) and key feasibility features. Strategic alternatives can be selected for large and seemingly complex design problems.

VI. ACKNOWLEDGEMENT

It gives us great pleasure in presenting the report for our topic Energy Efficiency Analysis_Using Pinch Technology. We would like to take this opportunity to thank our guide Prof. S .C. Bandpatte for giving us all the help and guidance we needed. We are really grateful to him for his kind support throughout the analysis and design phase. His valuable criticism and suggestions were very helpful.

REFERENCES

[1] Mathur. R.M. “Process Integration through Pinch Analysis”, User Guide on Process Integration for the Efficient Use of Thermal Energy by Linnhoff & others, Published by “The Institution of Chemical Engineers, Geo. E. Davis Building, 165 – 171 Railway Terrace, Rugby, Warks, CV21 3HQ, England”, 1982.
[2] Smith, “Chemical Process Design and Integration”, 8th Edition, 2006, pg. 317-437
[3] Shenoy, U.V., Sinha, A. and Bandy upadhyay, S. (1998) "Multiple utilities targeting for heat exchanger networks", Trans. IChemE. Chem. Eng. Res. Des., 76, Part A, March, 259-272.
[4] B. Linnhoff, T.N Tjoe, Using pinch technology for process retrofit, Chemical Engineering, 93, 1986, 4760.
[5] Introduction%20to%20Pinch%20Technology-LinhoffMarch.pdf
[6] RobinM.SmithChemicalprocessdesignandintegration-Wiley2005.pdf