SSRG International Journal of Mechanical Engineering
ISSN: 2348 – 8360 /doi: 10.14445/23488360/IJME-V6I8P102

Volume 6 Issue 8, 6-15, August 2019
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Pinch Analysis and Heat Integration in a Sugar Industry using Hint Software

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Abstract

The rising cost of energy and environmental concerns has led the Sugar industry to search for reducing energy consumption in operations. In this paper, pinch analysis was applied to a typical Sugar Industry process to target its energy requirements. Hint software was used for the analysis. At the chosen ΔT_{min} of 10˚C, the industry's minimum cooling and heating utility requirements were studied and determined 46594 kW and 3258 kW, respectively, with a pinch temperature at 113˚C. The company's hot utility requirements before (traditional) and after pinch analysis approach were found to be 45574 KW and 3258 kW, respectively, while the cold utility requirements were 102393 kW and 46594 kW, respectively, which presented an energy-saving potential of 62.9 %.

Keywords: *Pin Analysis, Hot Composite, Cold Composite, Pinch Point optimization, Energy Recovery*

I. INTRODUCTION

Fossil Fuel utilized in the enterprises is the primary wellspring of CO2. The industry is responsible for 21% of the world's direct CO2 emissions. [1] The prime reason for greenhouse gases emission from industry is the fossil fuel burned on-site at the energy facility. Note that industry also uses electricity

Pinch analysis is a process integration methodology for optimizing energy use by finding the thermodynamically feasible and minimum energy targets and achieving them by optimizing heat recovery systems. It is based on thermodynamic principles.[3]

Three golden rules can be identified [4]:

- No heat transfer to be done through the pinch;
- No cooling with external coolers above the pinch;
- No heating with external heaters below the pinch.

A violation of these rules is referred to as a *pinch violation*.

II. MATERIALS AND METHODS

Hint Software and its application in Process Heat Integration were used to analyze collected data as it performs the energy targeting using the problem table.[5]The process involves identifying process streams, data extraction, and Hint Software to

generated by power plants, so its total contribution is much larger. Measures for reducing CO2 emissions in the industry from a global perspective include energy efficiency measures. However, due to the ever-increasing cost of energy, a study of the efficient use of energy set in a financial context is becoming increasingly important.

Some potential measures for industrial energy efficiency improvement are -

- Cost-effective, currently available technology that can save primary energy supply to industry (economic potential);
- Energy efficiency measures that can potentially save money for industry
- Low-cost measures such as energy management offer significant scope for savings
- Improvements in electrical and mechanical equipment like motors, drives, boilers, and compressed air plants can save.
- Process-specific savings represent the largest potential for savings.

Given this huge potential in the process,-specific savings, energy efficiency should be high on every industry's list to cut costs and emissions. The sugar industry uses significant amounts of energy. The sugar mill demands a huge amount of energy for sugar production, especially heat. Heat is the primary energy that is used for several processes, including sugarcane trunk from sugarcane, making sugar cane juice, boiling juice, and crystallization until sugar. [2]

simulate the whole process. The streams are divided into two- Hot stream and Cold stream. A hot stream is a stream that needs to be cooled, and a Cold stream is a stream that needs to be heated. [6]Data Extraction involves knowing the mass flow rate, specific heat capacity, supply, and target temperature, and film heat transfer coefficient for the streams.[7]The Sugar industry is a significant consumer of energy. In addition to conventional Observations and analysis to estimate potential energy savings, pinch analysis is used to analyze an industrial process's heating and cooling demands. It has been successfully applied to several process industries where energy costs represent a significant proportion of the total production cost.

This study will apply pinch technology to a Sugar Production process to:

(a) To Calculate the Minimum Hot Utility, Cold Utility requirement, Pinch

Temperature, Minimum number of Heat Exchanger required, Maximum Energy Recovery in the process

(b) To analyze Variation of Pinch Temperature with DTmin, Variation of the energy requirements with DTmin, Variation of Capital Cost with DTmin

(c) To find the Capital Cost, Operating Cost, and Total Cost of the Project.

The following key hypotheses were used during the analysis:

- Thermal losses during heat transfer were neglected.
- The physical properties of the process stream were assumed as constant at the given process temperatures.

Use of Hint Software

Hint Software was used to analyze the process. Under the stream window, "Add Stream" is chosen. The hot/cold stream supply temperature, target temperature, and Enthalpy data are fed. Since we have assumed that the process stream's thermal properties as constant, the Cp value is considered linear Variation. We have taken DT_{min} as 10 ˚C in the process, as it is a feasible value to consider. [8]We see the Composite curve, Grand Composite Curve, Cascade Diagram and Available Temperature Difference Diagram on the Hint Software Screen's left-hand side. The Composite Curve is the T-H diagram (Temperature-Enthalpy diagram). The pinch point, hot utility requirement, cold utility requirement and the possible heat recovery in the process are determined. We get the analysis for DTminvs Energy Targets, Area Targets, Pinch Temperature, Minimum number of heat exchangers, and Cost targets under the diagram window.

III. PROCESS DESCRIPTION

Processes to produce granulated sugar include juice extraction, clarification process, preheat and evaporation, syrup treatment, crystallization, centri fugalization, and drying. Each process consumes a huge amount of both thermal and electrical energy, especially juice extraction.

The Figure illustrates a simplified production process from sugar cane. A typical example of Savannah Sugar Company is chosen for which the operating data extraction was carried out. [9]

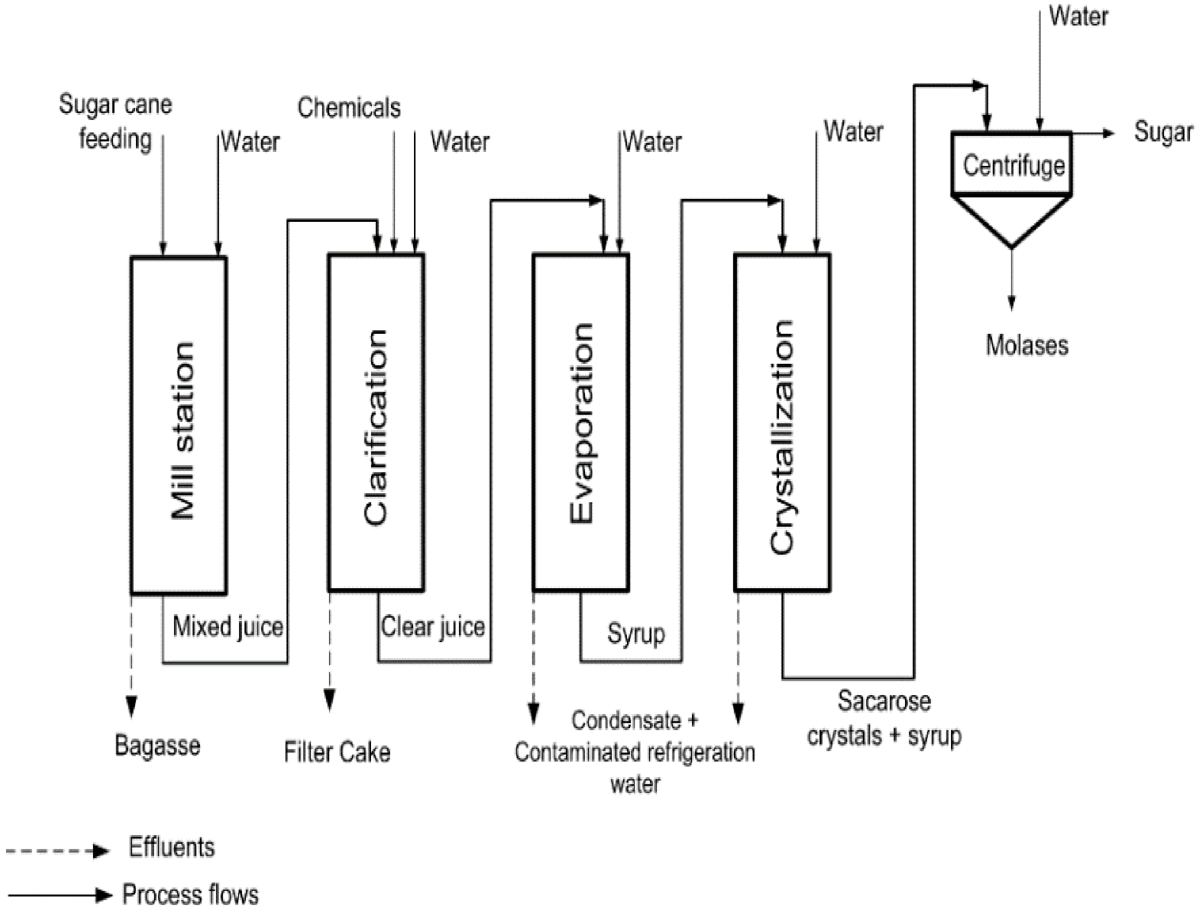

Figure 1. A simplified process of sugar production from sugar cane [10]

Table1: The operating data extraction of the sugar company

S.No.	Stream Type	Stream specification	Mass flow rates (kg/s)	Specific Heat cap (KJ/Kg/°C)	(KW/°C)	Supply Temp(°C)	Target Temp.(°C)	Enthalpy H (KW)	Heat Transfer Coefficient (W/m2°C)
1	Hot	Vapour I	24.5	127.2	3116.4	118	103	-46746.0	1.67
2	Hot	Vapour II	12.48	92.02	1148.4	103	84	-21819.8	1.17
3	Hot	Vapour III	10.22	35.27	360.5	84	53	-11174.2	0.79
4	Hot	Juice from evap II	53	3.66	194.0	118	104	-2715.7	0.17
5	Hot	Juice from evap III	43.94	3.53	155.1	104	85	-2947.1	0.33
6	Hot	Juice from evap IV	33.98	3.33	113.2	85	54	-3507.8	0.41
7	Cold	Juice from heater I	136	3.82	519.5	30	65	18183.2	0.44
8	Cold	Juice from heater II	126	3.85	485.1	65	85	9702.0	0.42
9	Cold	Juice from heater III	116	3.88	450.1	85	105	9001.6	0.33
10	Cold	Juice from evap pre-h	106	3.94	417.6	95	110	6264.6	0.16
11	Cold	Juice from evap I	78.88	3.84	302.9	110	118	2423.2	0.17

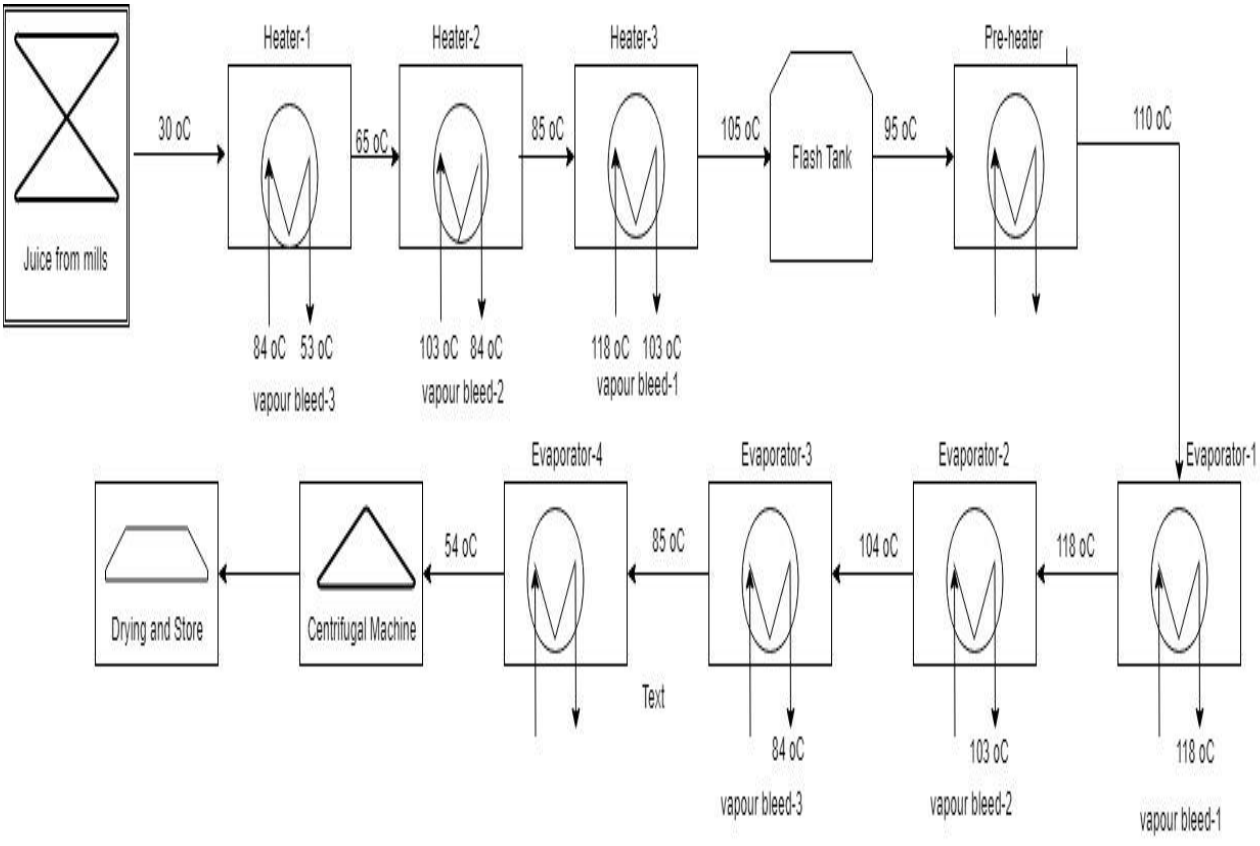

Figure 2. Process Flow Diagram of Sugar Production

IV. RESULTS AND DISCUSSIONS

Composite Curve

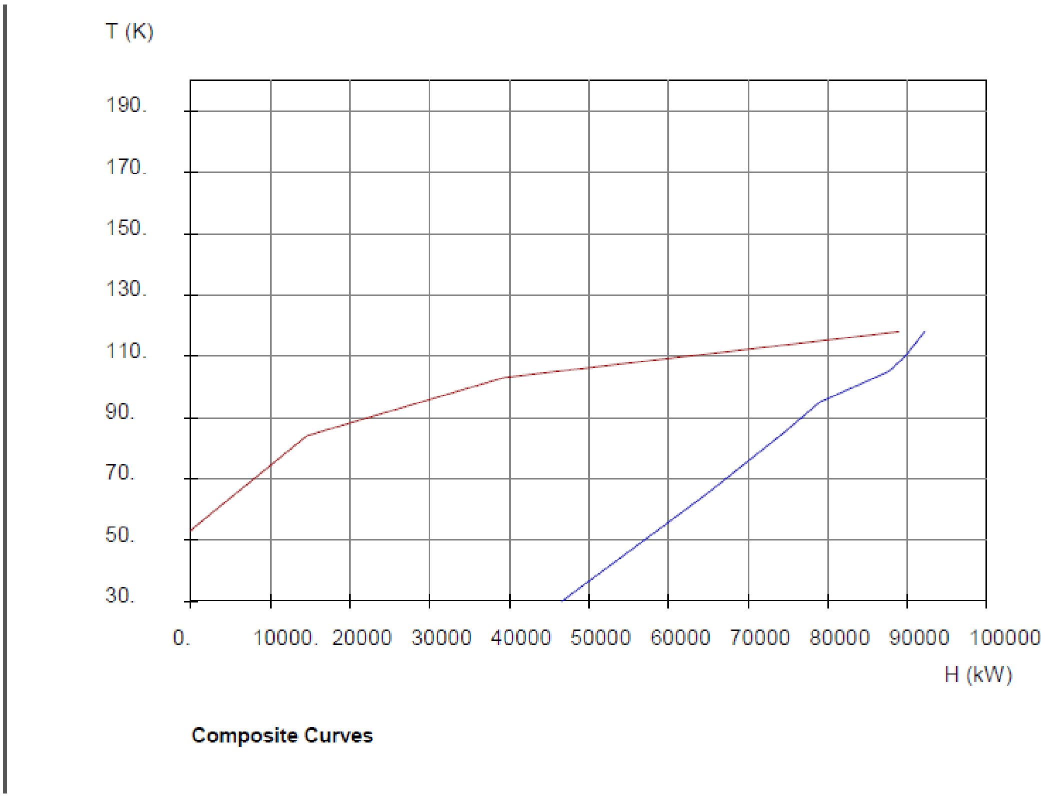

Figure 3. Composite curves (CC) for the process streams

The minimum cold utility requirement was 46594 KW (the hot streams composite curve that goes beyond the cold streams composite arc). Similarly, the minimum hot utility requirement was found to be 3258 kW. In our case, the pinch temperature was found to be 113 ºC.The min. Hot utility requirement, min. Cold utility requirements and pinch point temperature were calculated as 3258 kW, 46594 kW, and 113 ˚C, respectively.WithΔTmin = 10˚C, where there is an overlapping of the Hot composite curve and the cold composite curve, it can process heat exchange. We conclude the minimum energy requirements as 3258 kW and 46594 kW for the heating and cooling utilities. The overlap region indicates that the maximum energy recovery of 42316.6 kW can be recovered in the process. This presents a potential reduction of 62.9% in the utility requirements, as shown in Table 2 below:

Table 2.

Utility	***Current (kW)***	***Minimum (kW)***	***MER (kW)***	***% Recovery***
Heating	*45574.6*	*3258*	*42316.6*	
Cooling	*88910.6*	*46594*	*42316.6*	
Total	*134485.2*	*49852*	*84633.2*	*62.9 %*

Grand Composite Curve

The Grand Composite curve in Figure plotted using net heat flow (utility requirement) and shifted temperatures shows a sharp pinch at 113˚C. This is the pinch temperature at which enthalpy is zero. It also gives the same results for the minimum utility requirements as the composite curves.

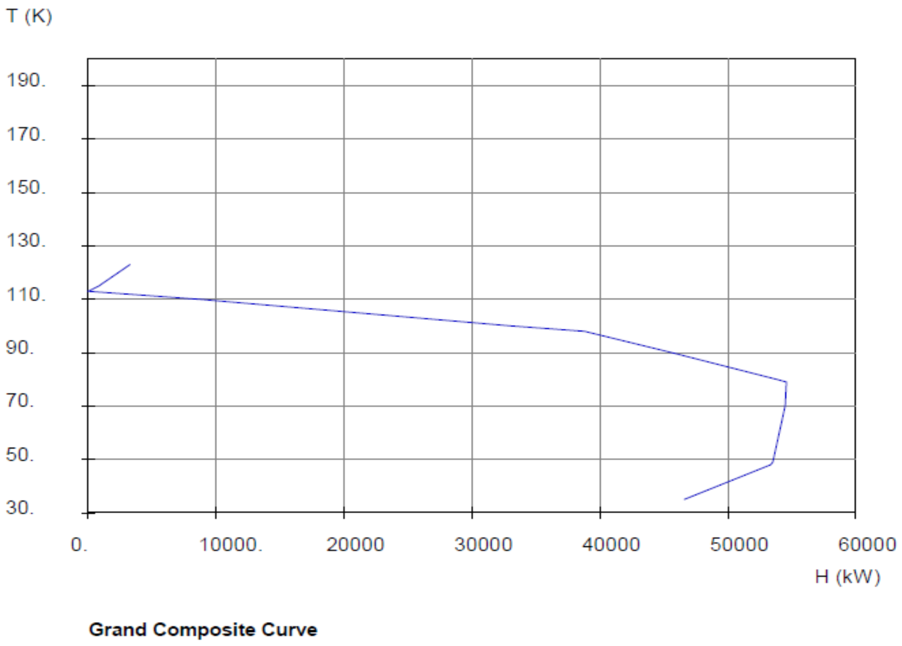

Figure 4.Grand composite curve (GCC).

Minimum Number of Heat Exchanger

The fixed cost of a heat exchanger network (HEN) depends upon the number of heat exchanger it employs. Thus, there exists a possibility that a HEN with a minimum no. of the heat exchanger will cost less. Thus, there is a strong incentive to reduce the number of heat exchangers (matches between hot and cold streams) in a HEN. The first step required for this process for its initiation is to identify the number of heat exchangers a HEN will require from the number of Hot, Cold, and Utility streams it handles.

$u_{\min} = N - 1$, Where $u_{\min}$ = minimum number of units (including heaters and coolers) and

N = total number of streams (including utilities).

In this case, Total streams are 11, and there are one hot utility and one cold utility, which gives

N = 13, therefore, $u_{\min} = N - 1 = 13 - 1 = 12$

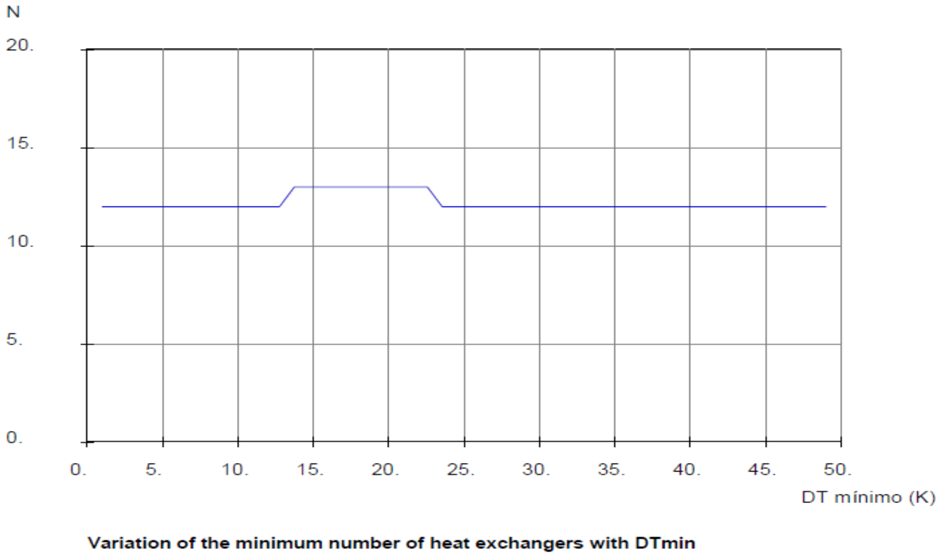

Figure 5. Variation of the minimum number of Heat Exchanger with DTmin

Variation of Pinch Temperature with DT_{min}

The temperature difference of 0°C is not practically possible since then the net heat transfer will be zero, and thus the infinite surface is required for obtaining the heat transfer. We kept the temperature difference as 10°C (i.e., ΔTmin). After keeping the ΔTmin 10°C the Hot pinch is found at 118 °C, and the Cold pinch is at 108 °C, and the minimum Hot and Cold utility are at 3258 KW and 46594 KW, respectively. A plot of energy targets versus ΔTmin in Figure shows that the possible range for the minimum temperature difference is from 0 <ΔTmin< 89˚C.

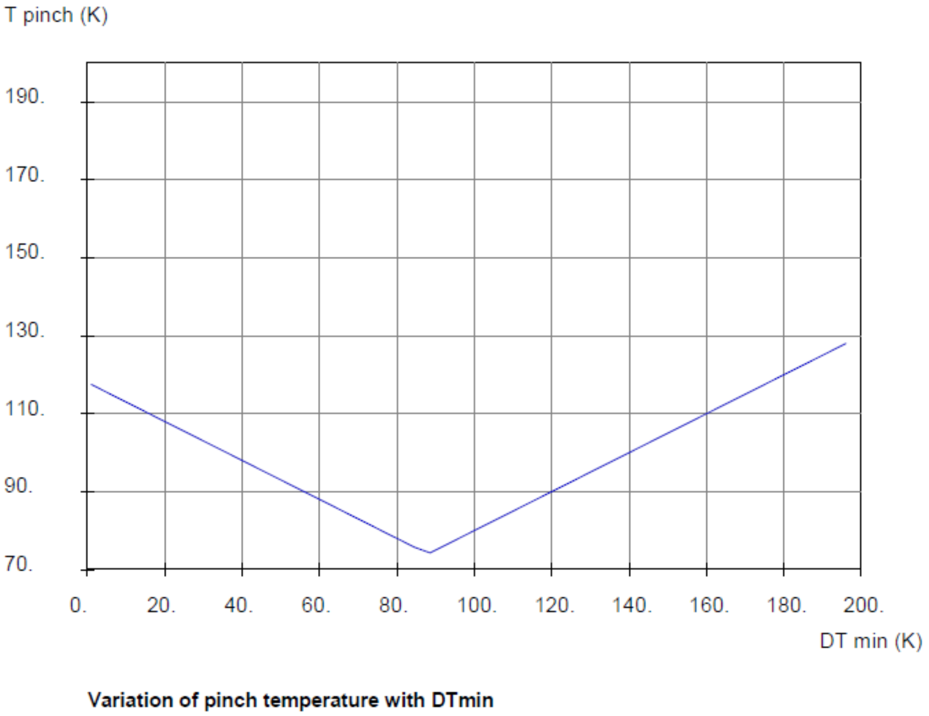

Figure6. Variation of Pinch Temperature with DTmin

Minimum Exchanger Area with DT_{min}

Variation of Minimum Exchanger Area with DTmin shows that as ΔTmin increases, there is a reduction in the heat transferred within the system, which requires a lower heat transfer area and therefore leading to a decrease in capital costs (if c < 1 in the cost equation Cost = a + bAc) as shown in Figure. Similarly, an increase in ΔTmin results in an increase in energy costs since greater external energy demand manifests in an increase in the requirement for the additional heat transfer utilities.

Capital Cost Targeting for similar material of construction

The capital cost of a heat exchanger depends primarily on its construction material, pressure rating, and the type of exchanger itself. Variation of Capital Cost with DTmin suggests that as the DTmin increases, there is a reduction in the project's capital cost. The capital cost decreases since there is a decrease in the minimum heat exchanger area with DTmin, which implies that capital cost will also decrease.

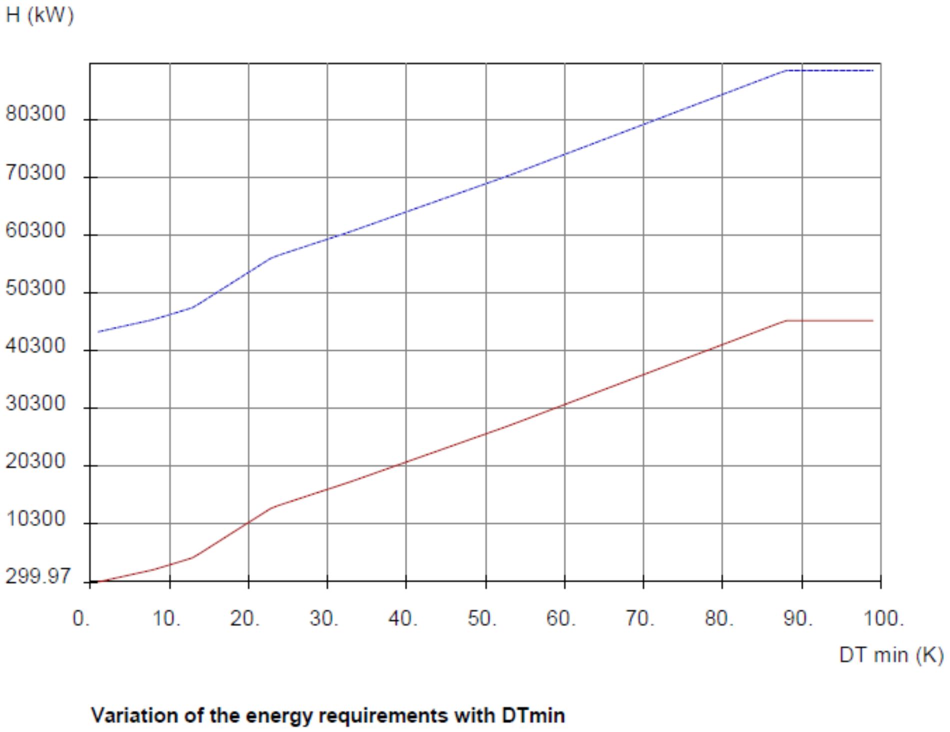

Figure 7.Variation of the energy requirements with DTmin

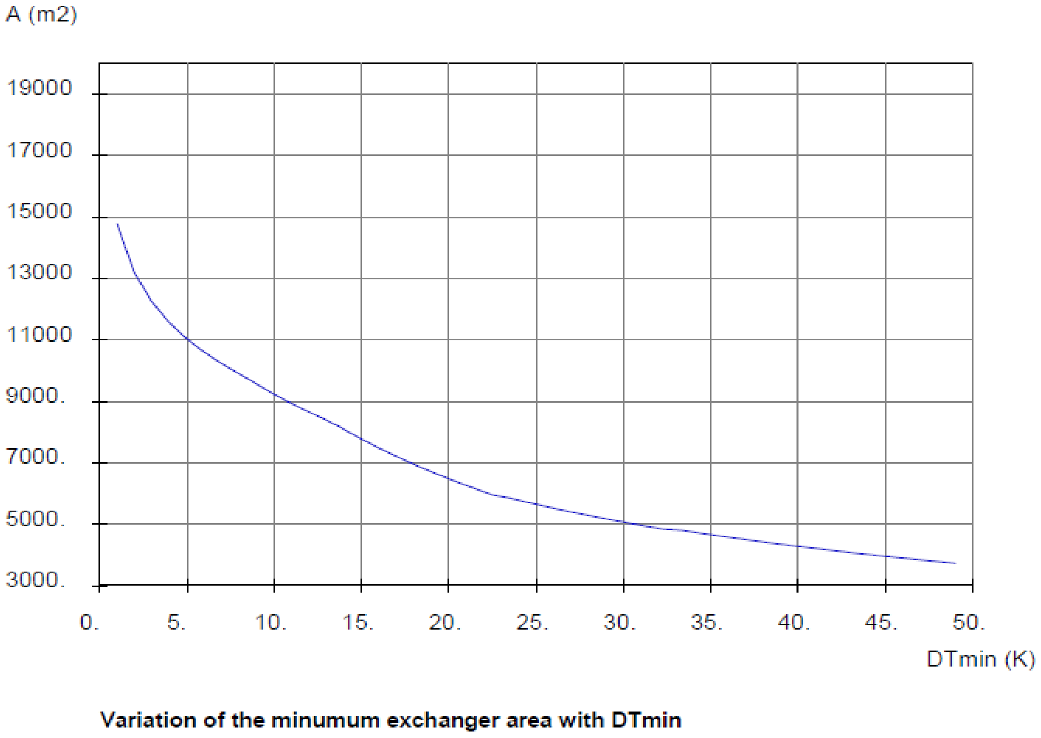

Figure 8. Variation of Minimum Exchanger Area with DTmin

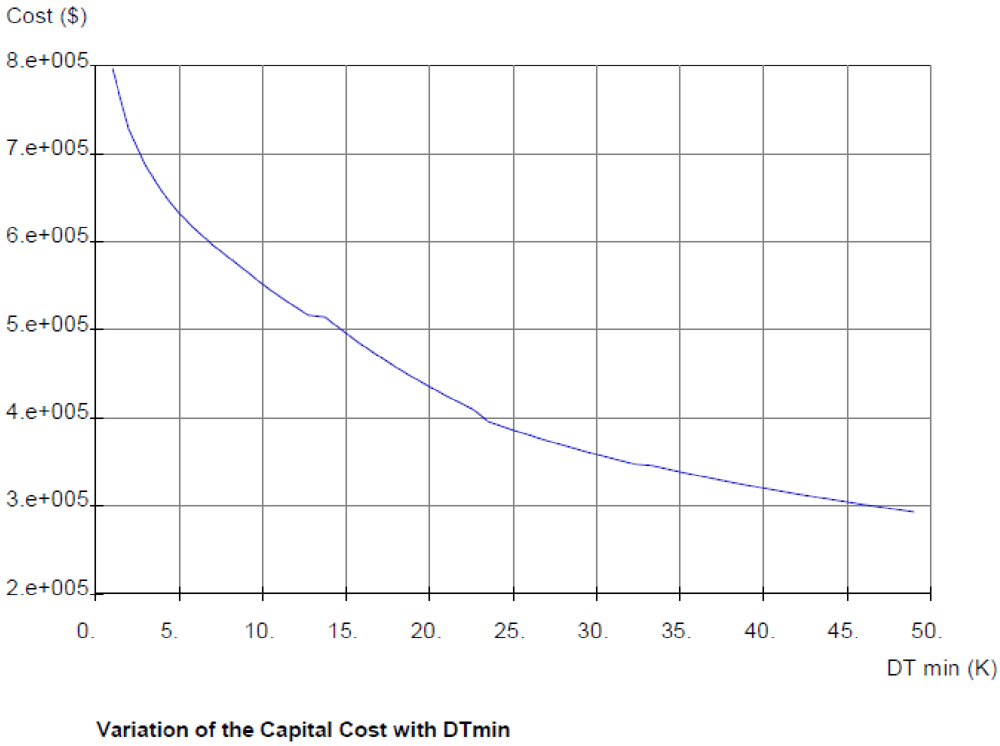

Figure 9. Variation of Capital Cost with DTmin

Operating cost targeting

Operating cost consists of hot and cold utility costs. For the present problem, the hot and cold utility is 3258 kW and 46594 kW.

The utility costs are: [11]
Steam cost = 120 ($.kW-1.y-1)
Cooling water cost = 10 ($.kW-1.y-1)
Hot utility cost = 3258 * 120 = 3, 90,960 $.yr-1
Similarly,
Cold utility cost = 46594 * 10 = 4, 65,940 $.yr-1

Total Operating Cost = 390960 + 465940 = 8, 56,900 $.yr-1

Total Cost Targeting:

The cost targeting is divided into two parts: - [11]
a) Capital cost Targeting and
b) Operating cost targeting.

With the change in driving force or ΔTmin, these two costs vary opposite to each other. For example, with an increase in ΔTmin, the utility costs increase as the utility consumption increases. However, capital cost decreases as the heat exchanger network area reduces with an increase in driving force. Thus, it is better to consider both the costs of targeting a heat exchanger network and further determine optimum ΔTmin using Super-targeting.

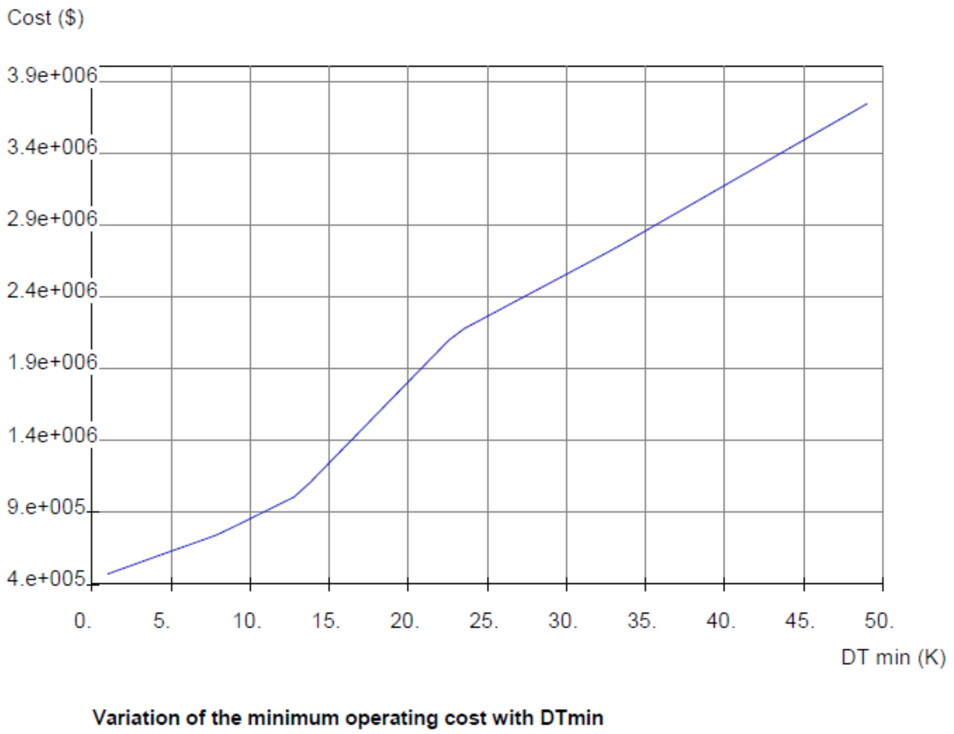

Figure 10. Variation of the Minimum Operating Cost with DTmin

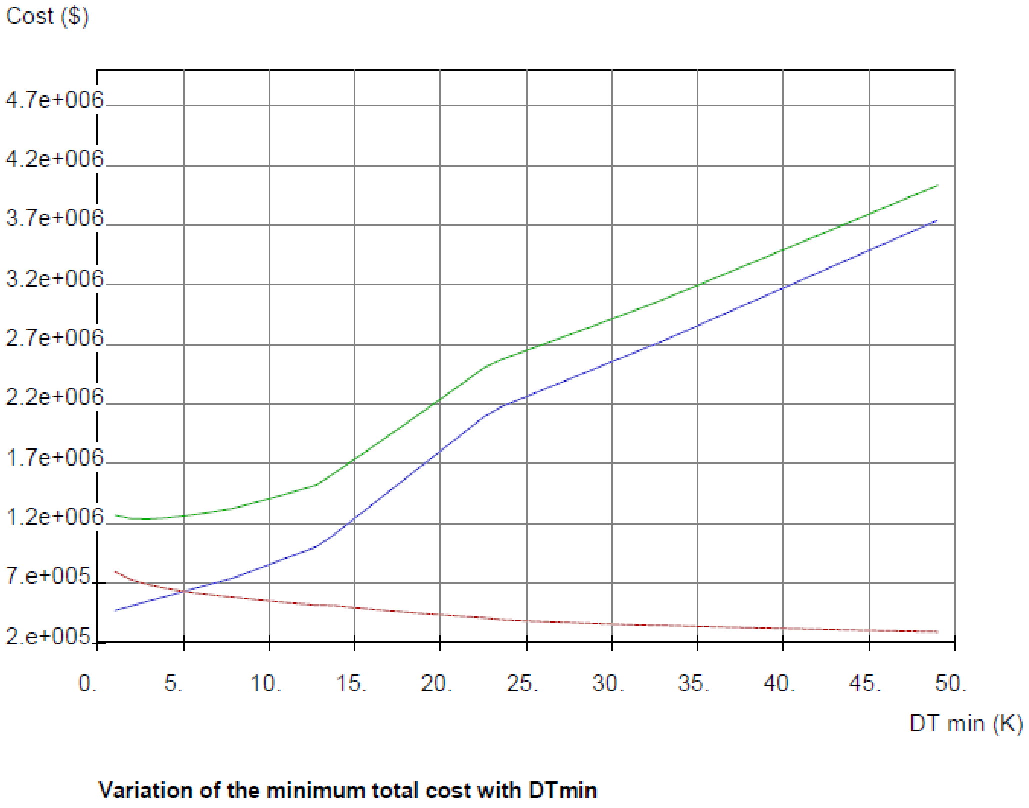

Figure 11. Variation of the Total Minimum Cost with DTmin

V. CONCLUSION

Energy Integration using Pinch Analysis was carried out in the typical sugar industry, keeping the driving force Tmin as 10 ºC. The Hot Utility requirement, cold utility requirement, was found to be 46594 KW, 3258 KW. This shows a potential reduction of 62.9% in the utility requirement. Variation of the minimum number of Heat Exchanger with DTmin was studied, and a minimum no. of the heat exchanger was found to be 12. For getting the feasible solution, the temperature difference is kept at 10°C, Pinch temperature was found to be 113 °C, Hot pinch is achieved at 118 °C, and the Cold pinch is at 108 °C. The Variation of energy targets vsΔTmin shows that the possible range for the minimum temperature difference is from 0 to 89˚C. As ΔTmin increases, there is a reduction in the heat transferred within the system, which requires a lower heat transfer area, resulting in a decrease in capital costs. With the change in driving force or ΔTmin, these two costs (Capital cost Targeting and Operating cost targeting) are very opposite. For example, with an increase in ΔTmin, the utility costs increase as the utility consumption increases. However, capital cost decreases as the heat-exchanger network area reduces with an increase in driving force. Thus, it is better to consider both the costs of targeting a heat exchanger network and further determine optimum ΔTmin.

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