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**Biannual Peer Reviewed Journal Issued by Research and Consultation Center,
Sabratha University**

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Editorial

We start this pioneering work, which do not seek perfection as much as aiming to provide a scientific window that opens a wide area for all the distinctive pens, both in the University of Sabratha or in other universities and research centers. This emerging scientific journal seeks to be a strong link to publish and disseminate the contributions of researchers and specialists in the fields of applied science from the results of their scientific research, to find their way to every interested reader, to share ideas, and to refine the hidden scientific talent, which is rich in educational institutions. No wonder that science is found only to be disseminated, to be heard, to be understood clearly in every time and place, and to extend the benefits of its applications to all, which is the main role of the University and its scholars and specialists. In this regard, the idea of issuing this scientific journal was the publication of the results of scientific research in the fields of applied science from medicine, engineering and basic sciences, and to be another building block of Sabratha University, which is distinguished among its peers from the old universities.

As the first issue of this journal, which is marked by the Journal of Applied Science, the editorial board considered it to be distinguished in content, format, text and appearance, in a manner worthy of all the level of its distinguished authors and readers.

In conclusion, we would like to thank all those who contributed to bring out this effort to the public. Those who lit a candle in the way of science which is paved by humans since the dawn of creation with their ambitions, sacrifices and struggle in order to reach the truth transmitted by God in the universe. Hence, no other means for the humankind to reach any goals except through research, inquiry, reasoning and comparison.

Editorial Committee

Notice

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The journal publishes high quality original researches in the fields of Pure Science, Engineering and Medicine. The papers can be submitted in English or Arabic language through the Journal email (jas@sabu.edu.ly) or CD. The article field should be specified and should not exceed 15 pages in single column.

All submitted research manuscripts must follow the following pattern:

- Title, max. 120 characters.
- Author Name, Affiliation and Email
- Abstract, max. 200 words.
- Keywords, max. 5 words.
- Introduction.
- Methodology.
- Results and Discussion.
- Conclusion.
- Acknowledgments (optional).
- References.

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All figures should be compatible with Microsoft Word with serial numerals. Leave a space between figures or tables and text.

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Invitation

The Editorial Committee invites all researchers "Lectures, Students, Engineers at Industrial Fields" to submit their research work to be published in the Journal. The main fields targeted by the Journal are:

- Basic Science.
- Medical Science & Technology.
- Engineering.

Refereeing

The Editorial Committee delivers researches to two specialized referees, in case of different opinions of arbitrators the research will be delivered to a third referee.

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CONTENTS

PINCH ANALYSIS OF HEAT INTEGRATION AND HEAT EXCHANGER NETWORK DESIGN WITH ASPEN ENERGY ANALYZER IN A NATURAL GAS SWEETENING UNIT

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Abstract

The cost of produced products largely depends on the amount of energy consumed in the plant during production of the products. The more the amount of energy consumed in a process plant, the higher the cost of products produced from the plant and vice versa. So, energy consumption is an important factor to be considered in any process plant to reduce the cost of products for consumers' sake and to gain more profit for the company. This article is divided into two parts. In the first part a process flow diagram for the gas sweetening is designed with Aspen HYSYS. The second part is to use Aspen Energy Analyzer software to calculate the pinch temperature and hot utility and cold utility. This research paper aims to make a Pinch Analysis for the Natural Gas Sweetening Unit in Millita Natural gas compound in Libya. Another objective is to utilize the saved energy by the Pinch energy Analyzer of the hot stream to exchange heat with the cold stream to save energy costs in order to obtain steam for heating the cold stream. The following briefed conclusion are observed for this research: The pinch temperature is found to be 108 ^{0}C (hot pinch) and 98 ^{0}C (cold pinch). In addition, the cold utility requirements is $4.696*10^7$ kJ/h (Cooling Water) and hot utility is $1.255*10^7$ kJ/h (HP steam).

Keywords: Pinch analysis; process integration; Heat recovery; Composite curve; Aspen Energy Analyzer.

Introduction

Minimization of energy consumption is a crucial factor to consider in any process plant. Traditionally, determining the minimum amount of energy required for chemical engineering processes has been challenging.

Process integration through the application of pinch analysis is a well-established approach for optimizing the energy efficiency of natural gas sweetening units (Linnhoff, B., Flower, J. R.,1978; Kemp, I. C., 2007). Pinch analysis relies on the concept of process stream thermodynamic profiles, which describe the heating and cooling requirements across the process. By analyzing the composite curves of hot and cold process streams, the pinch point – the temperature at which the energy demand of the hot and cold streams is balanced – can be identified (Smith, R., 2005). This pinch point divides the process into two regions: above the pinch, where cooling is required, and below the pinch, where heating is necessary.

The Aspen Energy Analyzer is a widely used software tool that streamlines the application of pinch analysis to natural gas sweetening units (Aspen Technology, 2023). This software enables the user to:

1. Model the process streams and their thermodynamic properties based on plant data or simulation results from tools like Aspen HYSYS (Aspen Technology, 2023).
2. Construct hot and cold composite curves to visualize the energy targets and identify the process pinch point (Kemp, I. C., 2007).
3. Synthesize an optimal heat exchanger network (HEN) design that minimizes utility requirements and capital costs while satisfying operational constraints such as pressure drop and fouling limitations (Biegler, L. T. et al., 1997).
4. Perform sensitivity analyses to evaluate the impact of parameter changes, such as stream flow rates, temperatures, or heat transfer coefficients, on the HEN design and energy efficiency (Linnhoff, B. et al., 1982).

By integrating pinch analysis with the Aspen Energy Analyzer, process engineers can systematically explore opportunities for heat integration and develop energy-efficient HEN designs for natural gas sweetening units. This approach can lead to significant reductions in utility consumption, greenhouse gas emissions, and operating costs, ultimately enhancing the overall sustainability and competitiveness of the natural gas processing facility (Klemeš, J. J.,2013).

This research aims to achieve two main objectives:

1. To perform a Pinch Analysis of Heat Integration and Heat Exchanger Network Design with Aspen Energy Analyzer for the Natural Gas Sweetening Unit in the Millita Natural Gas Compound in Libya.
2. To utilize the energy saved by the Pinch Energy Analyzer from the hot stream to exchange heat with the cold stream, thereby reducing energy costs and obtaining steam for heating the cold stream.

Literature Review

The natural gas industry has long focused on improving the energy efficiency of its processes, and one of the key techniques employed for this purpose is pinch analysis.

Pinch analysis is a systematic method for identifying optimal energy targets and designing corresponding heat exchanger networks, which can lead to significant energy and cost savings (Smith, R., 2016).

In the context of natural gas sweetening units, pinch analysis has been widely studied and applied to enhance overall process efficiency. For instance, (Kidnay, A. J., Parrish, W. R., 2006) provides a comprehensive overview of the fundamentals of natural gas processing, emphasizing the importance of the sweetening process and the role of heat integration.

Smith (Smith, R., 2016) further elaborated on the principles of pinch analysis and its application in chemical process design and integration. The author highlighted the step-by-step approach, from data collection to heat exchanger network synthesis, which is crucial for optimizing energy usage in natural gas sweetening units.

Linnhoff et al. (Linnhoff, B. et al., 1982) published a user guide on process integration, focusing on the efficient use of energy through pinch analysis. The authors discussed composite curve generation, pinch point identification, and heat exchanger network design, all of which are directly applicable to natural gas sweetening processes.

Aspen Technology (Kemp, I. C., 2007) developed the Aspen Energy Analyzer software, providing a comprehensive platform for conducting pinch analysis and heat exchanger network synthesis. The software’s capabilities in managing complex data and process models of natural gas sweetening units have been well-documented.

Kemp (Linnhoff, B. et al., 1982) offered a detailed overview of the pinch analysis methodology, including its mathematical foundations and practical implementation considerations. The author’s insights on optimization and sensitivity analysis aspects are particularly relevant for natural gas sweetening applications.

Klemeš and Kravanja (Klemeš, J. J., Kravanja, Z., 2013) reviewed the historical development and current state of pinch analysis, highlighting its integration with mathematical programming techniques. This integration is crucial for optimizing heat exchanger networks in natural gas sweetening units, as demonstrated in the work by Aspen Technology (Aspen Technology, 2020).

The reviewed literature clearly establishes the importance of pinch analysis in optimizing energy usage in natural gas sweetening units. This systematic approach, spanning from data collection to heat exchanger network design, has been extensively documented and can be effectively applied to improve energy efficiency and reduce operating costs in critical natural gas processing facilities.

Other works have explored similar methodologies in various plant sections. Akpa and Okoroma (Akpa, J. G., Okoroma, J. U., 2012) performed pinch analysis on the heat exchanger networks of the crude distillation unit at the Port Harcourt refinery. They identified a pinch penalty of approximately 98,916.1 kW for hot utility and 8,298.7 kW for cold utility.

Lukman et al. (Lukman, Y., et al, 2018) conducted an evaluation of the Naphtha Hydro-Treating Unit (NHU) of Kaduna Refinery using pinch technology to identify areas for improvement in the heat exchanger networks. Their study aimed to minimize total costs and revealed an optimal total cost of \$263.115, reduced from the initial target cost of \$298.815. They also observed that the target heating and cooling requirements were 1.395×107 kcal/h1.395 \times 10^7 \, \text{kcal/h}1.395×107kcal/h and 1.440×107 kcal/h1.440 \times 10^7 \, \text{kcal/h}1.440×107kcal/h, respectively, while the design heating and cooling values were 1.228×107 kcal/h1.228 \times 10^7 \, \text{kcal/h}1.228×107kcal/h and 1.273×107 kcal/h1.273 \times 10^7 \, \text{kcal/h}1.273×107kcal/h.

Materials

The materials used include: Aspen Energy Analyzer version 11 (used to produce the composite curve, balanced composite curve, grand composite curve and grid representation of the heat exchanger networks), Gas sweetening unit process data from MELETHA plant and process flow diagram showing the inlet and outlet temperatures, mass flow rates, specific heat capacities, enthalpy per unit temperature and enthalpy of each process streams and utilities.

Methodology

The case study in this research involves performing a pinch analysis using Aspen Energy Analyzer software on stream data from the Gas Sweetening Unit of the Melita Gas Plant.

The Aspen Energy Analyzer V.11 tool was employed to perform a detailed and accurate pinch analysis of the heat exchanger network for the gas sweetening unit. The thermal data and block diagram were obtained from the Melita plant's sweetening unit, as shown in Table (1) and Figure (1), respectively. This data was fed as input into the software to construct the composite curve, grand composite curve, and grid representation of the network. The following pinch rules were applied to achieve the minimum energy target for the gas sweetening unit:

1- Heat must not be transferred across the pinch.

2- There must be no external cooling above the pinch and no external heating below the pinch. Violating any of these rules will lead to across pinch heat transfer resulting in an increase the energy requirement beyond the target. Any heat transfer across the pinch is excess the heat which is wasted, and expressed as a pinch penalty.

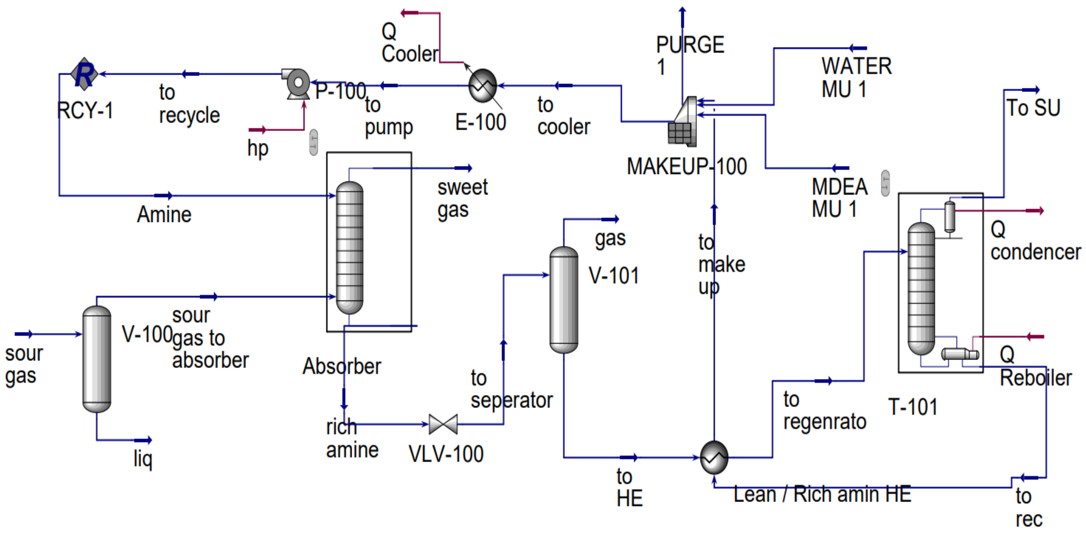


Figure 1: Process Flow Diagram for Sweetening Unit of Millita Gas Plant.

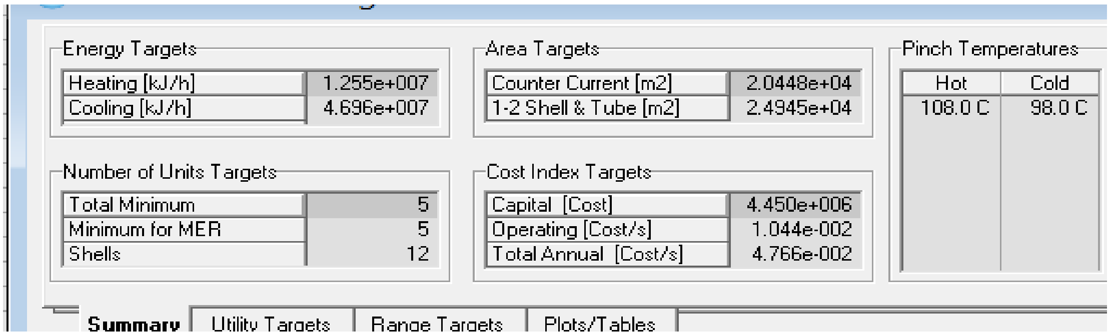
Table (1): Stream Data.

Stream No.	**Stream Type**	**T_{supply} °C**	**T_{Target} °C**	**m (kg/h)**	**Cp kJ/°C.Kg**	**m.Cp (kJ/h.C)**
1	Cold	57	98	357300	3.4	1215000
2	Cold	98	119	329800	3.75	1237000
3	Hot	98	34	27570	0.9	24810
4	Hot	119	30	329800	3.7	1220000

Results and Discussions

1 Feedback of Aspen Energy Analyzer

Figure (2) shows the minimum cooling and heating duty requirement, pinch temperature and area targets for given for $\Delta T_{min} = 10$°C



Energy Targets

Heating [kJ/h]	1.255e+007
Cooling [kJ/h]	4.696e+007

Area Targets

Counter Current [m2]	2.0448e+04
1-2 Shell & Tube [m2]	2.4945e+04

Pinch Temperatures

Hot	Cold
108.0 C	98.0 C

Number of Units Targets

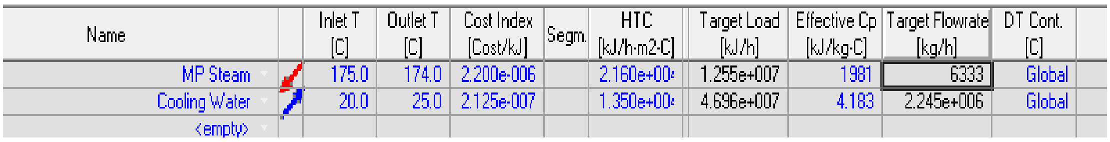
Total Minimum	5
Minimum for MER	5
Shells	12

Cost Index Targets

Capital [Cost]	4.450e+006
Operating [Cost/s]	1.044e-002
Total Annual [Cost/s]	4.766e-002

Figure (2): Results Extracted from Aspen Energy Analyzer for ΔT$_{min}$ = 10°C.

Based on the requirement utilities were added to meet heating and cooling duty; shown in Figure (3).



Name		Inlet T [C]	Outlet T [C]	Cost Index [Cost/kJ]	Segm.	HTC [kJ/h-m2-C]	Target Load [kJ/h]	Effective Cp [kJ/kg-C]	Target Flowrate [kg/h]	DT Cont. [C]
MP Steam		175.0	174.0	2.200e-006		2.160e+00	1.255e+007	1981	6333	Global
Cooling Water		20.0	25.0	2.125e-007		1.350e+00	4.696e+007	4.183	2.245e+006	Global
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Figure 3: Utility Requirements.

2 Composite Curve

Figure (4) shows the temperature versus enthalpy or composite curve. The composite curve for given data the upper curve represents the hot streams (Red) composite curve while the lower curve represents the cold streams (Blue) composite curve. The part of the hot stream in composite curve that is extended beyond the start of the cold stream, cannot be cooled by process-to-process heat transfer. Therefore, minimum cooled utility of $Q_{min} = 2.125 * 10^7 \ \frac{KJ}{h}$ is required. The part of the cold stream in composite curve that is extended beyond the start of the hot stream, cannot be cooled by process-to-process heat transfer. Therefore, minimum hot utility of $Q_{min} = 2.2 * 10^6 \ \frac{KJ}{h}$ is required.

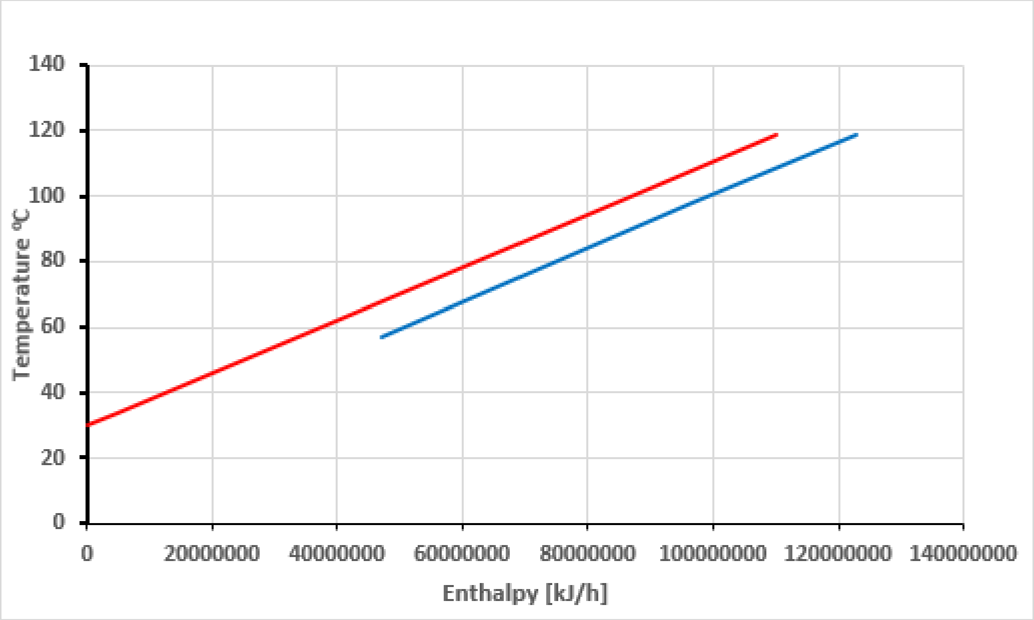

Figure (4): The Composite Curve.

Figure 5 shows the Grand Composite Curve (GCC) depicts the heat accessible at various temperature intervals as well as process net heat flow which is zero at the pinch. GCC tells us how much net heating and cooling is needed.

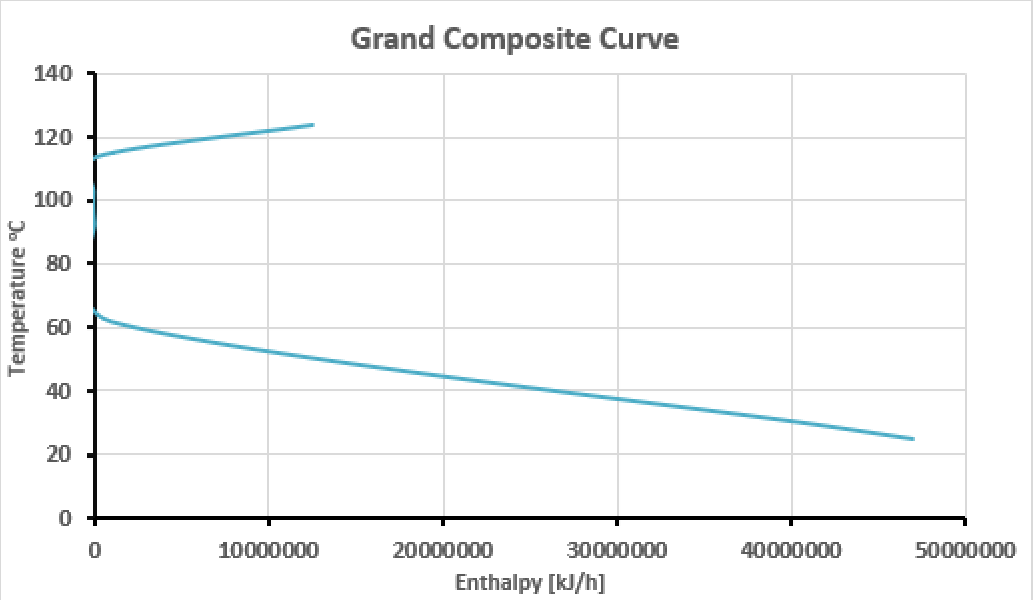

Figure (5): Grand Composite Curve.

Figure 6 shows the relationship between ΔT_{min} with Area, total const and heating energy. It was revealed that lower ΔT_{min} values give larger and more costly heat exchangers.

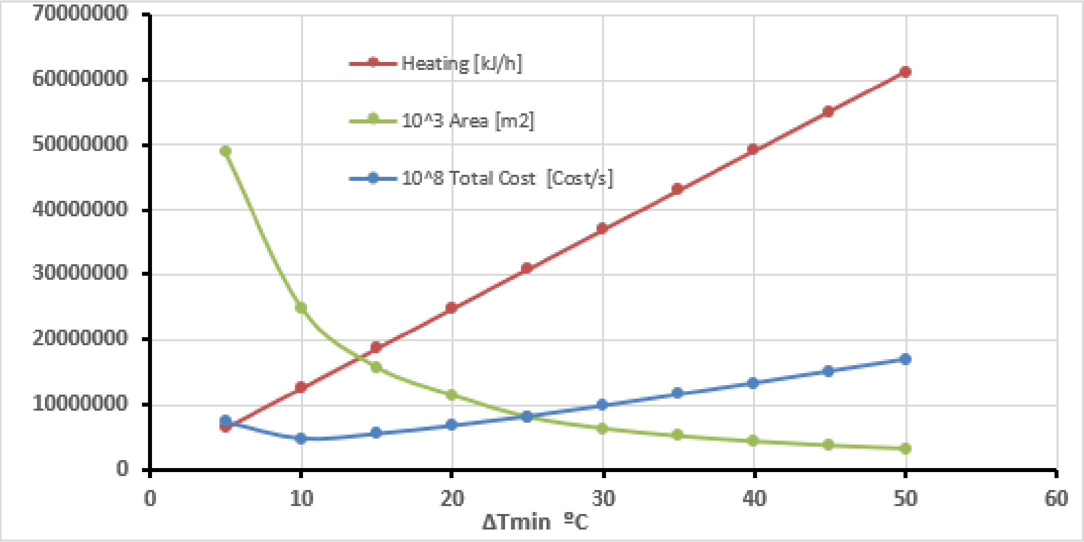

Figure (6): ΔT_{min} Verses Utility, Exchanger Area and Total Cost Variation.

3 Heat Exchanger Network Analysis

In Aspen Energy Analyzer, heat exchanger can be done manually and automatically by recommended design. For the given data software had generated 5 designs. Theses designs were optimized and the best design was proposed. Table shows 5 recommended designs.

Table (2): Process Heat Exchanger Area and Load Data.

No.	Design	Area m^2	Duty (KJ/h) $*10^7$
1	E-100	4659	1.342
2	E-101	298	1.255
3	E-102	17260	4.981
4	E-103	3220	4.537
5	E-104	62.53	0.1588

From the Aspen Energy Analyzer:

Minimum Hot Utility = $1.255*10^7$ kJ/h = 3486.11 kW.

Minimum Cold Utility = $4.696*10^7$ kJ/h = 13044.44 kW.

Hot Streams Pinch = 103 + 5 = 108°C.

Cold Streams Pinch = 103 – 5 = 98°C.

4 Network Design

Figure (7) shows Network design for heat exchangers above the bench and below the bench and for this simulated bench analysis there is no heat transfer across the bench.

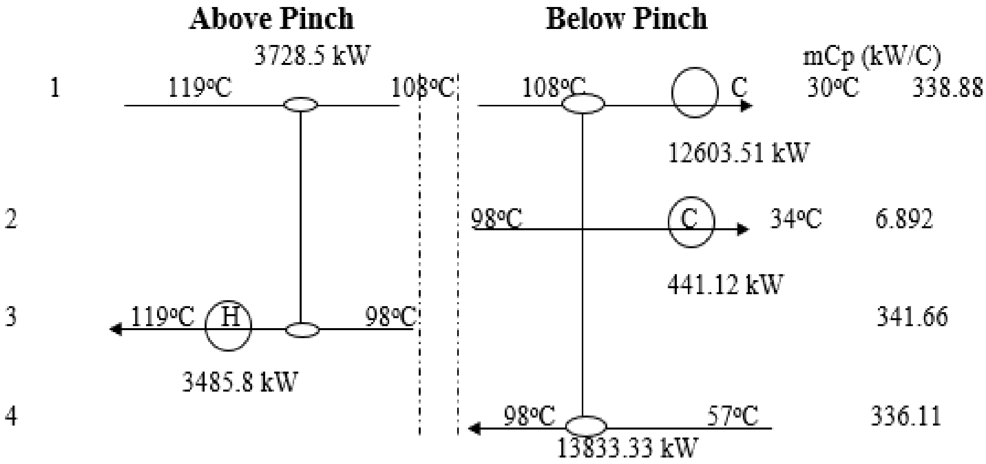

Figure (7): Network Design for Heat Exchangers Above and Below the Pinch.

Figure (8) shows the overall network design for the sweetening unit after making pinch energy analysis by using Aspen energy analyzer to get the best design for heat exchange in order to reduce the heating cost optimize the heat recovery

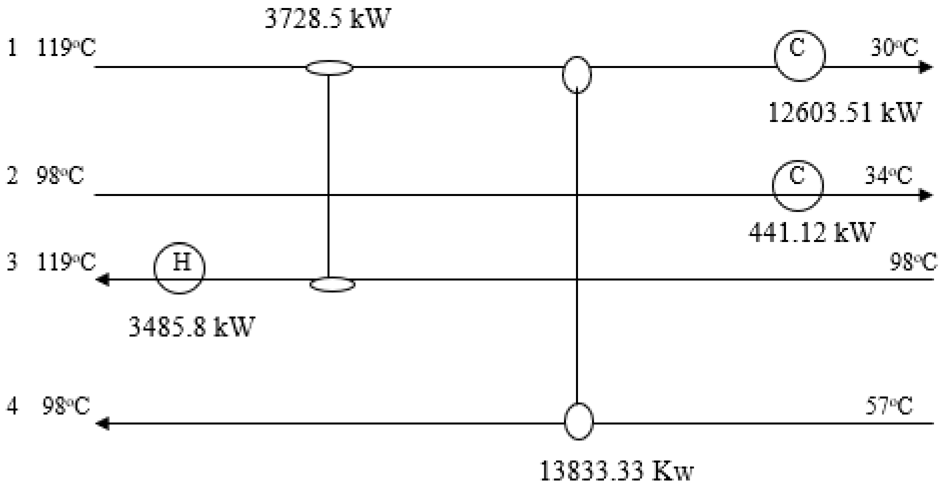

Figure (8): The Overall Pinch Energy Simulated Network Design for the Sweetening Unit.

Conclusion

The following specific conclusions were observed after this study:

- The pinch temperature was found to be 108°C (hot pinch) and 98°C (cold pinch). The cold utility requirements are 4.696×107 kJ/h4.696 \times 10^7 \, \text{kJ/h}4.696×107kJ/h (Cooling Water), and the hot utility requirement is 1.255×107 kJ/h1.255 \times 10^7 \, \text{kJ/h}1.255×107kJ/h (HP steam).
- Pinch Technology was successfully utilized to analyze the energy requirements of the heat exchanger network. The minimum heating and cooling requirements of the process streams in the network were determined from the composite curve and grand composite curve.

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