ENERGY CONSERVATION FOR PRODUCTION OF 100,000 MT/A ISOBUTYLENE PLANT AND EFFECT TO THE PLANT ECONOMIC

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ENERGY CONSERVATION FOR PRODUCTION OF 100,000 MT/A ISOBUTYLENE PLANT AND EFFECT TO THE PLANT ECONOMIC

NOOR ADILA BT ZULKEPA

A report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Chemical Engineering

Faculty of Chemical and Natural Resources Engineering

University Malaysia Pahang

JUNE 2010

I declare that this thesis entitled “*Energy Conservation for Production of 100,000 MTA Isobutylene and Effect to the Plant Economic*” is the result of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.”

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Name : Noor Adila bt Zulkepa
Date :

To my beloved mother Serimah Hasan, and to all of you, thanks for being part of my research…

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Thank God for giving the opportunity of studying this particular research and successfully finished it on time. Many obscures happened throughout this study from the research background to the results of the study. I acknowledge with appreciation the suggestions, counsel and encouragement from many people directly or indirectly contributed to the contents of this study. My appreciations go to supervisor, Encik Shaiful Zaidi Mat Desa for continually giving ideas and critics. To my colleagues Nor Hazwani, Afifah and also my others fellow undergraduate, these guys were relentlessly helped me out in making this study completed. Great thanks to my family for helping me in term of financial and moral support. Thanks to all people that have been mentioned or carelessly missed to mention that, I must apologize. Thank you.

ABSTRACT

This research shows how the application of Pinch technology can lead towards great energy saving. A few step need to undergo before start a heat exchanger network design which, analysis of process flow diagram data, pinch analysis and economic analysis. The heat exchanger network of the isobutylene process plant has been studied and it was shows how the application of pinch technology makes it possible to reduce the demand of hot and cold utility. After design the heat exchanger network, the overall heat exchanger required in these process is seven heat exchanger and all of them need to be redesign. The energy saving for total cooling is 65% and for total heating 38% which mean the good investment. Heat recovery is slightly reduced as the different minimum temperature increase. Even though the value of capital investment is higher than original process, but by implement pinch analysis in this plant, energy saving for utilities can recover the capital investment. Pay back period for the project is 0.8 year (9 month 3 days) that means, this project can be classify as quick win project

ABSTRAK

Kajian ini menunjukkan bagaimana aplikasi teknologi cubitan boleh membawa kearah penjimatan tenaga. Beberapa langkah dilakukan sebelum memulakan pengubahsuaian rangkaian penukar haba, iaitu menganalisa proses gambarajah tapak isobutylene, teknologi cubitan dan menganalisa ekonomi. Kajian menunjukkan aplikasi teknologi cubitan berkemungkinan boleh mengurangkan penggunaan pemanasan dan penyejukan. Selepas pengubah suaian rangkaian penukar haba dijalankan, jumlah penukar haba yang diperlukan dalam proses ini adalah 7 dan semua daripadanya hendaklah diubahsuai semula. Penjimatan tenaga untuk jumlah penyejukan ialah 65 % dan untuk jumlah pemanasan ialah 38% yang membawa maksud pelaburan yang baik. Pemulihan tenaga adalah berkadar songsang dengan beza suhu minima. Pun begitu nilai modal yang dikeluarkan adalah tinggi berbanding dengan proses asal. Tapi oleh kerana teknologi cubitan dilaksanakan di dalam plant ini, maka penjimatan tenaga untuk penggunaan boleh diimbangi. Masa bayaran balik untuk projek ini adalah 0,8 tahun (9 bulan 3 hari) yang bermaksud, projek ini diklasifikasikan sebagai projek menang mudah.

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LIST OF ABBREVIATIONS

A_t - Heat transfer area

CC - Composite curve

CHP - Combined heat and power

CP - Heat capacity

C_{TM} - Total manufacturing cost

EAOC - Equivalent annual operating cost

FCI - Fix capital investment

F_t - Correction factor

GCC - Grand composite curve

HEN - Heat exchanger network

HENS - Heat exchanger network synthesis

MT/A - Metric Tonne per Annum

N_{cs} - Number of cold stream

N_{hs} - Number of hot stream

PI - Process integration

T_1 - Hot fluid temperature inlet

T_2 - Hot fluid temperature outlet

t_1 - Cold fluid temperature inlet

t_2 - Cold fluid temperature outlet

ΔT_{lm} - Log mean temperature different

$\Delta Tmin$ - Minimum temperature different

U_o - Overall heat transfer coefficient

CHAPTER 1

INTRODUCTION

1.1 Introduction

In recent years, isobutylene has become an important product in industries because it is used as an intermediate chemical and largely used in polymerization process to produce the polisobutylene or that mostly used in butyl rubber industry. Isobutylene also were used in the MTBE industry. More that half of the butylenes produced worldwide are utilized as alkylate and polymer gasoline. Because of the market of isobutylene is continuously increased, more plant is designed annually. In the isobutylene plant, heat exchangers are widely used both for cooling and heating large scale processes. Heat exchanger process is desirable to increase the temperature of one fluid while cooling another make them are become major consumers of energy in process plant. Increasing of energy in a process plant can cause of producing a large quantity of carbon emission, which can cause global warming. This situation contributes to more study on energy conservation for chemical plant due to depletion of natural recourses and concern of environment. The integration of a new process into the existing facility provides significant improvements in the design of process plants that would minimize the net cost of energy purchase. The most useful tool that enables this design advance is pinch technology. It is a comprehensive and reliable technique to be applied in order to conserve the energy usage of a chemical plant and will contribute to sustainable and environmental friendly chemical process and has a significant economical impact on the plant's operation.

1. 2 Plant descriptions – production of 100,000 MT/A isobutylene

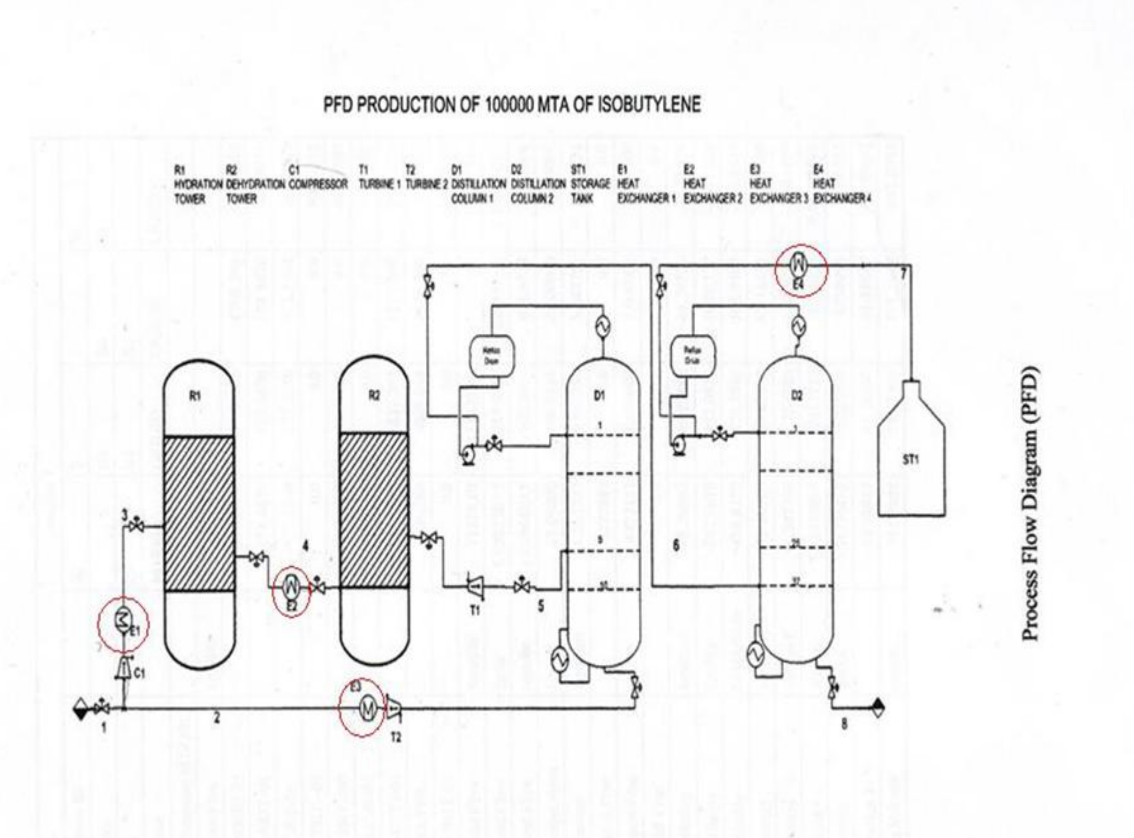

Figure 1.1: Process flow diagram for production of 100,000 MT/A of isobutylene.

Figure 1.1 show the process flow diagram for production of 100,000 MT/A of isobutylene. The process consists of four major process which are mixing process, hydration reaction, dehydration reaction and separation process using distillation column. These processes involve four heat exchangers, two distillation columns, two reactors, two turbines and a storage tank. From the process in figure 1.1 the focus of the study was made to the initial process whereby feed stream one to reactor one (R1) is heated, and inlet to a reactor two (R2) which is stream four the product stream is to be cooled. The heating and cooling are done by use of steam (heat exchanger-1) and cooling water (heat exchanger-2) respectively. Another stream that consists of heating and cooling process is at stream two and stream seven. When the process involves single hot and cold stream, it is easy to design an optimum heat recovery exchanger network. The data extracted for figure 1.1 is presented in table 1.1.

Table 1.1: Data extracted for production of 100,000 MT/A isobutylene.

Stream	Name	Ts, ^oC	Tt , ^oC	CP, kW/^oC	ΔH, kW
4	Hot 1	115	50	384.54	-24995.1
7	Hot 2	77	25	9.23	-479.96
1	Cold 1	50	106	420.5	23548
2	Cold 2	25	156.36	149.357	19619.53

1.2 Problem statement

Petrochemical plant is important energy users, especially thermal energy. From the aspect of economy, the total production cost to produce 100,000 MT/A isobutylene is RM 376,362,299 and this characteristic is the reason for the appearance of many studies about energy savings alternative in the petrochemical plant. Energy saving reflects itself in many ways, for example reduced fuel consumption or reduce maintenance cost due to the lower load on various items of plant equipment. However, until now finding the best configuration for process equipment and heat exchangers has been a complicated business. In plant design, there is always a trade-off between energy costs and the capital costs of heat exchangers and other equipment required to optimize energy efficiency. Energy saving in process plant equipment has essentially been a trial-and-error procedure between changes in structure and simulation until satisfactory reductions are achieved. It was very important to optimize the use of energy in the plant so that we can decrease the maintenance cost for the plant every year and minimizing usage of utilities in a process plant. Pinch technology, is a new energy analysis tool that allows design engineers to track the heat flow from all process streams in a system and identify modifications that can cut energy costs by 20 to 40 percent. It is a complete methodology derived from simple scientific principle by which it is possible to design new plant with reduced energy as well as where the existing process require modification to improved the performance. Using pinch technology it can provides an easy way to analyze the trade-offs of capital cost and energy efficiency

1.3 Objective

This aim of the study is to minimize the cost utility for a production of 10,000 MT/A Isobutylene plant. The objectives of the study were;

i.) To minimize the energy usage of the plant.
ii.) To study the effect of energy conservation to plant economic.
iii.) To find the different temperature minimum for isobutylene process.

1.4 Scope

i) To observe the effect of energy saving in the plant by using Pinch analysis method
ii) Analysis the effect of cost investment for new heat exchanger design
iii) Analysis the effect of pay back period to the plant economic

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Today's petrochemical industry is challenged by many circumstantial variations. Oil price has risen radically in the past three years and stays at high level. Regulations about environment are getting more difficult to comply. Many people think the chemical industry is harmful and hazardous and this brings about many troubles with NGOs or neighbors around the petrochemical complex. All of these problem give a badly effect to the chemical industry. In order to sustain growth, it is necessary for the chemical industry to come out with solution such as saving cost and raising productivity simultaneously with satisfying many regulations. Energy saving is the most important issue in the petrochemical industry associated with cost and regulations. Energy cost contributes significantly to the total cost and the budget of energy cost rises sharply due to high oil price recently. As an addition new imposed regulation, Kyoto Protocol, which restrains discharge of green house gases, is expected to require reduction of carbon dioxide discharge (S.G Yoon *et al*).

The increasing concern for the environmental impacts of human activities has stimulated the development of new methods for the analysis of industrial processes and the implementation of energy conservation measures. One particularly powerful method is pinch technology method, which matured during the last 15 year with major contribution from Linnhoff. The implementation of process integration methods can lead to significant energy savings and waste reduction (primary wastewater minimization). Some of the research centers (Gunderson T., 2000) reported that ‘‘Pinch technology is probably the best approach that can be used to obtain significant energy and water savings as well as pollution reductions for different kind of industries’’. Their experience, summarized for the wide variety of industrial processes (Fig. 2.1), points out the great potential for improving the efficiency of large and complex industrial facilities. This potential exceeded the results obtained by traditional audits, based on the separate optimization of individual process units.

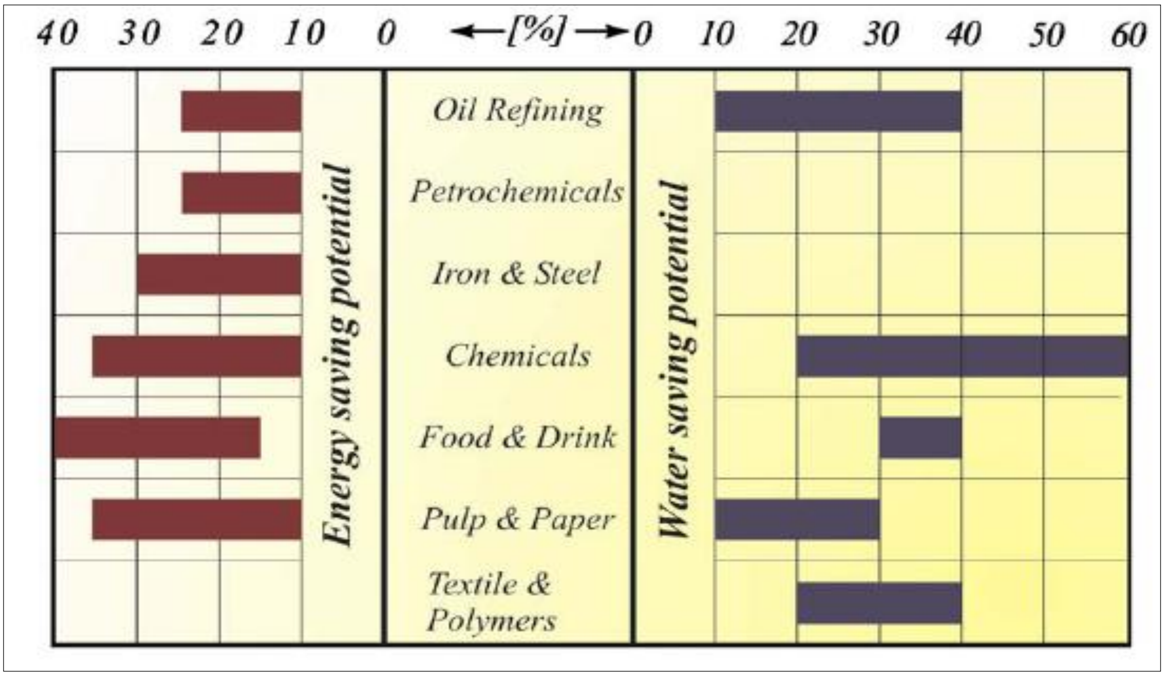

Figure 2.1: potential for reduction of energy and water consumption through Pinch analysis (Predrag et al., 2009)

2.1.1 Water uses and general approaches to water minimization within industry

In the production of 100,000 MT/A isobutylene plant (Azmin et al.,2009) its reported that the water utilities of the plant with specification RM 0.15 per 1000 kilogram cost almost RM 3 million per year. The cost of water utility can be reduced by using applied water minimization within the industry.

Most common water uses within a manufacturing facility in the process industries presented in figure 2.2. The figure illustrates common sources of wastewater, including process uses, condensate losses, boiler blowdown, and cooling-tower blowdown, wastewater from other uses such as housekeeping and storm-water runoff.

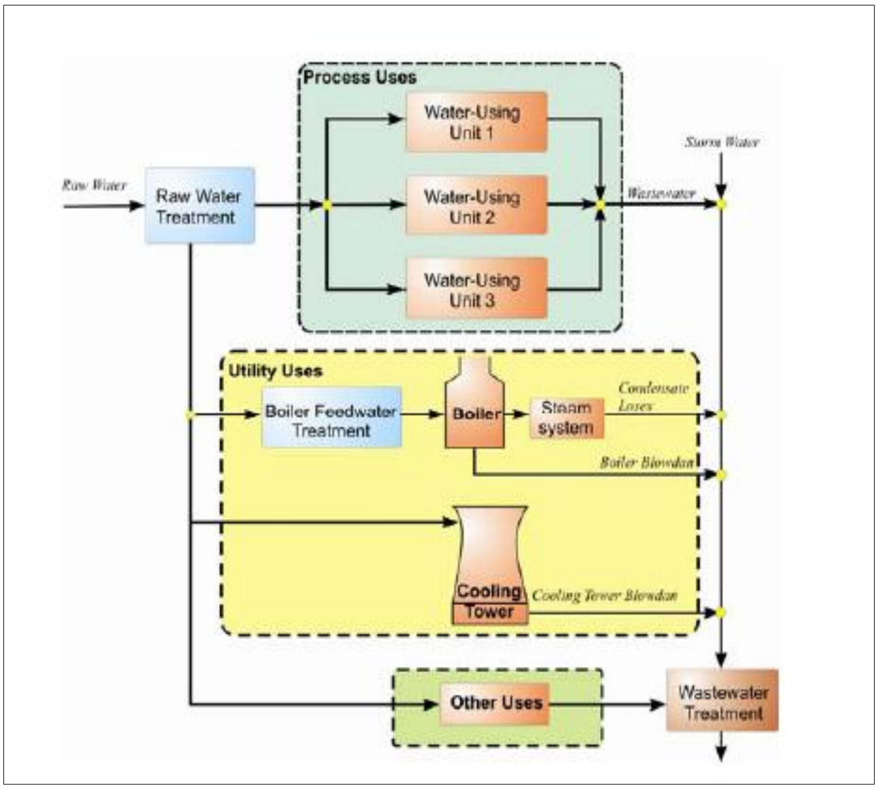

Figure 2.2: Typical water used on process site

Water is directed to process uses, utility uses or other uses. Four general approaches for the water minimization include process change, water reused, regeneration reuse and regeneration recycling.

2.1.1.1 Process change

A single source of fresh water is used to supply a variety of processes, *P*. Once used, the process waters are mixed and sent to a series of treatment operations, *T*, before discharge. Replacing the technology employed in a process can reduce the inherent demand for water. Sometimes it is possible to reduce water demand by changing the way existing equipment is operated, rather than replacing or modifying it (Rascovic.,2009) Figure 2.3 illustrated a process changes that involve in water minimization.

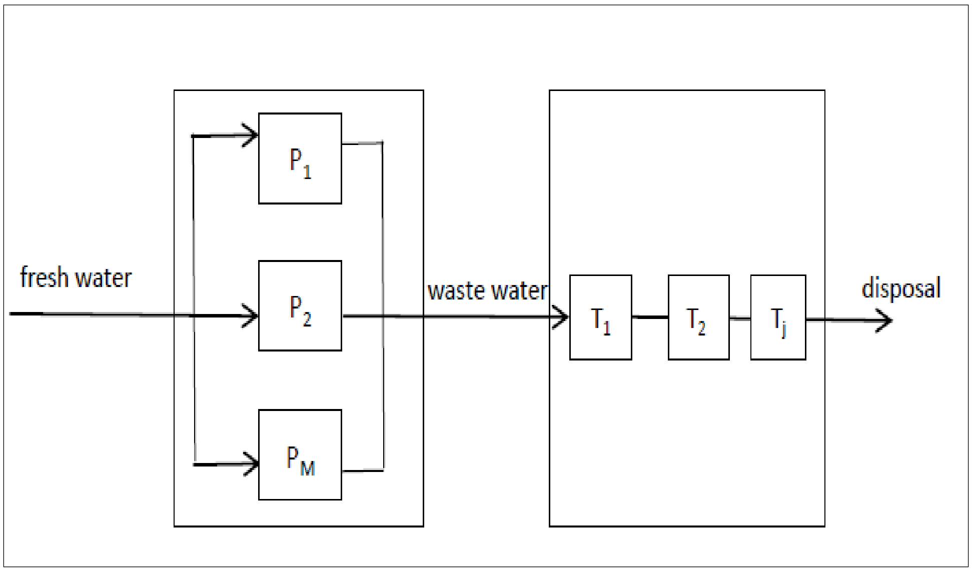

Figure 2.3: Process change

2.1.1.2 Water reused

The effluent from some process water uses can be used as the feed material for other process uses. Wastewater from one operation can be directly used in another operation, provided the level of contamination from the previous process does not interfere with the subsequent process. This will reduce overall fresh water and wastewater volumes, but not affect contaminant loads in the overall effluent from the system. Generally, reuse excludes returning, either directly or indirectly, to operations through which it has already passed, in order to avoid build-up of minor contaminants which have not been considered in the analysis.

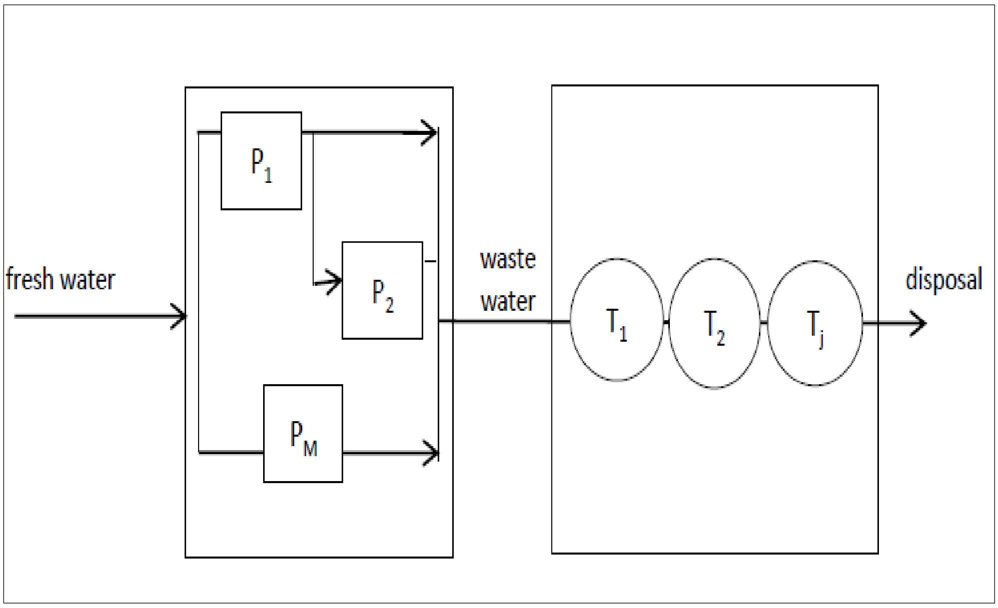

Figure 2.4: Water reused

2.1.1.3 Regeneration reused and recycling

Regeneration reuse is partial treatment of wastewater can remove contaminants which would otherwise prevent reuse. The regeneration process might be filtration, stream-stripping, carbon adsorption or other such processes. In this case both volumes and contaminant loads will be reduced. Where as regeneration recycling is refers to the situation where water is reused in an operation through which it has already passed. In this case, the regeneration step must be capable of removing all contaminants which build up in the system. Figure 2.5 illustrate of the regeneration reused and also regeneration recycling.

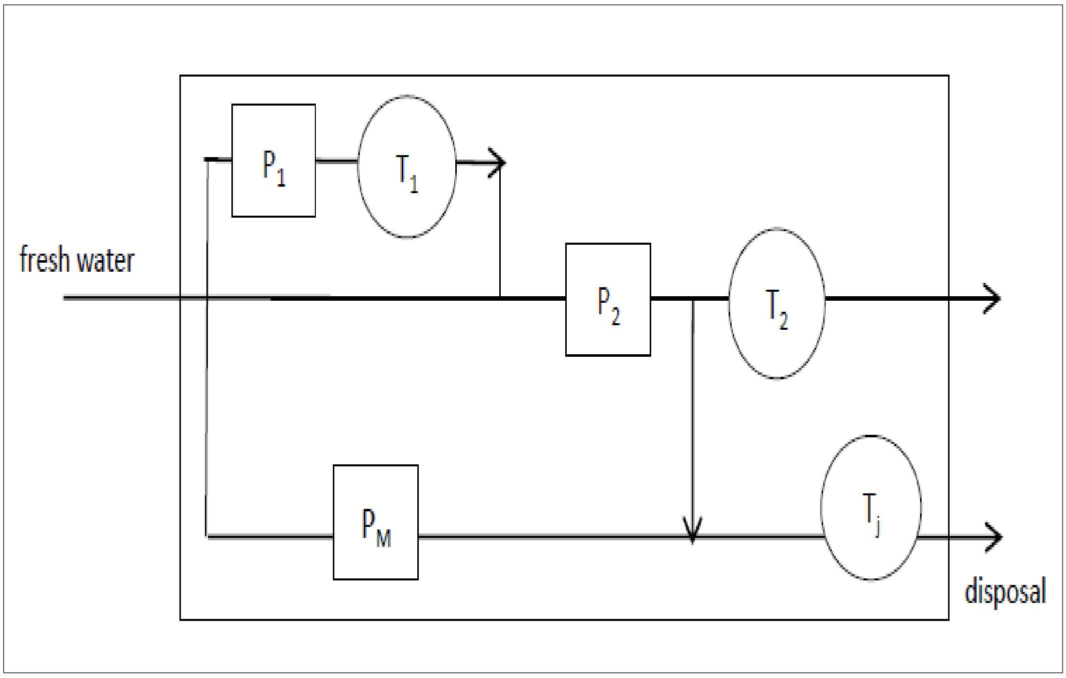

Figure 2.5: Regeneration reused

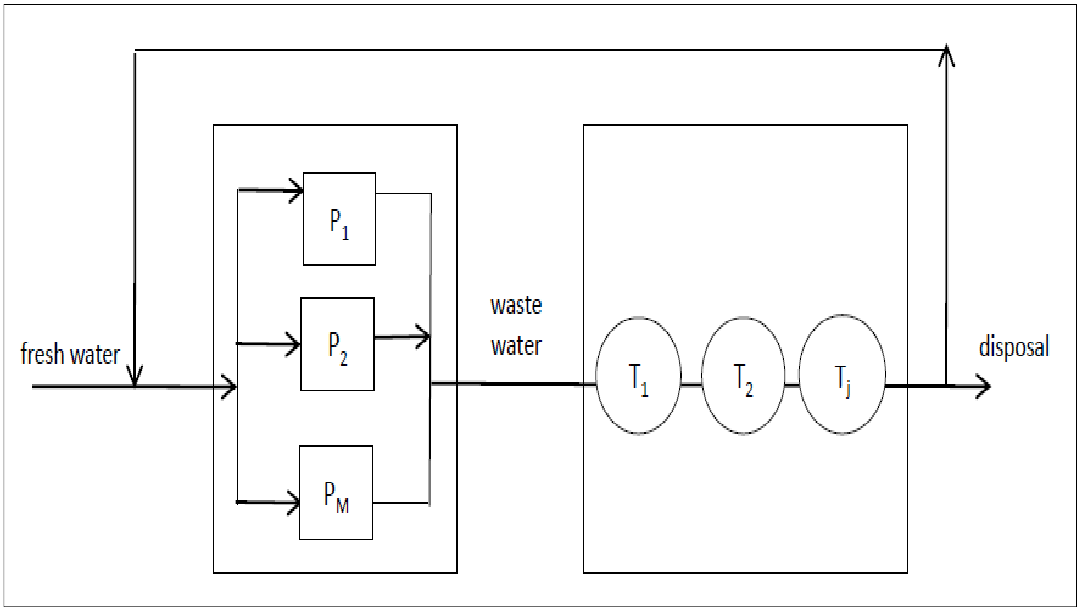

Figure 2.6: Regeneration recycling

2.2 Background of Pinch Analysis

In the late 1978, Bodo Linnhoff a Ph.D student from the corporate laboratory, Imperial Chemical Industries Limited, ICI, under the supervision of professor John Flower, University of Leeds, devised a new approach to describe energy flows in process heat exchanger networks (Kawari et al.,2000). It was an introduction of thermodynamic principles into what was then called ‘process synthesis’ and heat exchanger network design. Today, pinch technology has an established industrial track record. There are over 500 projects undertaken worldwide. The BASF Company alone has undertaken over 150 of these 500 projects. They have been able to achieve a saving of over 25 % of energy in their main factory at Ludwigshafen, Germany, by adopting this technique (Kawari et al.,2000).

Pinch technology is a complete methodology derived from simple scientific principles by which it is possible to design new plants with reduced energy and capital costs as well as where the existing processes require modification to improve performance. An additional major advantage of the Pinch approach is that by simply analyzing the process data using its methodology, energy and other design targets are predicted such that it is possible to assess the consequences of a new design or a potential modification before embarking on actual implementation. Pinch analysis originated in the petrochemical sector and is now being applied to solve a wide range of problems in mainstream chemical engineering. Wherever heating and cooling of process materials take place, there is a potential opportunity. The technology, when applied with imagination, can affect reactor design, separator design and the overall process optimization in any plant. It has been applied to process problems that go far beyond energy conservation. It has been employed to solve problems as diverse as improving effluent quality, reducing emission, increasing product yield and debottlenecking, increasing throughput and improving the flexibility and safety of the process (Akande et al.,2009)

2.3 Pinch Analysis

Recently the technique has been extended to address capital cost, in which the capital-cost target has been developed ahead of the design stage. An overall thermodynamic method has emerged which bring together energy and capital cost. In the beginning, the technique was applied for grass-root designs and subsequently it has been extended for the retrofits of old designs (Kawari et al., 2000). Pinch technique, which has evolved as an energy saving technique, present simple and easy ways of optimization based on complex thermodynamic rules. It is used to low operating costs, de-bottlenecking processes, raising efficiency and reducing capital investment. According to K.R Ajao and H.F Akande study on energy integration of crude distillation unit using pinch analysis shows that pinch analysis as an energy integration technique saves more energy and utilities cost than the traditional energy technique. The pinch design can reveal opportunities to modify the core process to improve heat integration. Pinch analysis is used to identify energy cost and heat exchanger network (HEN) capital cost targets for a process and recognizing the pinch point. Most processes need to consume energy at one temperature level and reject it at another level. This is achieved using utilities. Energy is provided to a process using such utilities as steam, hot water, and fuel gas it is rejected to cooling water, air, refrigerant or in heat recovery steam rising. Heat recovery is used to reduce the utility cost of a process. Evaluation of heat recovery involves a balancing of utility against the capital cost of the heat recovery system. The utility cost not only depends upon the amount of energy consumed and rejected but on the utility actually used (Akande et al., 2009) . From the curves shown in Fig.2.7, the performance of the plant can be determined and it will give a clear overall picture of the plant performance rather than having calculated the performance of each item of equipment individually (Kawari et al.,2000)

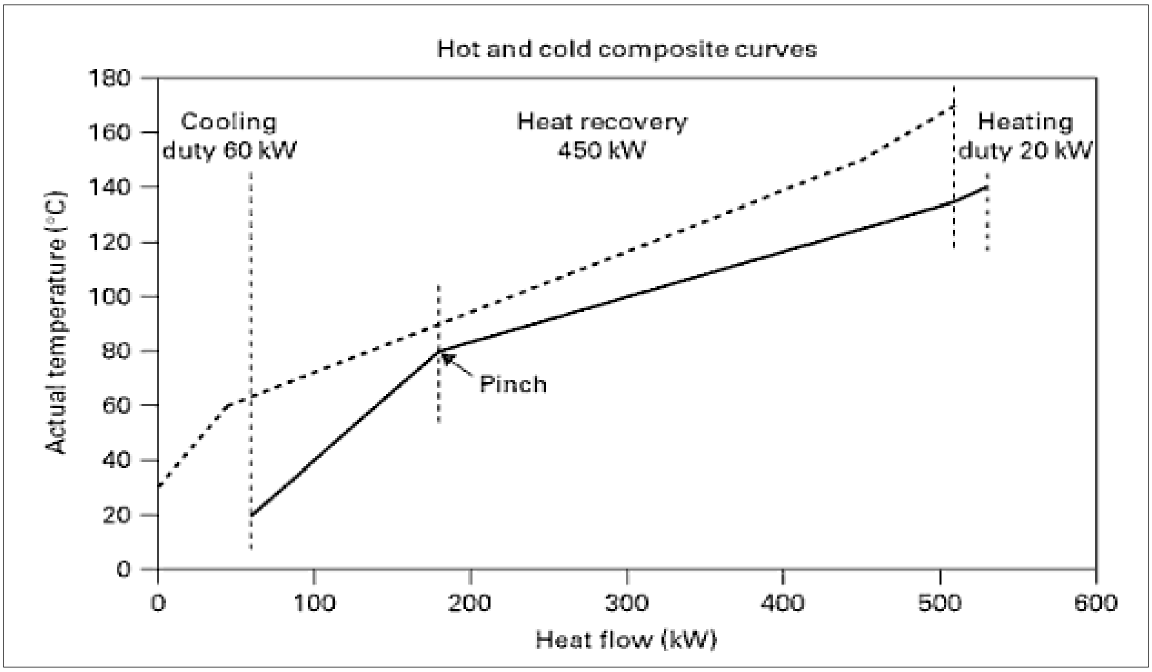

Figure 2.7: Pinch technology will convert the plant heat-exchanger streams to line called the hot and cold composites curve. (C.Kemp, 2007)

Pinch Technology provides a systematic methodology for energy saving in processes and total sites. The methodology is based on thermodynamic principles. Figure 2.8 show an onion diagram of process hierarchy in common process design. The design of a process starts with the reaction and chemical synthesis process (in the ‘core’of the onion). Then, the separation and process development (the second layer of the onion) can be start design after feeds, products, recycle concentrations and flow rates is identified. 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 side wide utility system.

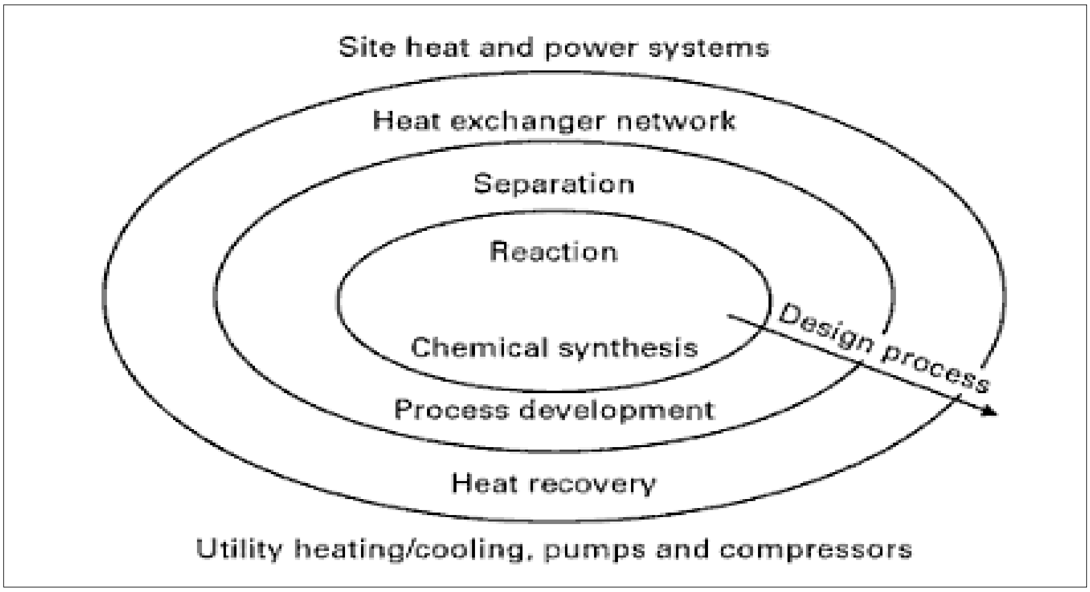

Figure 2.8: “Onion diagram” of process hierarchy in a process design (C.Kemp, 2007)

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 such as steam and refrigeration levels. The utility levels supplied to the process may be a part of a centralized site-wide utility system. Pinch technology extends to the site level, where in 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.

2.3.1 Composite curve

The most fundamental concept in Pinch analysis is composite curves and grand composite curves. A composite curve visualizes the flow of heat between the hot and cold process streams selected for heat integration. A composite curve is obtained by plotting the cumulative enthalpy of streams, cold or hot, against temperature (Grossman et al., 1998) . The representation of the process with the composite curves indicates, for a ΔT_{min}, the maximum potential of heat that can be recuperated inside the process and the minimum quantity of heat to be given up or eliminated by thermal utilities. From the composite curves perspective it is considered that the heating utilities are hot enough to provide heat at any temperature level required by the process, and the cooling utilities are cold enough to extract heat at any temperature level by the process. (Herrera et al ., 2003).

The concept known as grand composite curve is used to know the minimum temperature level, minimum heat quantity to eliminate and also the minimum heat quantity that must provide. The grand composite curves enable to make a more precise analysis in order to integrate the thermal utilities in the process. The grand composite curve is the difference between the heat supply (available heat) and heat demand (required heat) in different temperature intervals of the composite curves. Consequently it is the net heating quantity (in excess or missing) inside the process. These net needs should be covered by external utilities. Parts of the grand composite curve with positive slope represent temperature intervals in which heat has to be provided to the process using utilities. Parts of the grand composite curve with negative slope represent temperature intervals in which heat has to be eliminated in the process using utilities. The temperature in the grand composite curve for which there is zero thermal need corresponds to the location of the pinch point.

The grand composite curve is useful to identify not only the energy quantity that the process requires but also to identify temperature levels in which energy is required. This enables to fit utilities thermal load (quantity) and its temperature level to avoid its degradation with low efficiency, using excessive temperature gradients between utilities and process.

2.3.2 Selection of initial DT_{min} value

The design of any heat transfer equipment must always adhere to the second law of thermodynamic that prohibits any temperature crossover between the hot and the cold stream for example a minimum heat transfer driving forces must always ne allowed for a feasible heat transfer design. Thus, the temperature of the hot and cold streams at any point in the exchanger must always have a minimum temperature different. This DT_{min} value represents the bottleneck in the heat recovery. The value of DT_{min} is determined by the overall heat transfer coefficients and the geometry of the heat exchanger. In the network design, the type heat exchanger to be used at the pinch will determine the practical DT_{min} for the network. For example, an initial selection for the DT_{min} value for shell and tube maybe 3-5 ^{o}C at the best while compact exchangers such as plate and frame often allow for an initial selection of 2-3 ^{o}C. The selection of DT_{min} value actually has implication for both capital and energy cost. Just as for a single heat exchanger, the choice of DT_{min} is vital in the design of heat exchanger networks. A few values based on Linnoff March's application experience are tabulated at table 2.1 for shell and tube heat exchanger.

Table 2.1: Typical DT_{min} values

No	Industrial sector	Experience DT_{min} Values
1	Oil refining	20-40^{o}C
2	Petrochemical	10-20^{o}C
3	Chemical	10-20^{o}C
4	Low temperature Processes	3-5^{o}C

2.3.3 Pinch point principle

Consequently, a Pinch Point principle can be formulated as follows (Linnhoff and Hindmarsh,1982).

- Do not transfer heat across the pinch
- Do not used cold utility above the Pinch
- Do not used hot utility below the Pinch

If there is heat flow across the pinch, then the energy consumption is higher than minimum necessary. Both hot and cold utility consumption will increase with the same amount XP above the minimum target. The Pinch equation is:

$$\text{Actual energy (A) = target (T) + Cross-Pinch Energy Flow (XP)} \qquad 1.1$$

Thus transferring heat across the Pinch is a double loss in energy. However, during the effective design of the heat exchanger network, the initial target must be revised to accommodate constrains, as for example smaller number of units, or some imposed loads. The actual energy consumption could increase above the minimum targets, but the designer should try to keep the pinch violation as small as possible. Beside the stream data, supplementary information is needed as type, temperature and cost of utilities, partial heat transfer coefficients of stream and utilities, and maximum heat transfer area of the heat exchanger. Because of the energy target increase linearly with ΔT_{min}, the cost of utilities follows the same trend. On the contrary, the capital cost decrease non-linearly with ΔT_{min}. The cost function exhibits a jump when the number of units changes. Therefore, the reduction in the number of units is by far more important overall cost optimization than the incremental reduction of heat transfer area (Azmin et al., 2008)

2.4 Heat exchanger network synthesis

One of the most extensively studied and single most important industrial application area for process integration is Heat Exchanger Network Synthesis (HENS). The principal aspect of HENS can be found in the fact that most industrial processes involve the transfer of heat, from one process stream either to another process stream or from a utility stream to a process stream. Consequently, the target in any industrial process design is to maximize the process-to-process heat recovery and to minimize the utility requirements. To meet this goal, industrial cost-effective HEN that consisting of one or more heat exchangers that collectively satisfy the energy conservation task, is of particular importance. P.Ras kovic´ and S.Stoiljkovic in their study about Pinch design method in the case of a limited number of process streams describe the first rigorous definition that have been made by Masso and Rudd in 1969. The descriptive form of this definition is,

For given:

- a set of hot process streams, each to be cooled from its supply temperature to its target temperature, with known flowrates, heat capacities and film heat transfer coefficient;
- a set of cold process streams, each to be heated from its supply temperature to its target temperature, with known flowrates, heat capacities and film heat transfer coefficient;
- the utilities (external sources of thermal energy) available and the temperature or temperature range and costs for these utilities,

A steady state heat exchanger network with the minimum annualized investment and operating costs can be developed. The dimension of such problem can be explained by the use of the schematic drawing of an energy system presented in Fig. 2.9.

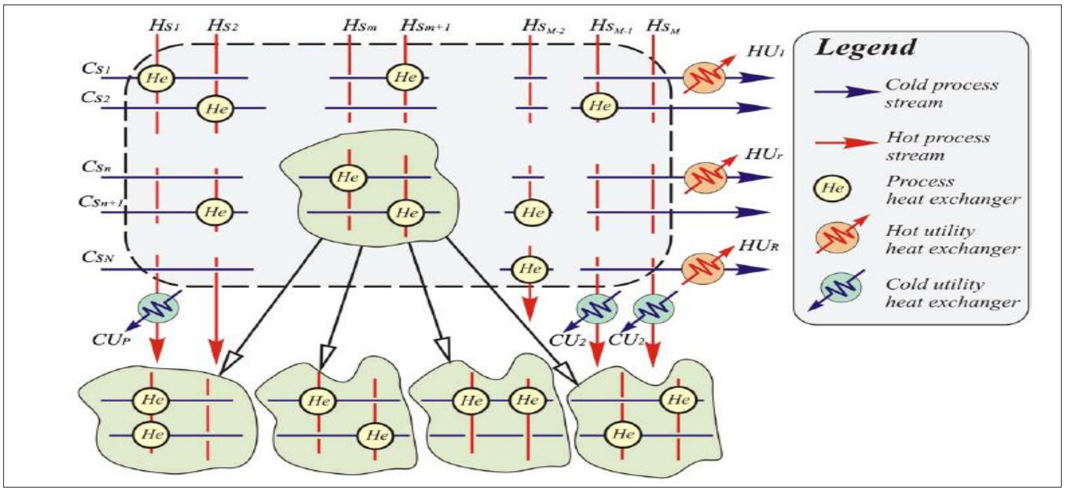

Figure 2.9: Schematic presentation of HENS task (Predrag et al.,2009)

Hot and cold process streams passing through the energy system, formed by process heat exchangers units, perform the interchange heat transfer among them. In order to accomplish the target temperature of the streams (if it is necessary), utilities, cold CU and hot HU, are added after the streams leave the control region. Of each of the hot process streams exchange heat with only one cold process stream in the heat exchanger (He), then the number of possible process streams matching which mean it is equal to the number of possible heat exchanger network configurations, in such one-exchanger- per-stream, is $p = N_{hs}N_{cs}$. For a simple case when $N_{hs}=N_{cs}=2$ four possible HEN configurations can be extracted. Furthermore, for any of these configuration there are p-1 possibilities to couple the next pair of hot and cold streams, hence the number of two-exchanger-per-stream HEN configurations is p(p-1). Similarly, the number of three-exchanger-per-stream configurations will be p(p-1)(p-2), and the number of all possible schemes then becomes N = p! [4]. For example, if $N_{hs} = N_{cs} = 5$, then the number of HEN configurations could be approximately 1.5 x10^{25} (Raskovic et al., 2009).

However, this is only theoretical explanation and the actual number of possible process streams matching is smaller. Some of them are thermodynamically impossible if the cold process stream is hotter than the hot process stream and some them are not desirable for those who resulting in too small exchanger. According to the situation, which foregoes process design, HENS can be addressed to two different tasks. The first is the design of the new HEN, or grassroot design, which presents the most straight forward situation since it has the most freedom to choose the design options and the size of equipment. The second, the retrofit design, is carried out to modify the existing HEN in order to increase capacity, change the feed or product specifications, reduce operating costs, improve safety or reduce environmental emissions. Typically, these modifications include the addition of new heat exchangers or areas to an existing unit, change internals in heat exchangers, modify the piping system, and move a heat exchanger to a new location.

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2.5 Cost optimal heat exchanger network

From the economical point of view, the benefits of Pinch technology are classified according to the possible project pay back period in figure 2.10. (Raskovic et al.,2009).

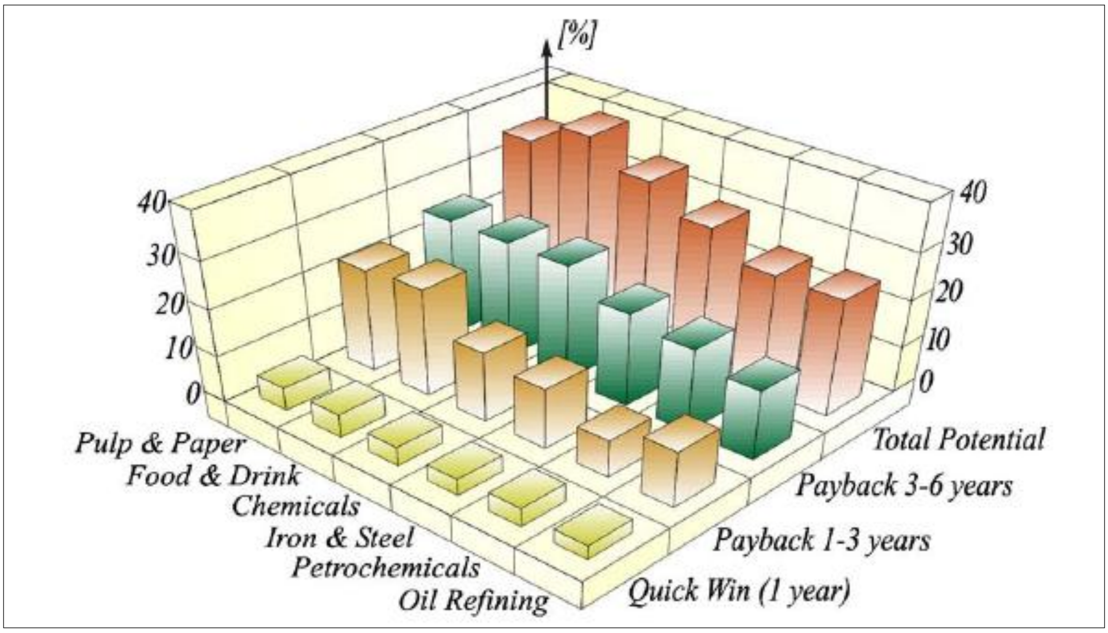

Figure 2.10: Possible project pay back period trough pinch technology technique. (Raskovic et al.,2009).

- Quick-win project : saves up to 5% of energy with a 1-year payback
- Medium-payback projects : produce a further 10–15% energy saving within a 1–3-year payback
- Long-pay back project (typically, utility infrastructure projects): additional energy savings of up to 25% with overall payback times of 4–6years.

Evaluating the capital cost of the exchanger network is the final step in the pinch analysis to estimate the number of heat exchanger unit that required for the network. If the number of shell required for each heat exchanger is calculated, the total number and areas of each exchanger required for the design can be calculated.

The used of the correct number of shells is important if an accurate estimate of the fixed capital cost (FCI) of the heat exchange network to be obtained

(Timmerhaus et al.,2002). Several economic criteria can be used to evaluated the profitability of a given heat exchanger network. The equivalent annual operating cost will be used:

$$\text{EAOC} = FCI\frac{i(1+i)^n}{(1+i)^n-1} + \sum \text{(utility cost)} \qquad 2.1$$

Where the fixed capital investment, FCI, is the total module cost of the heat exchanger network, the second term on the right-hand side of equation 1 is the yearly cost of the hot and cold utilities and n is the number of year over which the economic analysis is carried out. For a complete after-tax economic analysis, provision must be made for depreciating the FCI. To simplify the analysis, a before tax hurdle rate can be used to compared cases with different minimum approach temperature.

2.6 Benefit and application of Pinch technology

One of the main advantages of the pinch technology over conventional design method is the ability to set energy and capital cost targets for an individual process or for an entire production site ahead of design (Pinch Technology: Basic for beginner). By using the PI the process engineer enable to update or modify the process flow diagram and it can show where process changes reduce the overall energy not just local energy consumption. Beside that when specifically applied to debottlenecking studies, pinch analysis can lead to reduction in capital costs and also decrease in specific energy demand giving a more competitive production facility. A well designed combined heat and power (CHP) system significantly reduces power costs, pinch show the best type of CHP system that matches the inherent thermodynamic opportunities on the site. Unnecessary investment and operating costs can be avoided by sizing plants to supply energy that take heat recovery into consideration. Heat recovery should be optimized by Pinch analysis before specifying CHP system. Due to the many studies about the pinch analysis, J. De Ruyck et al presented a paper that proposed a technique to enlarge the capabilities of pinch analysis by introducing virtual heat exchanger (Rascovic). The concept is applied to chemical reactors and is shown to lead the better optimization. But this new concept is high technology for the new beginners.

2.7 Conclusion remark

Process integration using pinch technology offers a novel approach to generate target for minimum energy consumption before heat recovery design. Heat recovery and heat utility system constrains are then considered in the design of the core process. Interaction between heat recovery and utilities system are also considered. The pinch design can reveal opportunities to modify the core process to improve heat integration. This method helps to optimize the heat transfer equipments during the design of the equipment.

CHAPTER 3

METHODOLOGY

3.0 Methodology

Pinch point technology is based on process thermodynamic analysis. The methodology used in this work has therefore uses fundamental points mass and energy balance and the optimum use of the heat flows in process and consist of following steps:

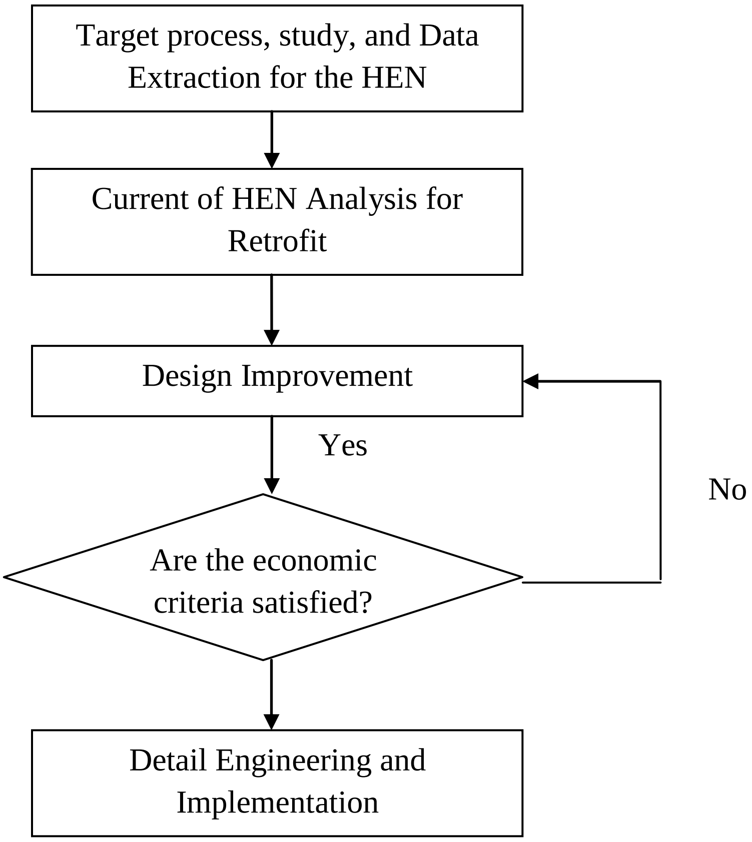

Figure 3.1: Practical flow of Pinch analysis

3.1 Analysis of Process Flow Diagram data

3.1.2 Data Extraction Flowsheet

In order to start the Pinch Analysis, a data need to be extracted from the process flow diagram Isobutylene plant. It involved the identification of process heating and cooling duties. Assumptions that have been made in this step is the reboiler and condenser duties are neglected for simplicity of analysis. Table 3.1 present a stream data from the production of 100,000 MTA isobutylene plant.

Table 3.1: Extracted stream data for production of 100,000 MTA isobutylene plant

Stream	**Name**	**T_s**	**T_t**	**CP**	**ΔH**
		°C	**°C**	**kW/°C**	**kW**
4	Hot 1	115	50	384.54	-24995.1
7	Hot 2	77	25	9.23	-479.96
1	Cold 1	50	106	420.5	23548
2	Cold 2	25	156.36	149.357	19619.53

The result clearly shows potential for energy integration between these four streams. Two require heating and two cooling, and the stream temperatures are such that heat can be transferred from the hot to the cold streams.

3.2 Pinch Analysis

3.2.1 Construction of composite curves

Composite curve (CC) displays the cumulated enthalphy of all streams, hot or cold, available in the temperature interval between stream temperature and target temperatures. The partition in temperature interval based on the analysis of stream population. For the stream in table 3.1 there are three intervals for hot and two intervals for cold streams.

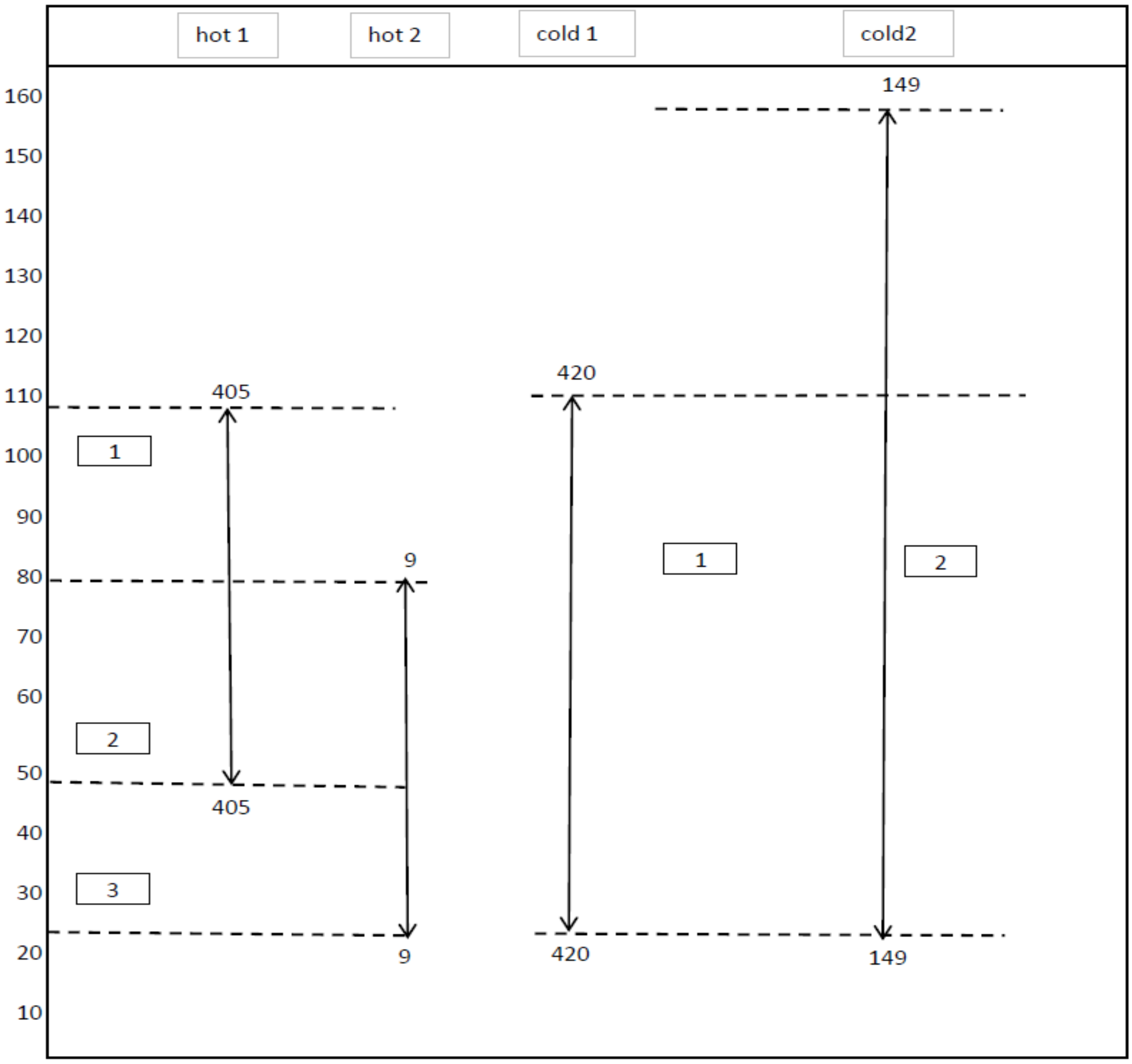

Figure 3.2: Temperature intervals of hot and cold streams

The constructions of grand composite curves are based on the temperature interval of hot and cold streams. Both cold and hot stream are plot in the same diagram (Figure 3.2). The cold CC shift to the right by adding an amount of heats such to achieve ΔT_{min}.

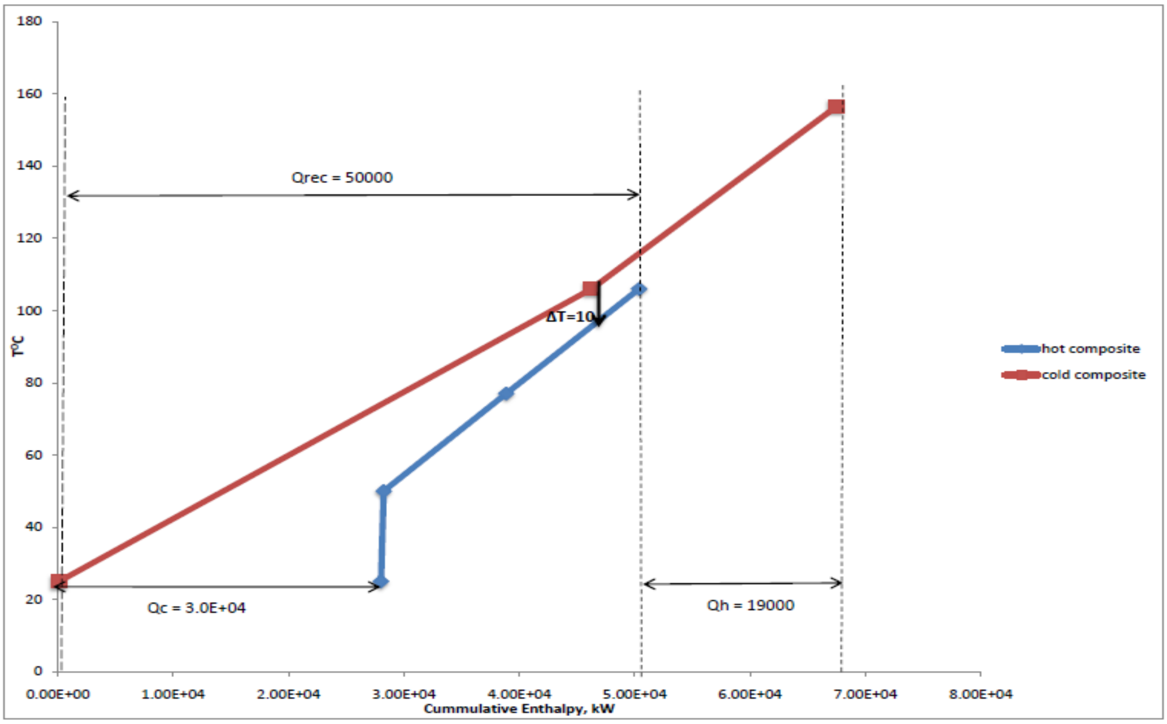

Figure 3.3: Shifting the composite curve modifies ΔT_{min} and utility target

Based on the figure 3.3, the Pinch is located at 98-108 ^{o}C for ΔT_{min} is 10 ^{o}C. Constructing of composite curve is the most crucial part since the analysis and design of HEN start at the Pinch. When there is no pinch, it means that the heat integration is not feasible since Pinch is where the heat transfer is most constrained.

3.2.2 Problem table algorithm

The temperature scale is modified to accommodate a minimum driving force ΔT_{min}. Hot stream represents on the left scale, and cold stream are plotted on the right scale. The temperature is shifted with ΔT_{min} that is equal to 10^{o}C. Both hot and cold streams can be referred to shifted temperature scale (Fig 3.4), where the hot stream temperatures are moved down with $\Delta T_{min}/2$ and the cold stream temperature shifted up with $\Delta T_{min}/2$.

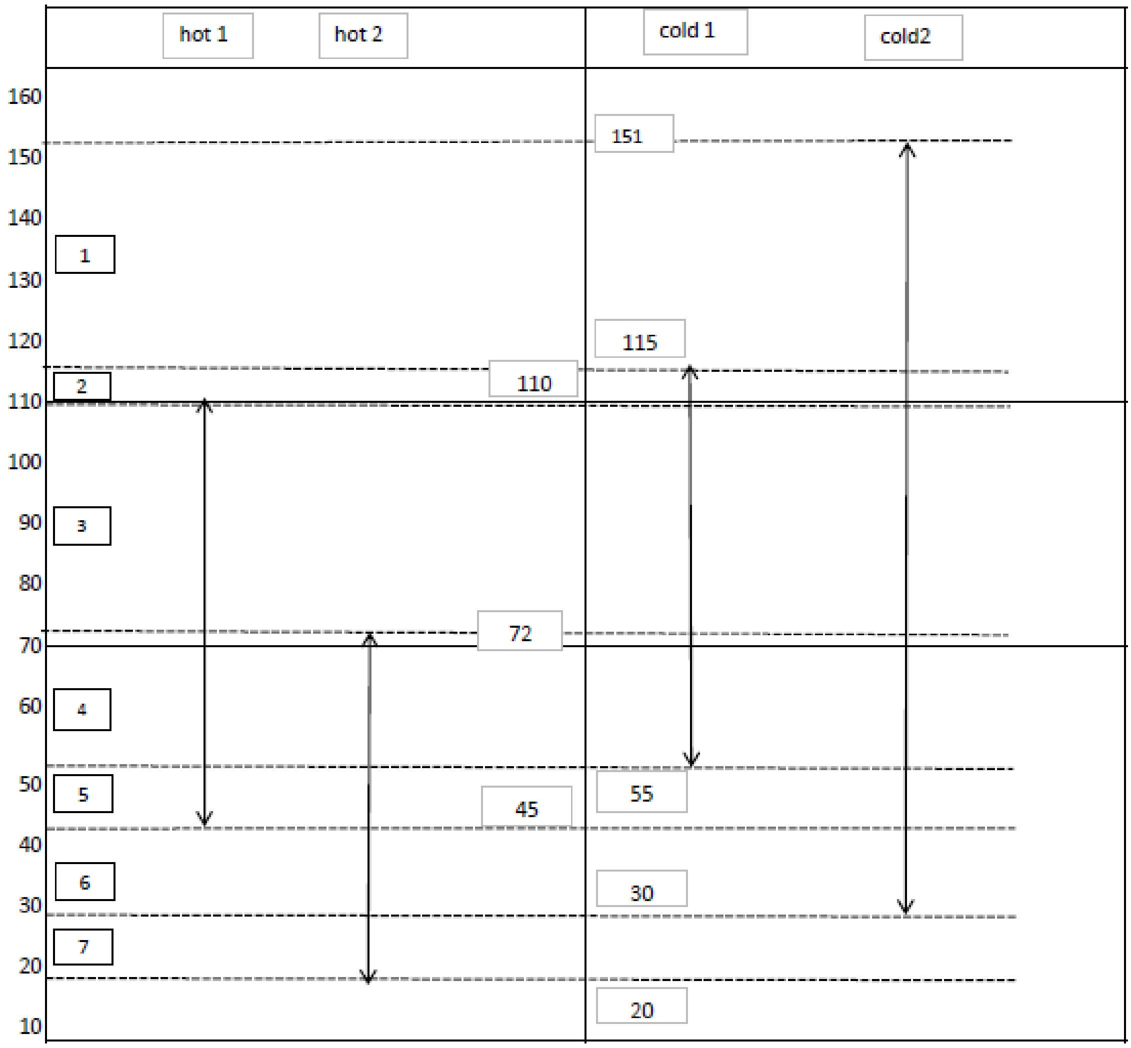

Figure 3.4: Shifted temperature scale

Secondly, temperature intervals for heat integration are identified. There are six intervals in figure 3.4 and based on shifted temperature scale, problem table algorithm is constructed (table 3.2)

Table 3.2: Problem table algoritm

Thot	Shift T	Tcold	Interval	ΔT_{in}	Cp_1	Cp_2	Cp_3	Cp_4	Cp_{int}	ΔH	Heat
156	151	146									
			1	36	0	0	0	1	149.357	5376.852	deficit
120	115	110									
			2	5	0	0	1	1	569.857	2849.285	deficit
115	110	105									
			3	38	-1	0	1	1	185.317	7042.046	deficit
77	72	67									
			4	17	-1	-1	1	1	176.087	2993.479	deficit
60	55	50									
			5	10	-1	-1	0	1	-244.413	-2444.13	surplus
50	45	40									
			6	15	0	-1	0	1	140.127	2101.905	deficit
35	30	25									
			7	10	-1	0	0	0	-9.23	-92.3	surplus
25	20	15									

As shown in table 3.2, the first three columns contain hot and cold stream temperature as well as shift temperature. Column five to nine indicate the active streams necessary for CP calculation: zero indicates inactive stream, -1 for hot active stream, and 1 for cold stream. Finally, enthalpy variation of each interval was found by multiplying each value of CP by ΔT_{in}. The negative value at the last column indicates heat surplus, which means excess heat, can be removing by cold utility. Meanwhile, positive value means deficit that means heat can be recover by hot utility.

The coupling of interval can be found by organizing the flow of heat in a cascade manner. The result of cascading heat flow can be seen in the figure 3.5. After the first interval the net flow is 8226.137 – 5379.852 = 2849.285 kW. The cascade of heat flow goes on until the lowest interval is reached. The location where the heat flow is zero is the Pinch Point.

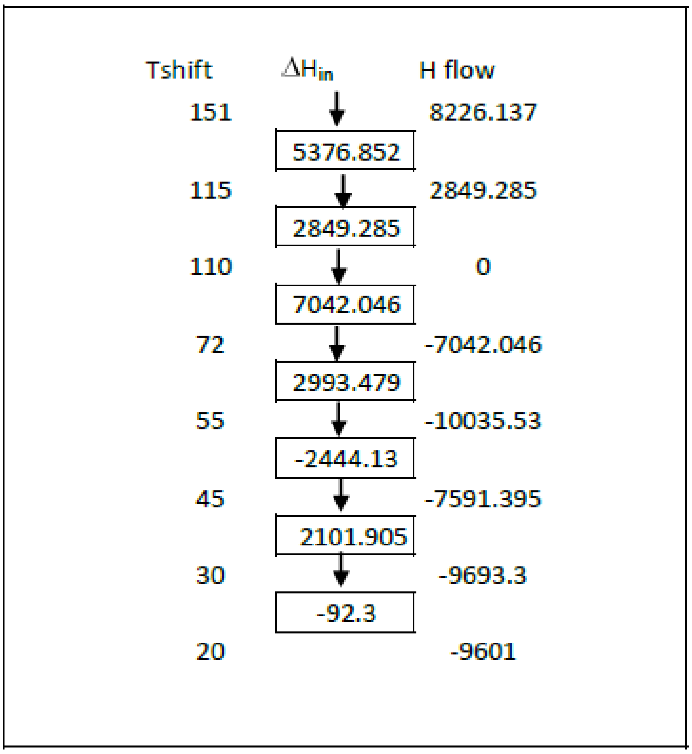

Figure 3.5: Cascade diagram

3.2.3 Grand composite curve

From the figure 3.6 information, the grand composite curve (GCC) is constructing. A GCC is obtain from plotting graph heat flow (x- axis) temperature shift (y- axis). Figure 3.6 present GCC.

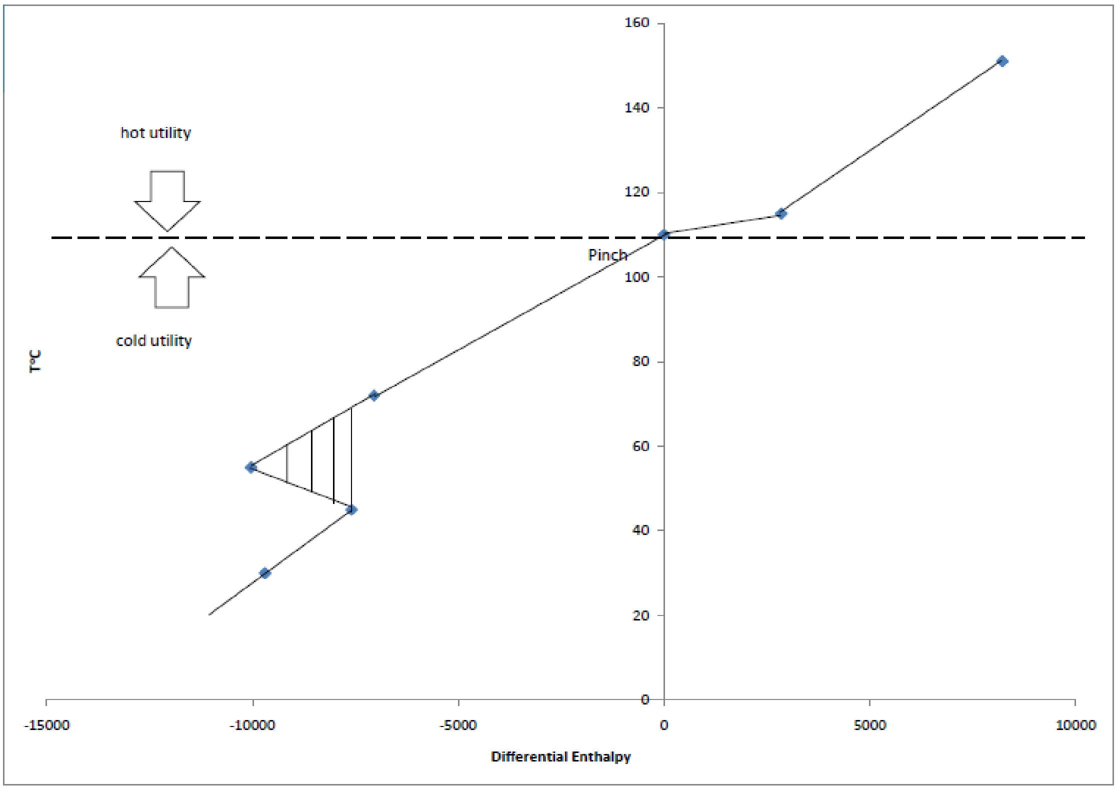

Figure 3.6: Grand Composite Curve

3.3 Design of heat exchanger network

HEN is easily revealed by grid diagram. Figure 3.7 is a grid diagram of the current HEN of the isobutylene process. The process has two hot stream and two cold stream. Hot stream are located at the upper side of the grid diagram and cold stream are in the lower side.

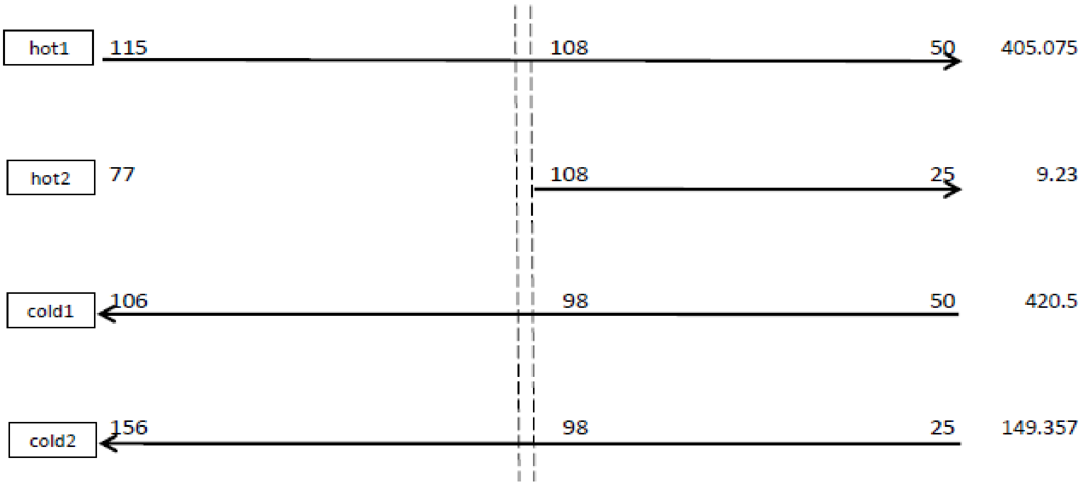

Figure 3.7: Grid diagram of the current HEN isobutylene process

3.3.1 The network design

The network above pinch features one hot stream and two cold streams (Figure 3.8). There are one heat exchanger, and it is suggested to matched stream four and one because it heuristics hold, for above pinch CP's of cold streams must be greater than CP's of hot streams.

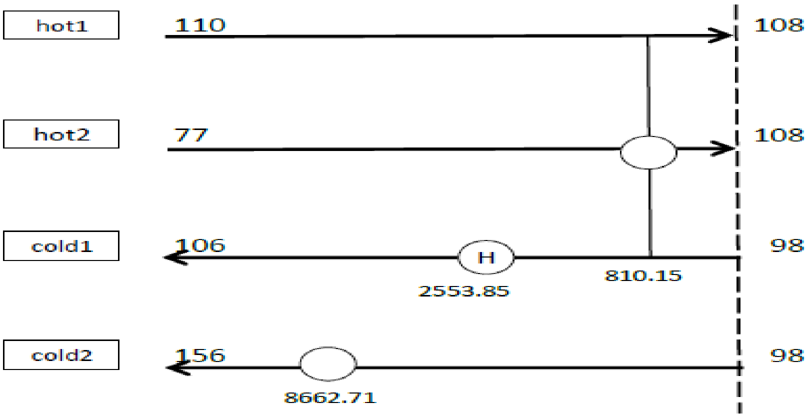

Figure 3.8: Network design above pinch

Network design below pinch, features two hot streams and two cold streams. The match between stream four and stream two is feasible because the CP of the hot stream is greater than the cold stream. The network design of the process production of isobutylene is shown in figure 3.9.

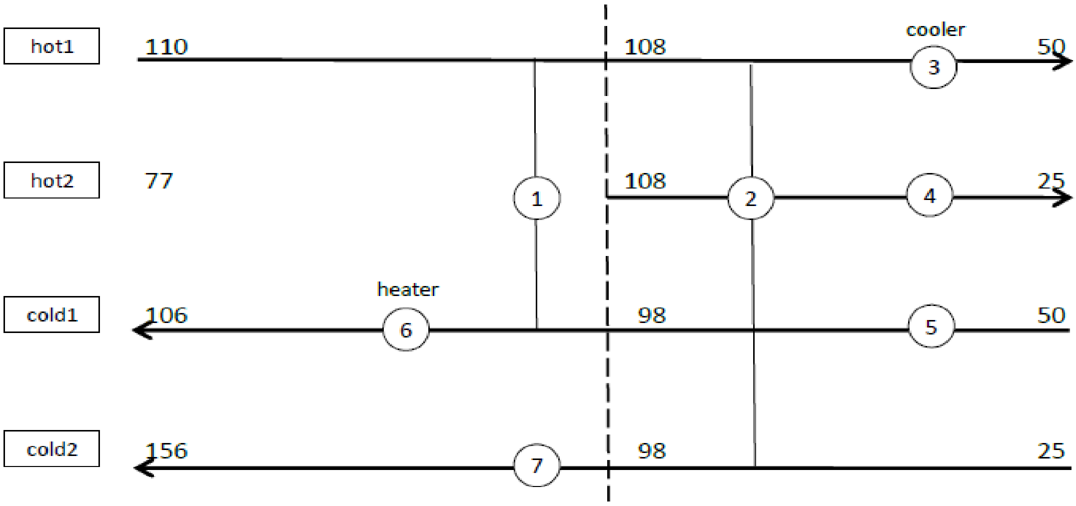

Figure 3.9 : Overall heat exchanger network design

3.3.2 Heat exchanger area

For sizing calculation, an assumption has been made which, overall heat transfer coefficient, for the heat exchanger is assuming to be 1140 W/m2.K according to table 3.3.

Table 3.3 : Typical values of Overall Heat Transfer Coefficients in Shell and Tube Exchanger (Geankoplis, 2003)

	U (W/m^2.K)	U (btu.h.ft^2.F)
Water to water	1140-1700	200-300
Water to brine	570-1140	100-200
Water to organic liquids	570-1140	100-200
Water to condensing steam	1420-2270	250-400
Water to gasoline	340-570	60-100
Water to gas oil	140-340	25-60
Water to vegetable oil	110-285	20-50
Gas oil to gas oil	110-285	20-50
Steam to boiling water	1420-2270	250-400
Water to air (finned tube)	110-230	20-40
Light organic to light organic	230-425	40-75
Heavy organic to heavy organic	55-230	10-40

Equation 3.1, 3.2, and 3.3 is used to calculated area of new design heat exchanger.

$$\Delta T_{lm} = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln \frac{(T_1 - t_2)}{(T_2 - t_1)}} \qquad 3.1$$

$$\Delta T_m = F_t \Delta T_{lm} \qquad 3.2$$

$$A_t = \frac{Q}{U_o \Delta T_m} \qquad 3.3$$

3.4 Economic analysis

The economic analysis for the new optimized plant will be carried out for further analysis the feasibility of the investment. The economic analysis will be involving the calculation of fixed and total capital investment cost, operating labor cost, utilities cost and pay back period.

3.4.1 Total Capital Investment cost

Total capital investment is a very important step in order to proceed at the pay back investment analysis. It includes total module cost, which refer to the cost of altering an existing facility. The total module cost can be evaluated from

$$C_{TM} = \sum_{i=1}^{n} C^{o}{}_{TM,i} = 1.18 \sum_{i-1}^{n} C^{o}_{BM,i} \qquad 3.4$$

Where n represent the total number of piece of equipment.

3.4.2 Operating labor cost

The technique to estimate operating labor requirement is based on the approach given by Ulrich. Table 3.3 provides a list of the labor required for a variety of equipment modules.

Table 3.4: Operator Requirements for Various Process Equipment (from Ulrich, G.D., A Guide to Chemical Engineering Process Design and Economics)

Auxiliary Facilities	Operator per equipment per shift
Air plants	1.0
Boilers	1.0
Chimneys and stacks	0.0
Cooling tower	1.0
Water dimineralizers	0.5
Electric Generating Plants	3.0
Incinerators	2.0
Mechanical Refrigeration Unit	0.5
Waste water treatment plant	2.0
Water treatment plant	2.0
Process equipment	
Evaporators	0.3
Vaporizers	0.05
Furnaces	0.5
Fans*	0.05
Blowers and Compressors*	0.15
Heat exchangers	0.1
Towers	0.35
Vessels	0.0
Pumps*	0.0
Reactors	0.5
*For equipment with spares such as compressors and pumps, just count equipment plus spare as one item	

Assumption being made on an average single operator working in chemical plant, which operates 24 hrs/day, 365 days/year and 3 shifts/day. For costing purpose a single operator is calculated as equivalent to 4.5 operators to ensure the plant operate properly.

3.4.3 Utilities cost

The cost of utilities are directly influenced by the cost of fuel. Specific difficulties emerge when estimating the cost of fuel, and utilities such as electricity, steam, and thermal fluids are directly impacted. Most often, utilities take part in energy, work and heat exchange activities in the plant. Table 3.4 can be used to determine the cost of utilities.

Table 3.5: Utilities provide by Off sites for a plant with multiple process unit (Turton, 2009, p. 233)

Utility	Description	Cost ($/GJ)	Cost $/ common unit
Air supply	Pressurized and dried air		
	a. Process b. Instrument		$2.3/100m3 $4.7/100m3
Steam from boilers	Process steam: latent heat only		
	a. Low pressure (5barg,160^{o}C) b. Medium pressure (10barg, 184^{o}C) c. High pressure (41barg, 254^{o}C)	3.17 3.66 5.09	$6.62/1000kg $7.31/1000kg $8.65/1000kg
Cooling tower	Process cooling water	0.16	$6.7 / 1000m^3
Water	30^{o}C to 40^{o}C or 45^{o}C		
Other water	High purity water for		

	a. Process use		\$0.04 / 1000kg
	b. Boiler feed water		\$2.54 / 1000kg
	c. Potable (drinking)		\$0.26 / 1000kg
	d. Deionized water		\$1.00 / 1000kg
Electric substation	Electric distribution a. 110 V b. 220 V c. 440 V	16.8	\$0.06 / kWh
Fuels	a. Fuel oil (no 2)	4.0	\$170 / m^{3}
	b. Natural gas	2.5[3]	\$0.085 / std. m^{3}
	c. Coal (FOB mine mouth)	1.2	\$31 /tonne
Refrigeration	a. Moderately low T: 15^{o}C[4]	20	Based on process cooling duty
	b. Low T : -20^{o}C	32	
	c. Very low T : -50^{o}C	60	
Thermal system	a. Moderately high T : to 330^{o}C	4.9	Based on process heating duty
	b. High T : to 400 ^{o}C	5.2	
	c. Very high T: to 600^{o}C	5.9	
Waste disposal (solid and liquid)	a. Non – hazardous		\$36 / tonne
	b. Hazardous		\$145 / tonne
Waste water treatment	a. Primary (filtration)		\$39 / 1000m^{3}
	b. Secondary (filtration + activated sludge)		\$41 / 1000m^{3}
	c. Tertiary (filtration, activated sludge, and chemical processing)		\$53 / 1000m^{3}

[1] Based on $\Delta T_{\text{cooling water}} = 10^{o}C$. Cooling water return temperatures should not exceed 45^{o}C due to excess scaling at higher temperature

[2] Approximately equal credit is given for condensate returned from exchangers using steam

[3] Based on Lower Heating Value of Natural Gas

[4] Cost for refrigerated water supplied at 5^{o}C and returned at 15^{o}C.

3.4.4 Payback Period

Payback period is the period required for the profit or other benefits from an investment equal. The payback period is the simplest method of looking at one or more investment projects or ideas. The Payback Period method focuses on recovering the cost of investments. PP represents the amount of time that it takes for a capital budgeting project to recover its initial cost. The Payback Period Calculation is as follows:

$$Payback\ period = \frac{\text{the cost of project/investment}}{\text{Annual cash flow}} \qquad 3.5$$

The pay back period concept holds that all other things being equal, the better investment is the one with the shorter payback.

CHAPTER 4

RESULT AND DISCUSSION

4.0 Determination of ΔT_{min} and Construction of Composite Curves

Generally, the composite curve can give conceptual understanding of how energy target can be obtained. The composite curve has two curves, which are a hot composite curve and a cold composite curve. Each curve shows composited hot streams and cold streams. Therefore the composite curve represents heating and cooling demand of the process corresponding to the temperature range. The two composite curves are located in the most adjacent position to discover the amount of maximum energy recovery. The position is determined by DT_{min} (minimum temperature difference), which means the minimum driving force for heat exchange. Temperature differences of the two curves have to be over ΔT_{min} in all temperature range. At the pinch point, two curves approach closest and the temperature difference of two composite curves is ΔT_{min}. For this research,in order to determine the suitable minimum temperature difference for this process, it is required to analyze the ΔT_{min} equal to 5°C,10°C,15°C,20°C and 25°C. Hot and cold composite curves are graphical representation of heat availability in process (hot composite curve) and heat demands in the process (cold composite curve). The composite curve will generate accurate value for the pinch temperature and minimum hot and cold heating requirement for the entire process (Manan et al,. 2000)

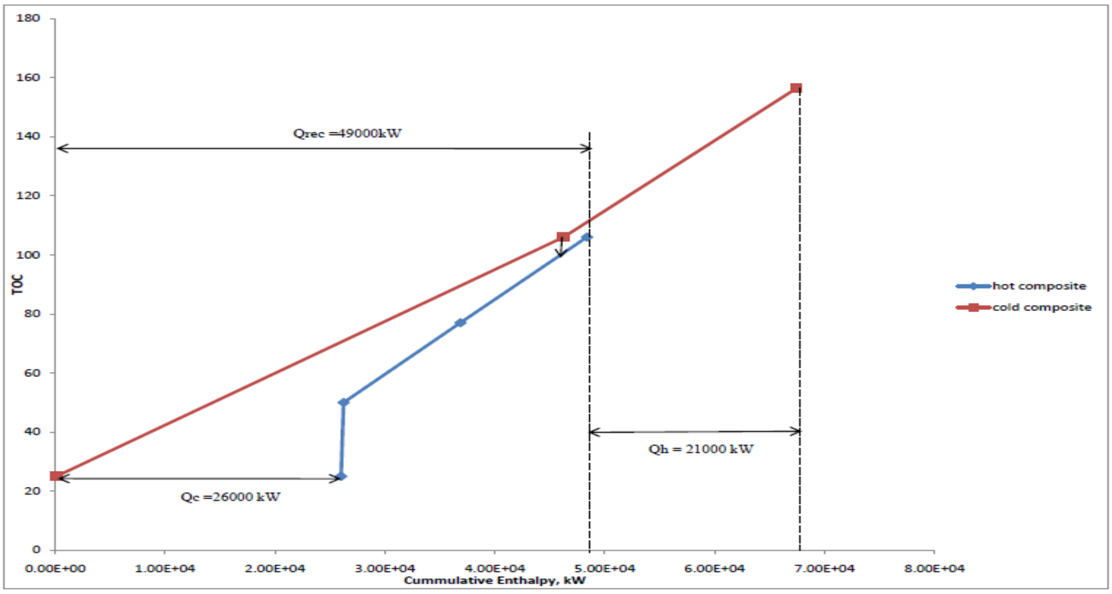

Figure 4.1 (a) : Composite curve with ΔT_{min} = 5^oC

From the figure, 4.1 (a) we have identified the Pinch Point, which is the point of closest approach between the composite hot and cold curves. The heat transfer is most constrained at this point. The pinch temperature for ΔT_{min}= 5^oC is equal to 100 ^oC, the minimum hot utility target is equal to 21000kW which represent the minimum external heating duty required by the process, and the heating duty can be supply by the use of steam or thermal oil. Whereas the minimum cold utility target is equal to 26000kW that represent the minimum external cooling duty required by the process, the cooling duty could be supply by the use of cooling water or refrigerant. The summary minimum heat utility and cold utility target with various minimum temperature differences showed in table 4.1.

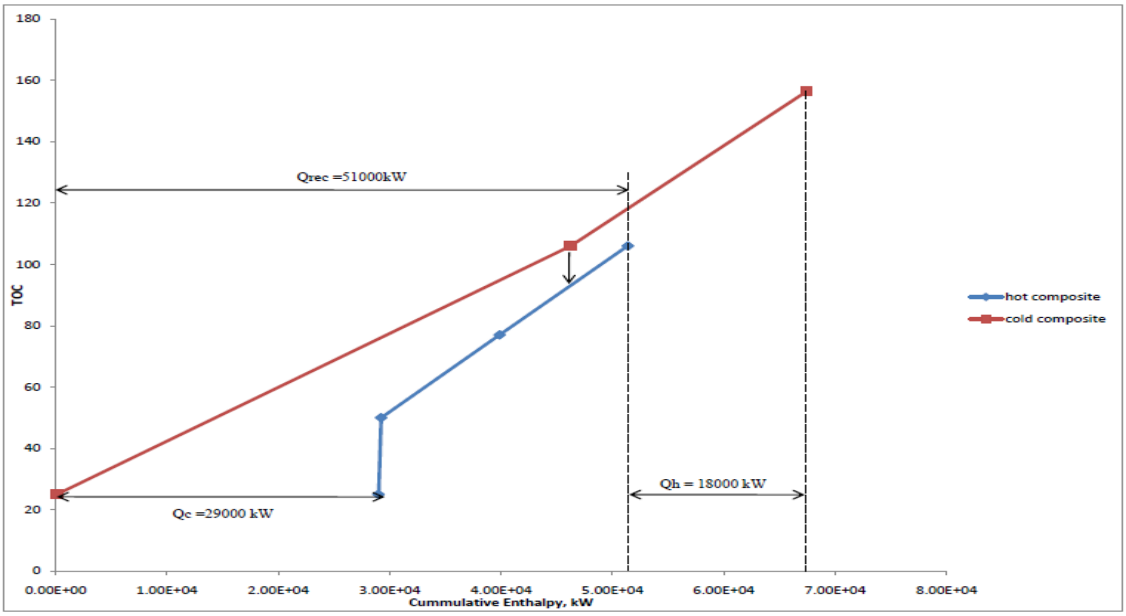

Figure 4.1 (b) : Composite curve with ΔT_{min} = 10^{o}C

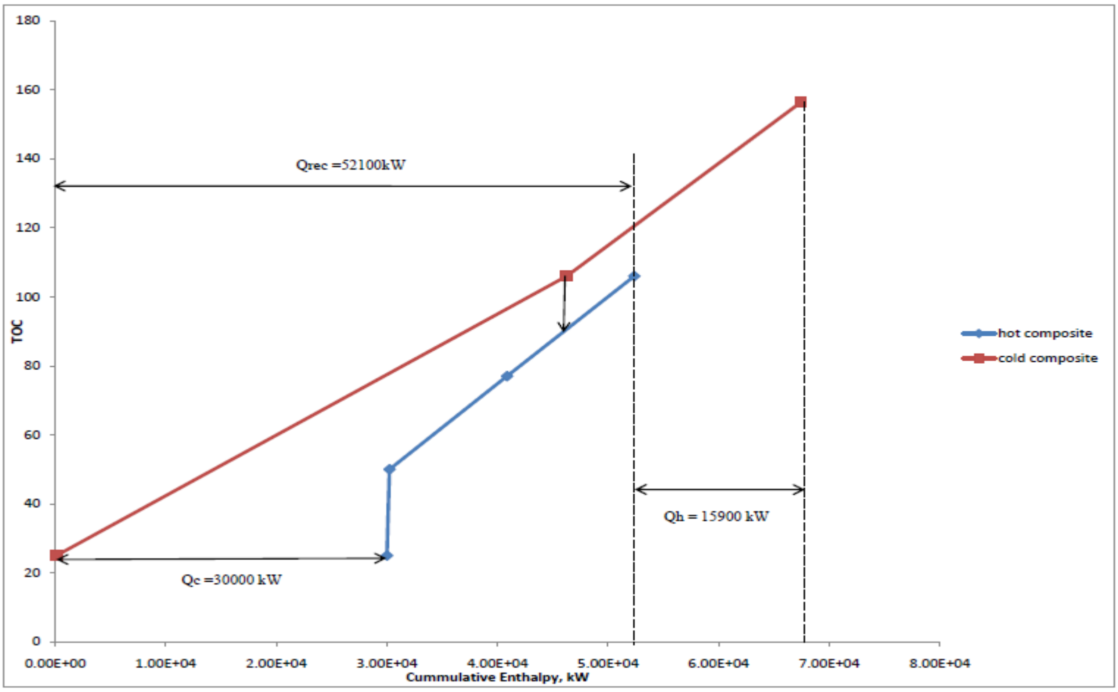

Figure 4.1 (c) : Composite curve with ΔT_{min} = 15^{o}C

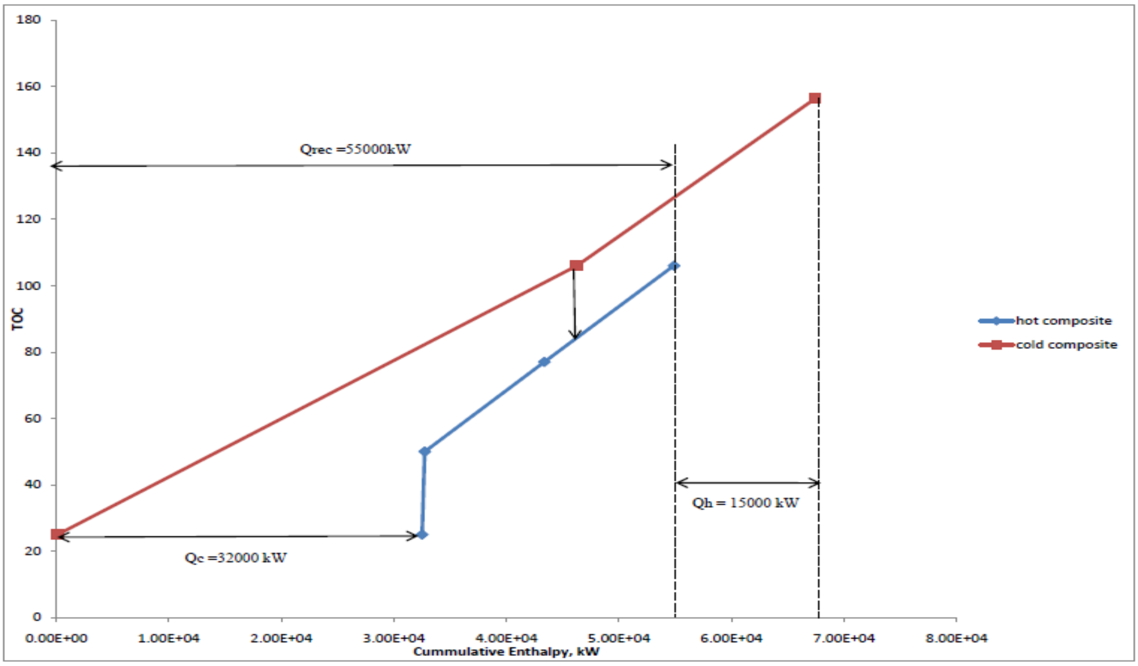

Figure 4.1 (d) : Composite curve with $\Delta T_{min} = 20^{o}C$

Table 4.1 : Summary minimum heat utility and cold utility target with various minimum temperature difference

Minimum temperature difference , ΔT_{min}	Heat utility target, kW	Cold utility target, kW	Heat recovery, kW
5	21000	26000	49000
10	18000	29000	51000
15	15900	31000	52100
20	15000	32000	55000

Table 4.1 showed the summary for the minimum heat utility target, cold utility target and heat recovery for every different minimum temperature difference. There is an imbalance, which must be supply by utilities (external heating and cooling). Above the pinch, cold utility target is larger than the value for hot utility target and the difference must be supplied by hot utility, whereas below the pinch hot utility is less than cold utility target and the excess heat is removed by cold utility.

4.1 Equipment cost

Application of Pinch analysis in isobutylene process yield overall heat exchanger network design as shown in figure 4.1.

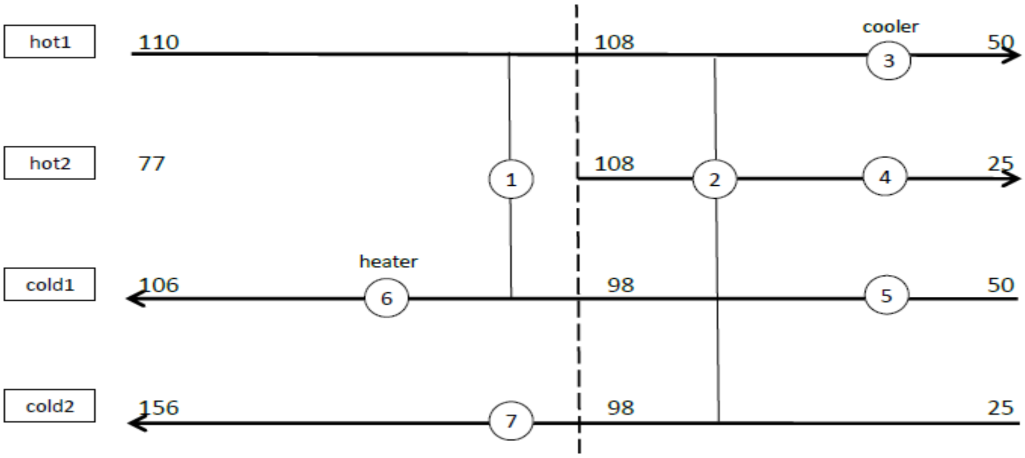

Figure 4.2 : Overall heat exchanger network for $\Delta T_{min} = 10^oC$

All the heat exchangers are removed from the original process, and replace with seven new heat exchangers added into the process based on the network design. Obeying the CP's rules, hot 1 matched against cold two in first heat exchanger. As we can see in the figure 4.1, energy from the stream hot 1 is used to supply energy for heating the substance in stream cold one. The residue energy at the stream hot one is reject by adding the cooling with duty Q 7166.9 units. It is about the same for another five heat exchangers. The cost for removing original heat exchanger or the possibilities for reusing them are not included. Table 4.1 showed the new heat exchanger area and the price after the network in Ringgit Malaysia.

Table 4.2 (a) : Summary of heat exchanger area before network

Heat exchanger	Area (m^3)	Equipment cost (RM)
1	162	578,451
2	38.9	308,507
3	251	709,069
4	74.8	410,513
	TOTAL	2,006,540

Table 4.2(b) : New heat exchanger area and price for ΔTmin = 10^{o}C

Heat exchanger	Area (m^3)	Equipment cost (RM)
1	110	807,053
2	197	532,656
3	314	355,104
4	24.6	5,004
5	118	161,411
6	63.2	80,705
7	81.6E	161,411
	TOTAL	2,103,344

Table 4.1 (a) and (b) show the different value of heat exchanger area and total cost equipment between before network and after network. The equipment cost is depending on how the area was calculated and types of the configuration HEN design are used.

4.2 Result of Manufacturing cost

4.2.1 Saving cost utilities

Due to the heat recovery, heaters and cooling water used can be reduced. Table 4.2 is a energy consumption for the HEN after doing a pinch analysis. The energy saving for total cooling is 65% and for total heating 38% which mean the good investment. Table 4.2 show the HEN is operated efficiently from cold stream since the energy consumption for cooling is slightly higher than heating process.

Table 4.3: Energy consumption of heat exchanger network

	QUANTITY				
Type	kJ/s	kJ/yr	GJ/yr	Cost ($/GJ)	Cost of utility
Heating	4451.8	1.3693E+14	136930.2	0.16	21908.83922
Cooling	7166.965	2.20444E+14	220444.4	3.66	806826.4171
TOTAL COST ($)					828735.2563
TOTAL COST (MYR)					2900573.397

4.2.2 Investment cost

The total investment cost for new process in isobutylene plant is RM 2482539.368 after taking account for the cost operating labor and price of water. Economic evaluation result of the Pinch analysis case exhibit in a table 4.2 and was interpret in graph as shown in figure 4.1.

Table 4.3: Economic data of heat exchanger network for isobutylene process

ΔT_{min}	Saving cost (RM)	Investment cost (RM)
5	473758.75	3164779.633
10	2900573.40	2482539.368
15	6724093.82	1466648.558
20	7971363.72	1474321.45
25	7931976.19	1273055.608

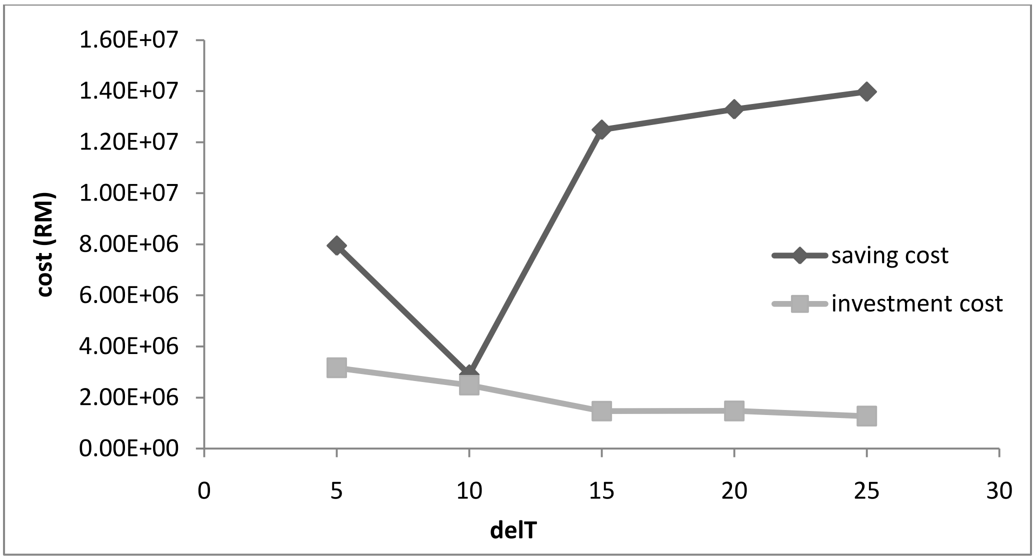

Figure 4.3: Graph saving cost and investment cost against ΔT_{min}

Figure 4.2 is a graph cost saving and investment against minimum temperature different. Based on the graph constructed, in order to generate the best minimum temperature difference, ΔT_{min} for this process need to be identified. ΔT_{min} value represents the bottleneck in the heat recovery. The graph showed, ΔT_{min} reflects the trade off between capital investments, which means, it will increased as the ΔT_{min} get decrease.

Based on the figure 4.2, the breakeven and sensitivity analysis is done to estimate the value of minimum temperature different. The breakeven point in this graph is 10^oC and we can say that, the best minimum temperature different for this process in $\Delta T_{min} = 10^oC$. This value enabled the realistic minimum temperature different for heat exchanger.

4.2.3 Payback period

Payback period is the last step for the economic evaluation in the heat recovery case. By knowing the pay back period we will able to decide either our project have a good investment or vice versa. In the energy recovery for isobutylene process, payback period was obtained with different minimum temperature different, ΔT_{min}. Figure 4.3 is the pay back period analysis with different ΔT_{min}.

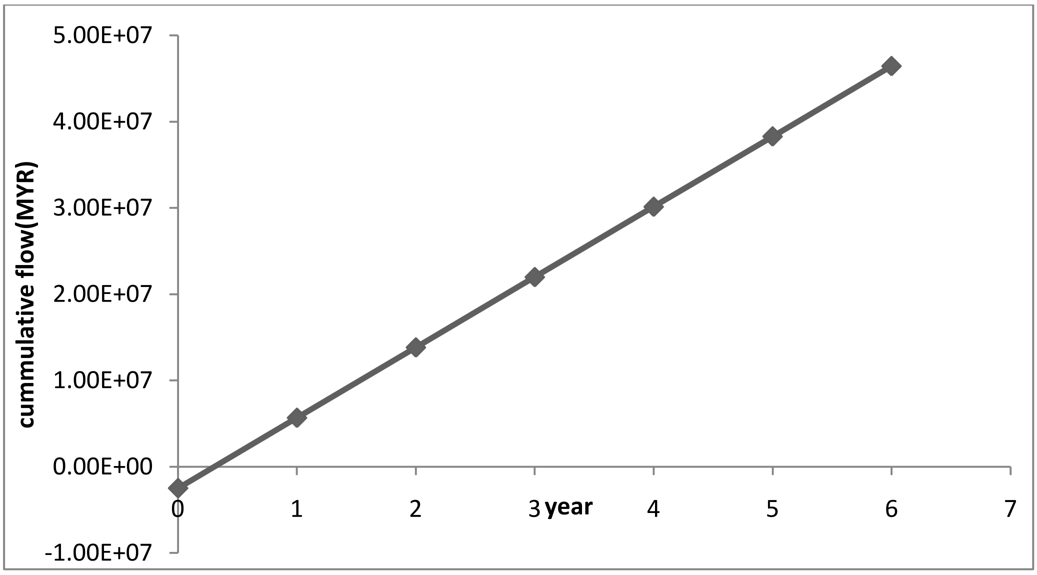

Figure 4.4 (a): Payback period with $\Delta T_{min} = 5^oC$

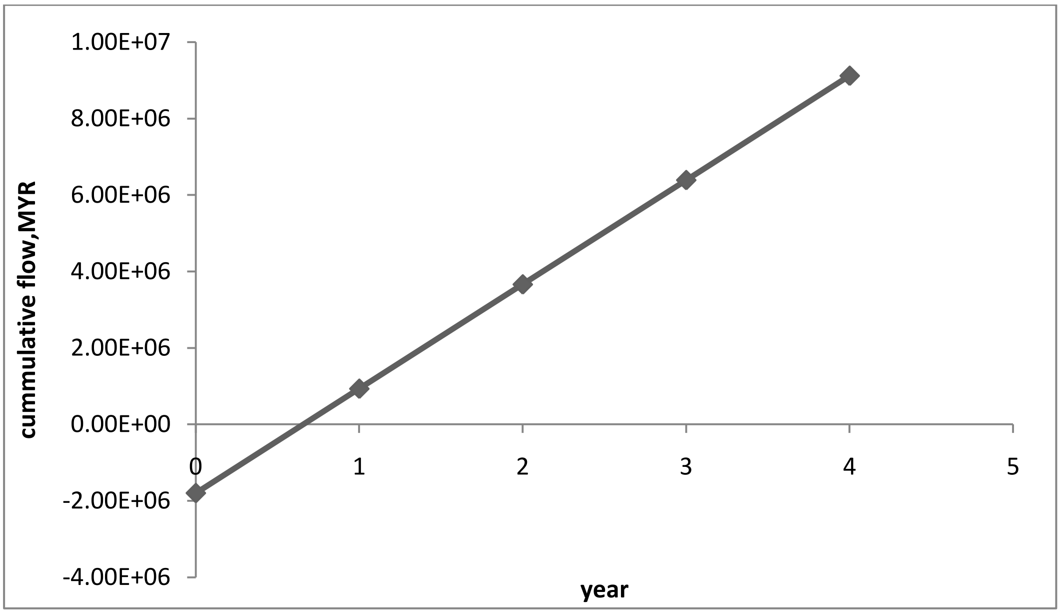

Figure 4.4(b): Payback period with $\Delta T_{min} = 10^oC$

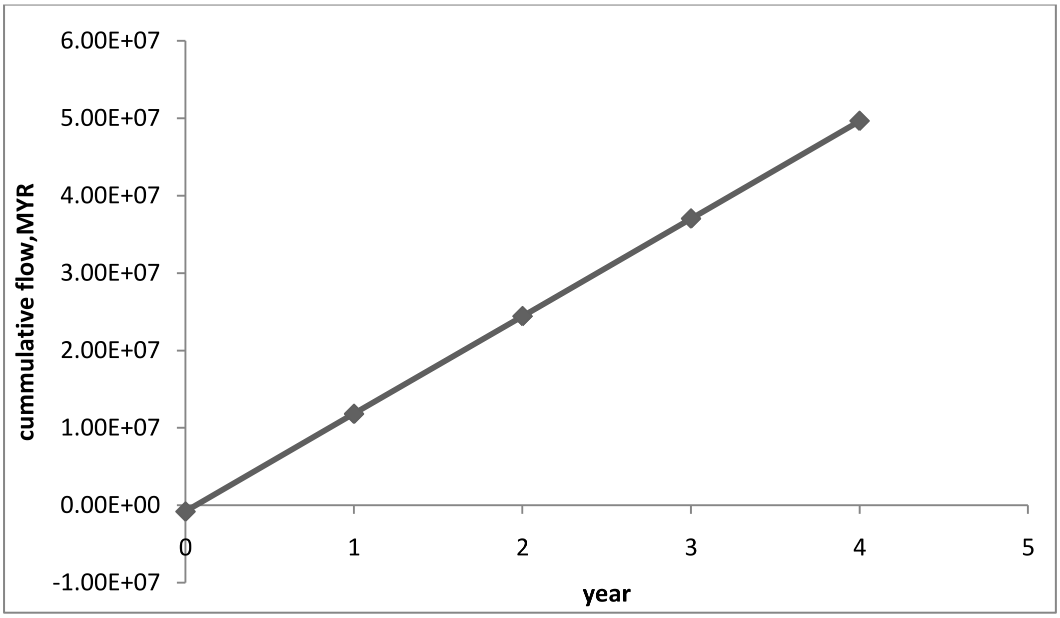

Figure 4.4 (c) : Payback period with ΔT_{min} = 15°C

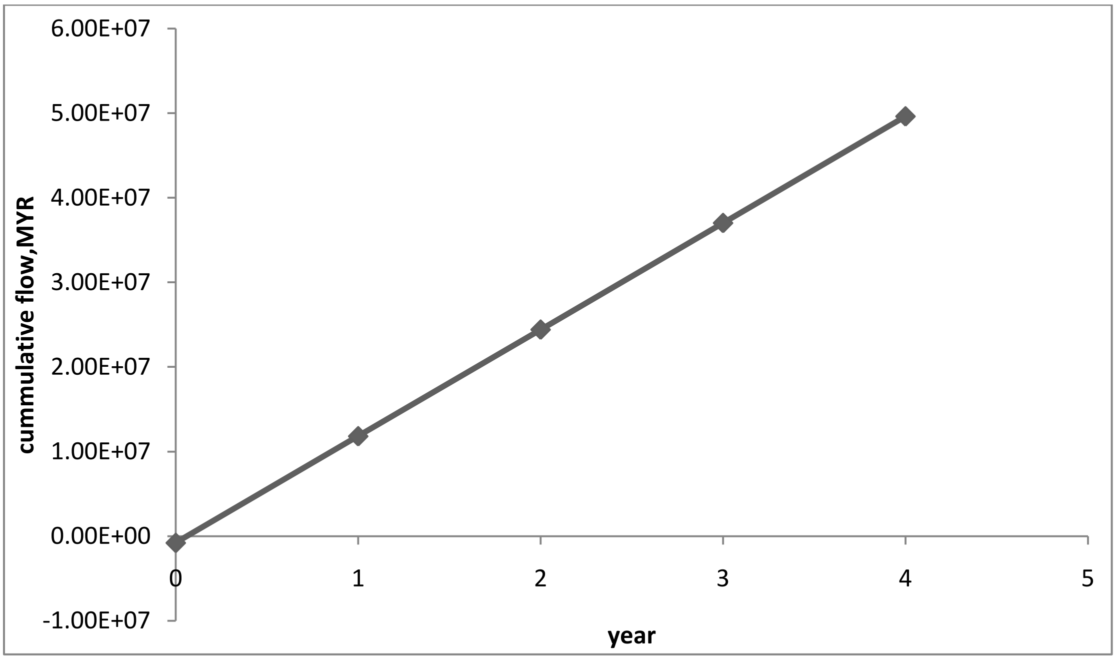

Figure 4.4 (d) : Payback period with ΔT_{min} = 20°C

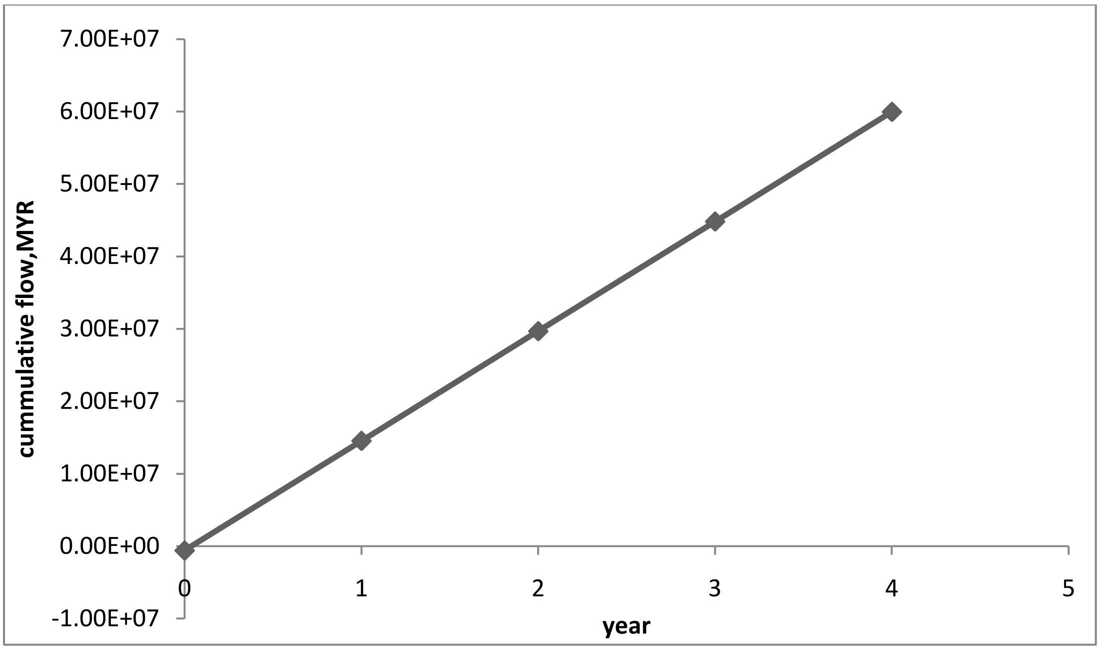

Figure 4.4(e) : Payback period with $\Delta T_{min} = 25^{o}C$

Based on the result, payback back period is constant after ΔT_{min} equal to $15^{o}C$. This is because the value of ΔT_{min} after $15^{o}C$ is not feasible for this process plant since temperature range for this plant is below $250^{o}C$ and the process has liquid phase phase reaction. From the economical point of view, the possible project for energy conservation of this process is quick – win project that saves up to 5% of energy with 1- year payback (Raskovic et al., 2009)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Pinch technology was clearly proud as the most practical method for applying process integration. The application of this technique enables process design engineers to gain fundamental insight into the thermal interactions between chemical processes and the utility systems that surround them. The use of Pinch technology is very often strongly limited by the existence of complex chemical process unit in the energy system of the plant.

This research shows how the application of pinch technology makes it possible to reduce the demand of hot and cold utility. After designing the heat exchanger network, the overall heat exchanger required in these process is seven heat exchanger and all of them need to be redesign. The energy saving for total cooling is 65% and for total heating 38% which means the good investment. The minimum temperature difference is obtained from the break-even sensitivity point which $\Delta T_{min} = 9^oC$ that is reliable for heat exchange and significant decrease of investment cost. Even though the value of capital investment is higher than original process, but by implementing pinch analysis in this plant, energy saving for utilities can recover the capital investment. Pay back period for the project is 0.8 year (9 month 3 days) that means, this project can be classify as quick win project. The result show significant improvement in energy utilization from the existing plant performance leading to increased plant efficiency.

5.2 Recommendation

From the result obtained, a Pinch analysis method is used a simple concept rather than complex mathematical method. However, there is much to improve for the future research trend. The following recommendation proposed to lead a better optimization:

a) Heat integration should be performing by using Aspen Plus software so that, the simulation result can be compared with manual calculation result.
b) Instead of applying this method to the design project, energy conservation can be applied for the real case situation. This is because, data from the real case are reliable if compared to design project.
c) More study on environment benefit for example on carbon dioxide release before and after the energy conservation.
d) More study on economic analysis, calculate the investment opportunity based on internal rate of return which will give better data for decision making.
e) Study should be performing on various case studies, so a comparison can be made between various case studies.

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