CRUDE PREHEAT IMPROVEMENT

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CHEMICAL ENGINEERING
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Crude Preheat Improvement

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Final Year Projects (FYP) is one of a compulsory requirement each of Universiti Teknologi PETRONAS (UTP) students need to fulfil. This course consist two credit hours. Final Year Project were separated in two stages, that is FYP I and FYP II. For my FYP, I have been given a title of Crude Preheat Improvement under supervision Dr. Suhaimi Mahadzir. This project is consumed to optimize energy recovery and cost effectiveness. Here the furnace duty is increasing as long as the usage of fuel gasses. This due to several causes such as the heat exchangers of the crude preheats is insufficiently to generate to the set point temperature before entering the furnace.

The problems that had been assumed are fouling, network arrangement and heat exchanger efficiency. The scope of this project is to gather all information for analyzing the current condition to find the root causes and develop options to solve the problems. The main step of this project is collaborating with engineers in the PETRONAS Penapisan Terengganu (PPTSB).

ACKNOWLEDGEMENT

Throughout the progress of my Final Year Project, I would like to acknowledge my family for always being there to provide moral support to me as well as to help me to obtain the data or information needed when there was a time constraint on me for being unavailable to return to my Internship host company to take the required data. My family also provided their knowledge on the respected field in order for me to input to the FYP as additional information.

The next acknowledgement would be tributed towards my Final Year Project supervisor which is Dr. Suhaimi Mahadzir. During the progress of the FYP, he provided lots of feedback that is related to the project as well as provided his valuable experience on the subject. He also introduced to me the aspects needed to do my FYP and the methods which are to be used to analyze the project so that the needed result can be obtained. Besides that, Dr. Suhaimi always encouraged us to do the best and that the project can be solved by multiple methods and that it is important that we do not stray from the main topic and that it is better to provide more alternatives for the project so that with more choices, chances that a better alternative can be found.

The next acknowledgement would be diverted to the various staff in my Internship host company which is PETRONAS Penapisan Terengganu (PPTSB). But most of the credit would be given to my supervisor during my internship at ESSO (M) BHD, Mr. Sabri Ahmad for assisting me during my visit to PPTSB and for the knowledge during internship also during at Terengganu.

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Chemical Engineering Programme
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BACHELOR OF ENGINEERING (Hons)
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Approved by,

(Dr. Suhaimi Madzir)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

HIZBULLAH BIN ZAZALI

CHAPTER 1
INTRODUCTION

1.1 Background

Crude blend stored in tanks will be pump to crude preheat exchangers. Crude preheats consist heat exchangers that exchange with cold and hot mediums usually the hot medium were from the hot rundown need to be cold or supplying some steam superheat. The crude will be heat up to a certain temperature or set temperature before entering desalters tower. A desalter is a process unit on an oil refinery that removes salt from the crude oil. The salt is dissolved in the water in the crude oil, not in the crude oil itself. The desalting is usually the first process in crude oil refining. After it entered the desalter tower, the crude then being preheated again by the crude preheats before entering the furnace. Here the crude is being heat up to a high temperature (set temperature). A high temperature of crude is feed to fractioning tower to crack it to different products. Crude oil is heated and recondensed in a fractioning tower with special trays at every 60cm all the way up the tower to facilitate the separation process. When oil is heated, oil vapours rise up the tower before they cool down at different levels, turning back into liquid. Any oil that has not vapourised will flow down the tower.

1.2 Problem Statement

Current crude preheat exchangers have a high pressure drop along the tube side that is the crude service. This can be influenced by the same result of high fouling occur inside the tube. Fouling can reduce the heat transfer coefficient and the heat duty of heat exchangers. The temperature of the crude preheat before entering the preflash tower is low than the required temperature. This will make the bottom of the preflash tower to get a low temperature. A low temperature crude entering crude heater (furnace) and causing heat duty of the furnace increase. Amount of fuel gasses used for heating up the crude will increase. This affect the cost of fuel gasses used per day. The project will focus on the squared area (See figure 1).

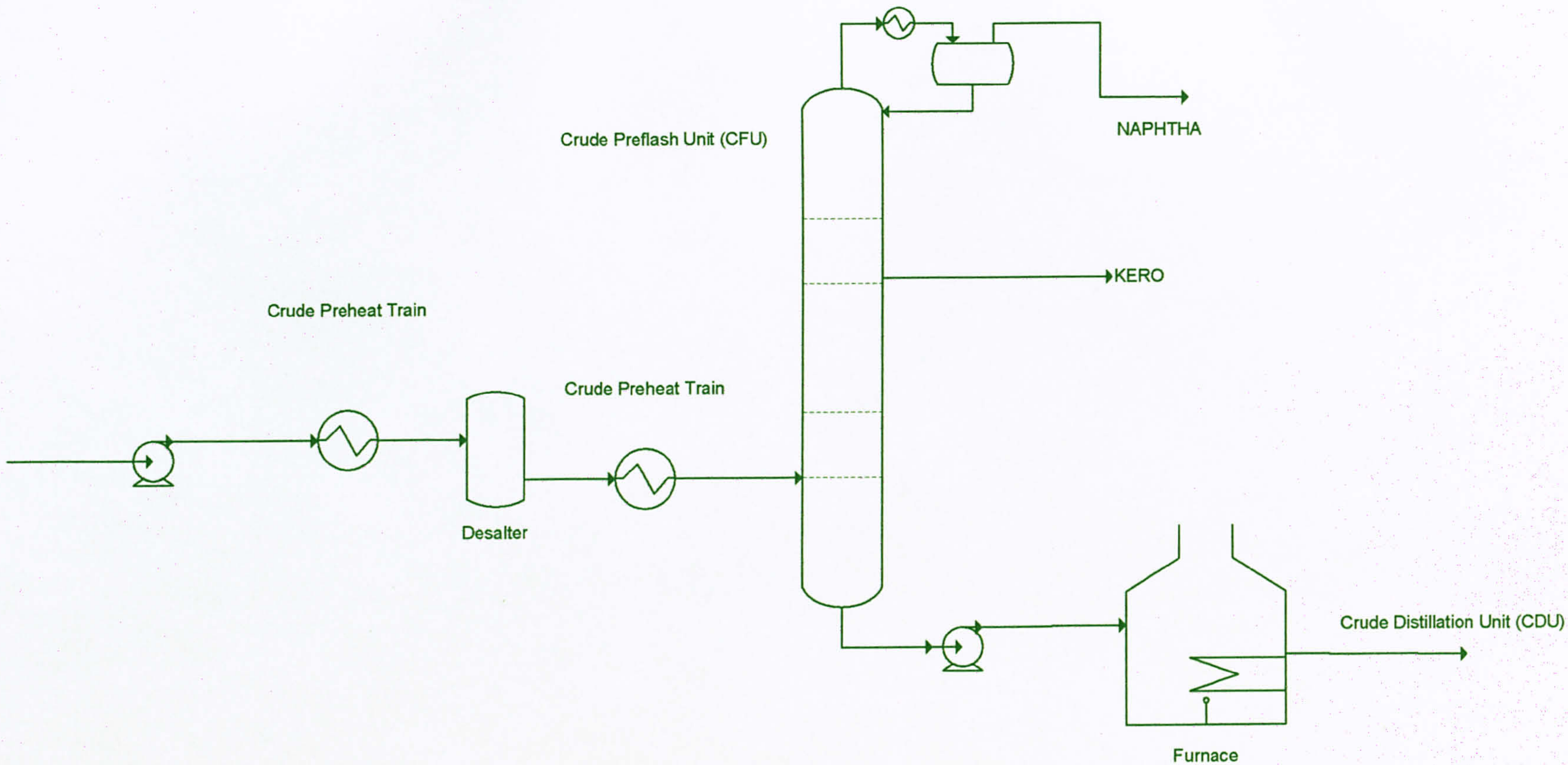

Figure 1.1: Process flow diagram

1.3 Objective and Scope

The objective is to reduce the usage of fuel gases used in furnace due to low temperature of the inlet. The scope is to improve the performance of the crude preheat heat exchangers by studying the problems and develop several options to counter the situation. The common problems occur in this situation are:

- Fouling on the heat exchanger
- Heat exchanger network less efficiency
- Arrangement of the heat exchangers network

The scope of study is to find the efficiency of the crude preheat networks throughout:

- Exergetic Analysis
- Pinch Technology Analysis

CHAPTER 2
LITERATURE REVIEW

2.1 Heat Exchanger Design

Assuming that shell and tube heat exchanger is the preferable heating equipment and the most common type of exchanger. It consists of a tube bundle enclosed in a cylindrical casing called a shell. Defines the nomenclature used for shell-and-tube exchangers, and a detailed discussion of this exchanger type. There are two basic types of shell-and-tube exchangers. The first is the fixed tube sheet unit, in which both tube sheets are fastened to the shell and the tube bundle is not removable. In this type of construction, differential expansion of the shell and tubes due to different operating and non-operating conditions may require the use of an expansion joint or a packed joint. The second type of shell-and-tube unit has one restrained tube sheet, called the stationary tube sheet, located at the channel end. Differential expansion problems are avoided by use of a freely riding floating tube sheet at the other end or the use of U-tubes. This is design may be used for single or multiple pass exchangers. The tube bundle is removable from the channel end, for maintenance and mechanical cleaning. Listing the above variations in shell-and-tube heat exchangers in order of increasing life-cycle cost for low to moderate pressure levels gives:

1 Fixed tube-sheet (single pass tube side).
2 U-tube.
3 Floating tube-sheet (called “floating head” unit).
4 Fixed tube-sheet with an expansion joint or a packed joint with a floating tube sheet. Shell-and-tube exchangers are designed and fabricated according to the standards of the Tubular Exchanger Manufacturers

The basic design equation for designing heat exchanger,

$$Q = U * A * F * LMTD$$

Where Q is total heat load to be transferred. U is the overall heat transfer coefficient. A is the area of heat transfer. F is the configuration correction factor of tube/shell passes. LMTD is the log mean temperature different apply for counter current flow configuration.

From the equation, we can estimate how much heat needed to be transferred also the area that needs to use all the heat wanted for the required temperature.

2.2 Log Mean Temperature Different (LMTD)

The log mean temperature difference (LMTD) is used to determine the temperature driving force for heat transfer in flow systems like heat exchangers. The LMTD is a logarithmic average of the temperature difference between the hot and cold streams at each end of the exchanger. The use of the LMTD arises straightforwardly from the analysis of a heat exchanger with constant flow rate and fluid thermal properties. Counter current flow, where the hot stream, fluid goes from say left to right, and the cold stream, again fluid goes from right to left. The LMTD is given by the following equation:

$$LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln \frac{(T_1 - t_2)}{(T_2 - t_1)}}$$

Where, T_1 = Hot Stream Inlet Temp. T_2 = Hot Stream Outlet Temp. t_1 = Cold Stream Inlet Temp. t_2 = Cold Stream Outlet Temp.

Less the LMTD, the more heat being recovers or transfers. This assumption cover overall the heat exchanger network.

2.3 Fouling

During the lifetime of a heat exchanger its performance will be influenced by what happens on the surface where the heat is exchanged. On the surface deposits of materials can accumulate that reduces the heat transfer and increase the pressure drop. This is referred to as fouling. Fouling can be caused by several mechanisms which in fact can happen at the same time (combined). The most important basic mechanisms are:

- Crystallization
- Decomposition of organic products resulting in tar or cokes
- Polymerization and or oxidation
- Settlement of sludge, rust or dust particles
- Biological deposits
- Corrosion

Fouling reduces the cross sectional area for heat to be transferred and causes an increase in the resistance to heat transfer across the heat exchanger. This is because the thermal conductivity of the fouling layer is low. This reduces the overall heat transfer coefficient and efficiency of the heat exchanger. This in turn, can lead to an increase in pumping and maintenance costs.

2.4 Exergetic Efficiency

To find out the efficiency of the heat transfer by the heat exchanger, the exergetic analysis method is used to determine the losses of heat when it exchange between two medium. Exergy of a system is the maximum work possible during a process that brings the system into equilibrium with a heat reservoir. When the surroundings are the reservoir, exergy is the potential of a system to cause a change as it achieves equilibrium with its environment. Exergy is then the energy that is available to be used. After the system and surroundings reach equilibrium, the exergy is zero. Determining exergy was also the first goal of thermodynamics.

For a given set of chemicals at given entropy and pressure, enthalpy H is used in the expression:

$$\text{Exergy} = \left(H_o - T_R.S_o\right) - \left(H_i - T_R.S_i\right)$$

Where, Hi and Ho is the enthalpy of the inlet and outlet stream. T_R is the temperature of surrounding. Si and So is the entropy of the inlet and outlet stream.

This method will be applied for every stream. The higher exergy value the more heat losses to surrounding and the less efficient of the heat transfer between heat exchanger.

2.5 Pinch Technology

Pinch analysis is a methodology for minimising energy consumption of chemical processes by calculating thermodynamically feasible energy targets (or minimum energy consumption) and achieving them by optimising heat recovery systems, energy supply methods and process operating conditions. It is also known as process integration, heat integration, energy integration or pinch technology.

2.5.1 The Pinch

The Pinch is a key concept in the analysis. This is the temperature region in a process where the hot and cold composites are closest together. It is therefore the region where heat recovery is most constrained and it is most important to ensure that heat transfer duties are correctly configured.

Cross pinch heat transfer

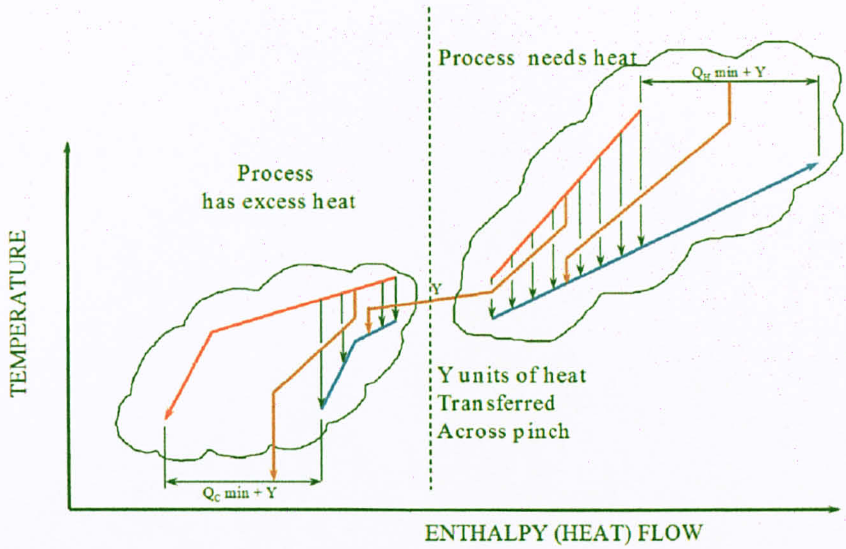

Figure 2.1: Pinch point

Above the pinch temperature there is a shortfall of heat and below it there is a surplus. The majority of processes exhibit a pinch at some intermediate temperature between that of the hottest and the coldest process stream. This is visible as the temperature at which the composite curves are closest together.

A minority of processes, known as threshold problems, do not exhibit a pinch. Threshold problems only need a single thermal utility (either hot or cold but not both). A feature of all conventionally pinched processes is that all process heating below the pinch and all process cooling above the pinch can be carried out by heat recovery.

In order to minimize thermal utility consumption it is therefore essential all heat available above the pinch must be used above the pinch and all process heating below the pinch must be carried out by heat recovery from below pinch hot streams. Likewise hot utilities should only be used above the pinch and cold utilities should only be used below the pinch.

2.5.2 Problem Table Algorithm

Some heat recovery is possible, but all of the heat cannot be recovered. The amount that can be recovered depends on the relative slopes of the two curves in the temperature interval. This problem can be overcome if, purely for the purposes of construction, the hot composite is shifted to be Tmin /2 colder than it is in practice and that the cold composite is shifted to be Tmin /2 hotter than it is in practice.

The shifted composite curves now touch at the pinch. Carrying out a heat balance between the shifted composite curves within a shifted temperature interval shows that heat transfer is feasible throughout each shifted temperature interval, since hot streams in practice are actually Tmin /2 hotter and cold streams Tmin /2 colder. Within each shifted interval, the hot streams are in reality hotter than the cold streams by Tmin .

2.5.3 Composite curves

Pinch analysis is a systematic examination of thermally intensive processes in which all heating and cooling duties (actual or potential) are extracted as temperature/energy flow (T/H) profiles and combined into composite curves for the whole process and/or site. The following diagrams illustrate the principle of composite curves and show how by combining the hot and cold composites the total potential for heat recovery on the plant can be quantified.

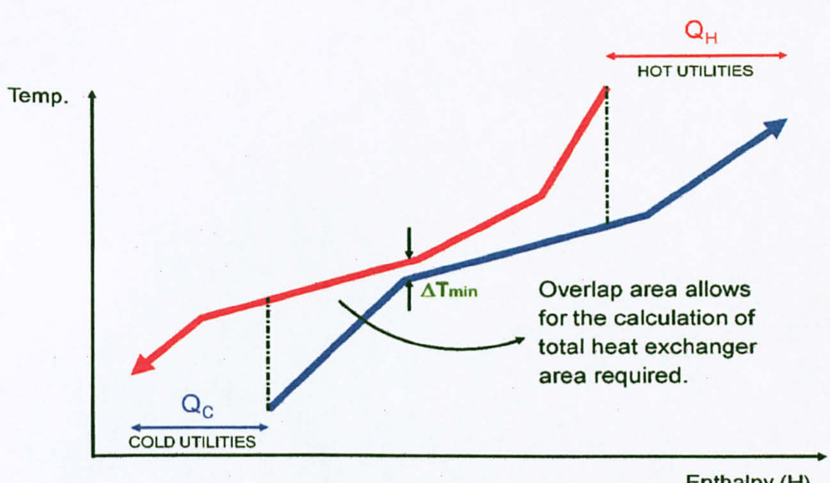

Figure 2.2: Composite Curve

2.5.4 The Grand Composite Curve

Pinch analysis is based on the significance of temperature in process thermal duties. Thermal utilities are increasingly expensive as their temperature is increasingly far away from ambient (both for heating and for cooling). The concept of utility pinches can be used to analyze which utilities should be applied to specific thermal duties. In order to minimize utility costs it is important that heat transfer does not cross either a process or a utility pinch.

The grand composite curve (GCC) is another important construction. This is effectively the net process heating or cooling requirement as a function of temperature based on the assumption that all feasible heat recovery will be implemented. Thus the GCC can be used to examine the most efficient thermal utility temperatures for a given process.

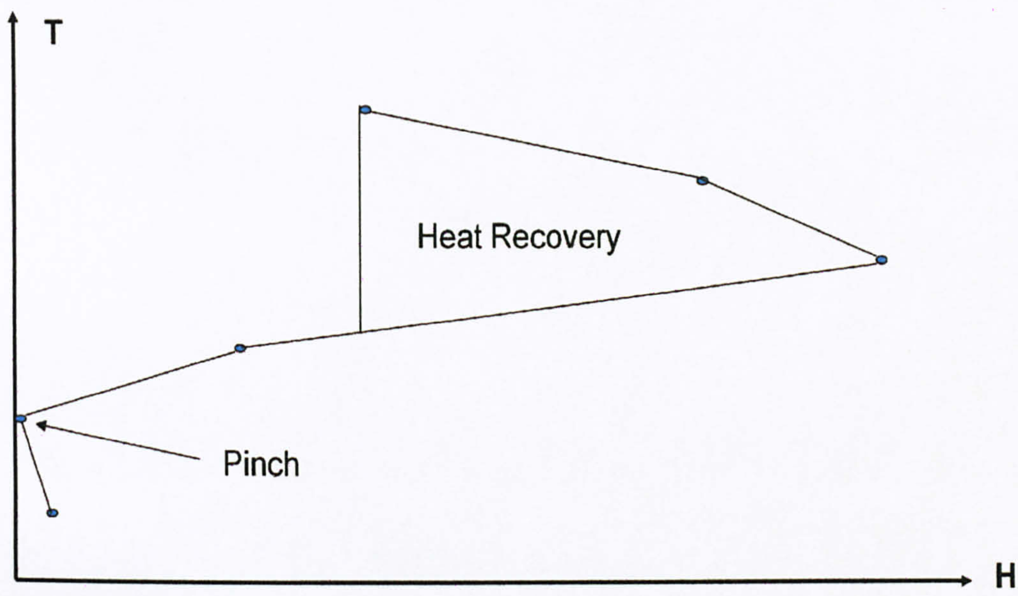

Figure 2.3: Grand Composite Curve

CHAPTER 3
METHODOLOGY

3.1 First Stage (Final Year Project I)

For the first stage is to find the possibilities root cause of the problem:

1. Understanding the plant design, operating and control. Collaboration with the engineers in PETRONAS Penapisan Terengganu Refinery (PPTSB) through communication and sharing information. The dealing takes maybe take a long time due to gain trust from the stuff.

2. Collecting plant operation condition data and equipment data involved especially on the heat exchanger design and the furnace design.

3. Analyze the exergetic or exergy of heat transfer between the services involved (cold stream and hot stream) and pinch analysis. The operation condition data will be analyzed through these methods. Both of this method will cover every each heat exchanger involved.

4. From here a list of root causes will be identified from the network.

3.2 Second Stage (Final Year Project II)

For the second stages is developing options to solve the problem identified:

1. Simulations with different cases base on actual plant data and condition (for equipment involved). The different case here means dependent on options available.

2. Using the Pinch Technology method to verify the whole focus area plant integration. By making the existing plant integration designs also the adjusted design. Create a new better or more efficient integration layout that has a maximum energy usage.

3. Discussing on the options produce with the operations and engineers. In this discussion, consideration and opinion from them is needed. Basically to produce a better option that has the most efficient and less costing for implementing.

CHAPTER 4
RERINERY UNDERSTANDING

4.1 Background

The common equipment that is available in each system and pump, flow controller, flow indicator, temperature controller, temperature indicator, pressure controller, pressure indicator, air fin cooler, heat exchanger, water cooler, column, vessel or drum. It is very important for the trainees to walk through the pipeline system of each unit, which indirectly he will know the location of the equipment and its function.

There are four main systems that cover the project scope that are Crude Preheat Train, Desalter, Preflash Tower (C-116) and Crude Heater (F-101). The flow diagram of the whole process involved is in Figure 2.

4.1.1 Crude Preheat Train

Crude Oil from Either D-901, D902 and D-903 (designed for Dulang Crude) is pumped by Crude Booster Pumps (G953 A/B for ex D901, D902 and G952 A/B for exD-903) via Crude Charge Pump (G-101A/B), all are located at off-site area (OMS area), to CDU. D-901, D902 and D-903 can be fed on 100% independently or on ratio mode by Adjusting/controlling Flow Ratio Control, Valve FIC-962, reset on FCV-960 and FCV-961 for D903 and D-901/902 feeding respectively. Crude Charge Pump pressure is regulated by Pressure Control valve (PCV-999) and the excess is returned to Slop Tank either D-901/902, normally the slop tank is the Feeding Tank. The Crude is preheated in the following heat exchangers and treated in the Desalter (C-115) before entering the Preflash Column (C-116) bottom on Flow Controller (FIC-101) reset by Preflash Tower (C-116) Bottom Level Controller (LIC-160), as a mixed vapor-liquid phase.

The crude preheats train heat exchangers:

- E-137 (Crude/Preflash Vapor Ex)
- E-105 B/A (Crude /Kerosene Ex)
- E-142 B/A Crude/Diesel Ex) then go through Desalter (C-115)
- E-108 B/A (Crude/LSWR Ex)
- E-139 (Crude/Kerosene P/A Ex)
- E-110 (Crude/LSWR Ex) then goes through Desalter (C-115) for Tapis Crude operation.
- E-115 (Crude/Diesel Ex)
- E-112 B/A (Crude/Diesel P/A Ex)
- E-128 (Crude/Kerosene Ex)
- E-113/114 (Crude/LSWR Trim Ex. and Crude/Diesel Ex.) in parallel
- E-136 (Crude/LSWR Ex)

4.1.2 Desalter (C-115)

The main function of the Desalter (C-115) is to remove salts, water and sediment present in the Crude Feed by electrostatic coalescence, whereby a high voltage of current with 415 volts and 11 ampere is passing through inside the desalter with layer of plate. The crude after going through Desalter is expected to minimize fouling in the Preheat train Exchangers and Crude Furnace. The water and sediment is discharged to the Oily Water Sewer.

Two take offs/returns are provided in the Preheat Train to/from the Desalter (C-115) in order to feed the Desalter at the required temperature of 130 – 145 deg C. For Dulang Crude operation the desalter is lined up after the Crude/Diesel Exchanger (E-142) and Tapis Crude after the Crude/LSWR Exchanger (E-110).

4.1.3 Preflash Tower (C-116)

The purpose of this Preflash Section is to remove light naphtha, mixed naphtha and light hydrocarbon gasses from crude oil. The balance of the heavier part of crude oil is then sent to Crude Column (C-101) for further fractionation.

The inlet crude feed is controlled and measured by Crude Feed Flowrate Control Valve (FIC-101) reset by Preflash Bottom Level Controller (LIC-160) and the inlet temperature by controlling (TIC-160) to a set point (which is normally set at 220 deg C) by allowing whether LSWR heat is exchanged with crude upstream (E-136) or downstream (E-140) of the Pre-flash Tower.

The Pre-flash Tower is equipped with 18 (Single Pass) fractionation trays located above the crude inlet. The crude inlet vapors from the Pre-flash Column Bottom Section rise up the tower where they are fractionated into Preflash side-draw, Preflash Overhead distillate and the liquid flows downward to the bottom.

4.1.3.1 Preflash Bottom

Preflash Tower Bottoms is pumped to Crude Heater (F-101) by Preflash Bottoms Pumps (G-120 A/B) to Preflash Bottoms/LSWR Exchanger (E-140), the flow rate is monitored by Pump Discharge Flow Indicator (FI-173) and controlled by all the Four Crude Heater Passes Inlet Control Valves (FIC-105,106, 107 & 108).

4.1.3.2 Preflash Flash Zone

Preflash sidedraw is taken as a total draw off from tray 7 and routed to Preflash Sidedraw Pump (G-121 A/B). From this pump, part of the sidedraw (3 % vol.of feed) is returned to tray 6 under Level Controller (LIC-161) to maintain sufficient liquid traffic in the Preflash Tower wash section to keep the trays loaded. The remainder of the Sidedraw is pumped under Flow Controller (FIC-164) to Crude Tower, at the Kerosene Pumparound Return for refractionation.

4.1.3.3 Preflash Overhead

Preflash Overhead Distillate, consisting of Preflash Overhead Liquid and Preflash Gas is routed to Gas Recovery Unit (GRU) via Preflash Overhead System. The Preflash Tower Overhead Product Vapor is cooled in the Preflash Overheads/ Crude Exchanger (E-137) and Preflash Overheads Condenser (E-138 A/B) from where it is routed to Preflash Reflux Drum (C-117) and separated into non-condensable vapor, liquid and water. Condensed water in the

Preflash Reflux Drum Boot, combined the discharge of Sour Water Pumps (G-109 A/B) is routed to the suction of Preflash Sourwater Pumps (G-123 A/B). Part of the Preflash Sour Water discharge pump(G-123 A/B) is injected back into the inlet of the Preflash Overheads//Crude Exchanger (E-137) and the individual air fin bundles of the Preflash Overhead Condenser (E-138) for washing out water soluble salts from the tubes. The remaining Sour Water is routed under Preflash Reflux Drum (C-117).

4.1.4 Crude Heater (F-101)

The Preflash Tower crude enters the Crude heater (F-101) in four parallel streams by flow controllers FIC-105, FIC-106, FIC-107 and FIC-108. In this heater, the heat required to obtain sufficient vaporization of the crude in the Flash Zone of Crude Tower is added. The crude, now at a temperature of approximately 220 deg C enters the four passes of Crude Heater (F-101) where it is further heated by gas and / or oil burners, before leaving the Crude Heater at approximately 360 deg C to enter the Crude Tower Flash Zone and is controlled by TIC-104 to set the Fuel Pressure Controllers, (PIC-102 for Fuel Gas and PIC-103 for Fuel Oil). To Generate Stripping and Atomizing Steam, steam superheating coils are provided in the Convection Section of the heater.

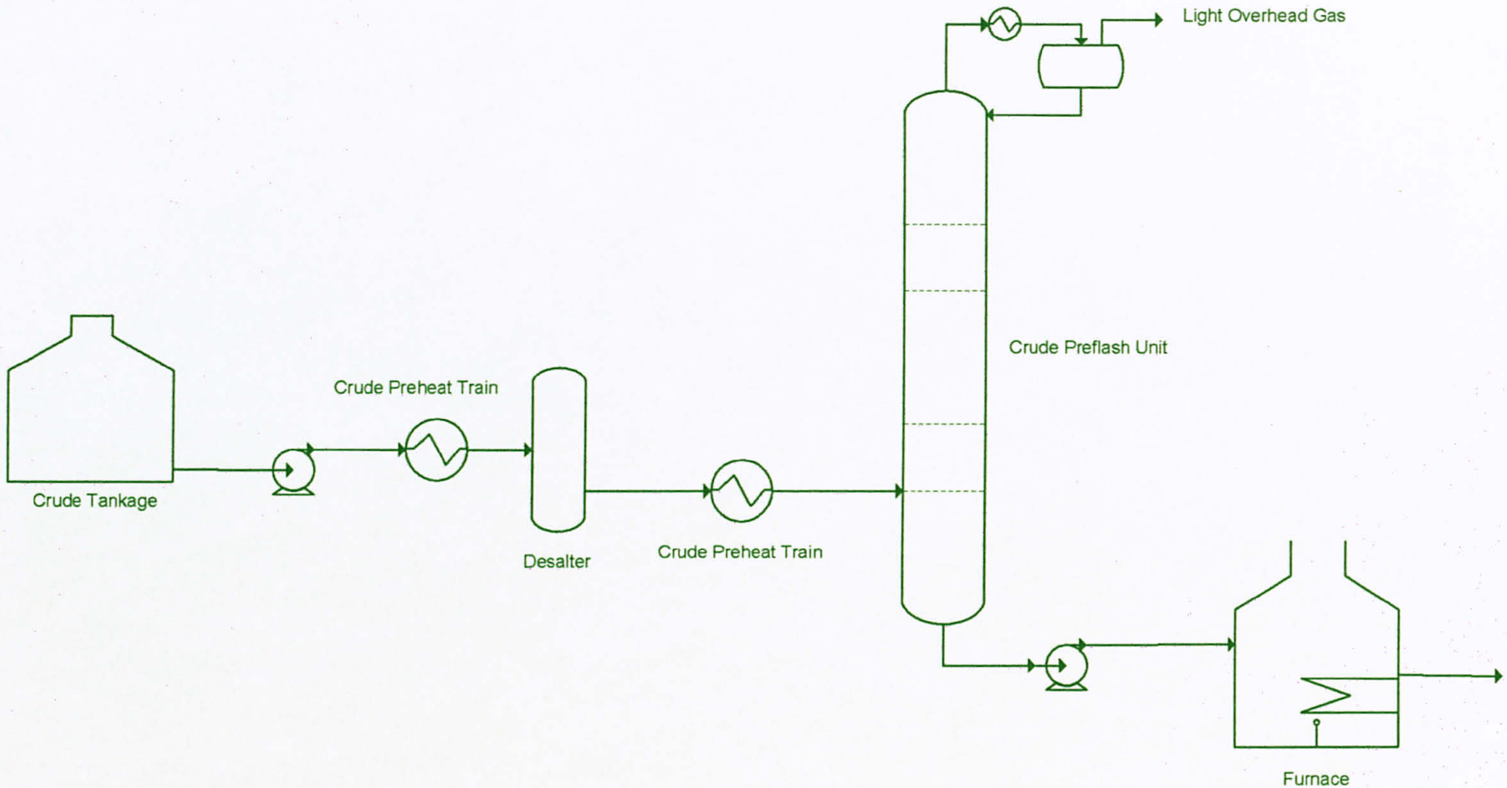

Figure 4.1: Flow Diagram

4.2 Heat Exchangers Arrangement

The crude preheats heat exchanger is recovered from Overhead Crude Preflash, Kerosene, Diesel and Low residue Waxy Sulphur (LSWR). Mostly the crude itself is connected to the tube side of the heat exchanger inside crude preheats. This due to the crude has been pump to a high pressure. Heat exchanger E-137 is an exchange between the crude and Overhead Crude Preflash. The Kerosene (KERO) from Crude Tower (C-101) is pumped to E-110 and E-189 before returning back to the tower. The stripped kerosene rundown then entered E-128 and E-105 B/A before being cooled by a finfan (E-109 A/B).

For Diesel Oil, Diesel Pumparound using Diesel Pumparound pumps (G-104 A/B). The stream is discharged to the tube side of the Kerosene Reboiler and to E-114 and E-112 A/B before returning back to crude tower. The other diesel draws flow is stripped from Diesel Stripper Column (C-119). The hot stripped Diesel from bottom of C-119 is pumped by the Diesel Rundown Pumps (G-103 A/B) to the Crude Diesel Exchangers E-142 A/B and E-115 before being further cooled by Diesel Rundown Finfan. LSWR from bottom of crude tower is pump to E-140 (crude preflash tower reboiler) than exchange with E-136 and E-113 also E-108 B/A before goes to tempered water cooling system.

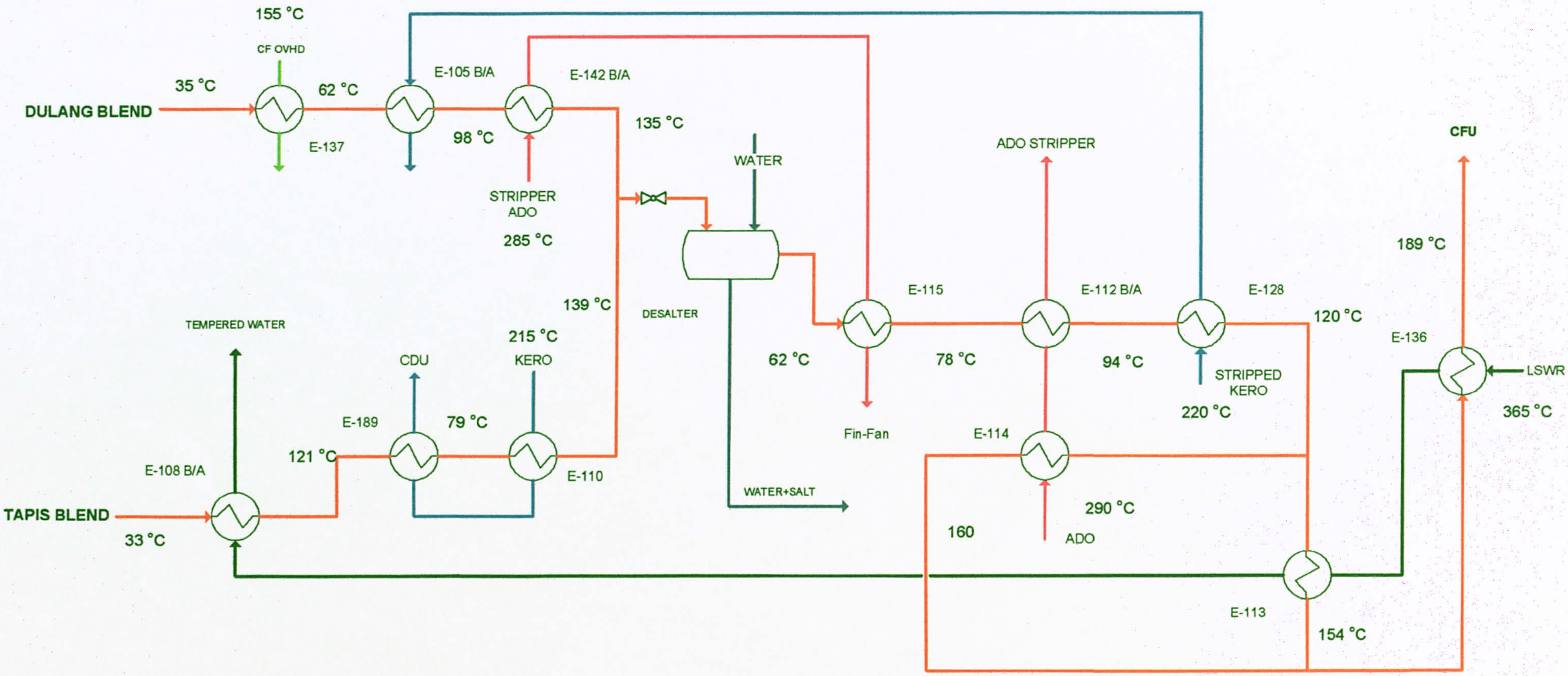

Figure 4.2: Diagram for the crude preheat

CHAPTER 5
EXERGETIC ANALYSIS

5.1 Background and Objective

Exergy analysis is a powerful thermodynamic technique for assessing and improving the efficiency of processes. In this analysis for PETORNAS Penapisan Terengganu (PPTSB) is to asses each of the heat exchanger efficiency. The efficiency involved on the heat transfer between stream in the heat exchanger and the heat loss to surrounding. An un-sufficient exergy usually had an anonymous heat loss due to the insufficient stream exchange.

The objective is to find the efficiency of the heat transferred between the crude stream and others stream. Assumption made is the higher of exergetic value means the heat loss is high, thus the heat exchange between two streams is inefficient.

5.2 Basis of Analysis

The basis is used to estimate to find the entropy and the enthalpy. Icon simulation was been used to find the above matter.

Crude Blend: Tapis and Dulang
Crude Rate: 40 KBD (20 KBD Tapis and 20 KBD Dulang)
Crude pressure: 1000 kPa-g
Heat Exchanger Tube delta P: 68 kPa

5.3 Method of Calculation

Given the exergy or exergetic formula:

$$\text{Exergy} = \left(H_o - T_R.S_o\right) - \left(H_i - T_R.S_i\right)$$

Where,

Hi and Ho	:	The enthalpy of the inlet and outlet stream.
TR	:	Temperature of surrounding.
Si and So	:	The entropy of the inlet and outlet stream.

Assumption: For this situation, assuming that the temperature surrounding at the refinery is 32 deg C.

Given that the temperature for crude type Dulang Blend is 35 deg C with entropy of 6.337 kJ/kg-C and enthalpy 44.19 kJ/kg. The outlet temperature is 62 deg C. The outlet entropy is 6.513 kJ/kg-C and 100.376 kJ/kg enthalpy. See figure 5.2.

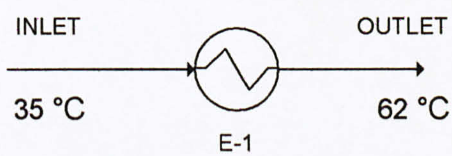

Figure 5.2: Example Diagram

Exergy = [100.376 kJ/kg - 6.513 kg/kJ-C (32 C)] - [44.190 kJ/kg - 6.337 kg/kJ-C (32 C)]

= -108.040 kJ/kg + 158.594 kJ/kg

= 50.554 kJ/kg

The calculation proceed by using excel spreadsheet for the other Heat Exchangers and streams.

Heat Exchanger	Tube Temp. (deg C)		Entropy (kJ/kg-C)		Enthalpy (kJ/kg)		Exergy kJ/kg
	Inlet	Outlet	in	Out	in	out	
E-137	35	62	6.337	6.513	44.190	100.376	50.554
E-105 B/A	62	86	6.513	6.664	100.376	152.879	47.671
E-142 B/A	86	140	6.664	6.993	152.879	279.581	116.174
E-108 B/A	34	121	5.767	6.303	53.064	241.012	170.796
E-189	121	125	6.303	6.327	241.012	250.490	8.710
E-110	125	135	6.327	6.387	250.490	274.304	21.894
E-115	141	158	6.695	6.815	276.973	327.579	46.766
E-112 B/A	158	170	6.815	6.885	327.579	357.976	28.157
E-128	170	175	6.885	6.914	357.976	370.761	11.857
E-113	175	185	6.914	6.972	370.761	396.702	24.085
E-114	175	188	6.989	6.914	404.583	370.761	-31.422
E-136	188	195	6.980	7.029	400.657	422.940	20.715

Table 5.2: Exergy Analysis

5.4 Conclusion

From the exergy analysis, the most heat loss to surrounding is 170.796 kJ/kg. E-108 B/A has the possibilities to be the less efficiency heat exchanger. E-142 B/A also has a high exergy value. This due to heat that transferred was high, regarding to the delta T different. But this method is part of the analysis that we could not jump to the conclusion.

CHAPTER 6
PINCH TECHNOLOGY

6.1 Pinch Design Analysis

Any theory, however ingenious and rigorous, is of little use unless it can be effectively applied on practice on real industrial equipment. Throughout the development of pinch analysis, research and application have gone hand-in-hand and this has ensured that the techniques are practical and usable.

6.1.1 Crude Preheat Train

The fractionators of crude oil into its major components such as naphtha, gasoline, kerosene and fuel oil are a common process, being a major step in oil refining. In the fractionation process to be described here, a facility needed updating by 25% to handle increased demand. Design studies carried out an actual plant design that is PETRONAS Penapisan Terengganu (PPTSB). It possible to increase the temperature but the cost to operate is not what in mind also the space inside the plant is restricted to install a new heat exchanger or heater. Safety issues of the operation can make the instalment quite a difficult mission to handle regarding on plant shutdown or etc. Thus the conventional way is to use pinch technology method. The reason using this method is, we tried to find the best heat exchanger network layout for a better crude preheating or better energy exchanger rather than loss or waste.

6.1.2 Process Description

There are fourteen heat exchangers involved in this heating situation. That means 28 streams being exchange for those heat exchangers. Figure 6.1 showing the flow diagram and the heat exchanger arrangement. Furthermore, Tapis blend and Dulang blend were used as the crude for the refinery. From 30 deg C crude temperature, it will be heated to 140 deg C to satisfy the desalter operationable condition. Further heating of the crude will take about six heat exchangers that the ends temperature is 210 deg C. The ΔTmin used in this study is 10 deg C where the minimum temperature that each stream will exchanges. This project can reduce the power usage of electrical power for product rundown cooling fan.

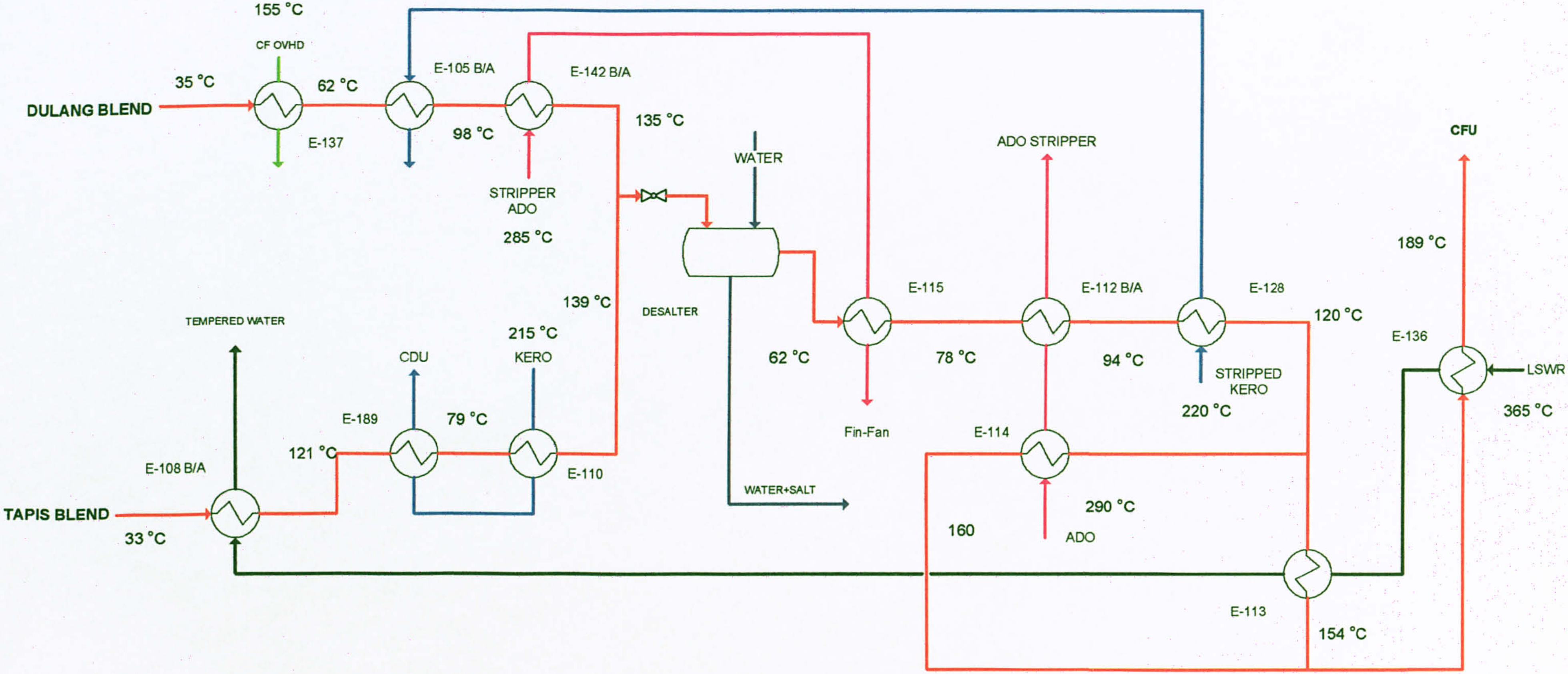

Figure 6.1: Diagram for the crude preheat

6.1.3 Data Extraction and Energy Targeting

The data was taken from the actual plant data. The streams involved are Tapis blend crude, Dulang blend crude, Mixed Tapis and Dulang crude (TD), Naphtha, Kerosene (KERO), Kerosene Pumparound (KPA), Diesel Oil (DO), Diesel Pumparound (DPA) and Low Sulphur Waxy Residual (LSWR). All the data were illustrated using network grid.

Stream	Type	Tin	Tout
TAPIS	C	32	108
DULANG	C	33	142
TD	C	127	186
NAPHTHA	H	155	149
KERO	H	220	80
KPA	H	220	210
DO	H	260	158
DPA	H	260	210
LSWR	H	300	136

Table 6.1: Temperature data of the streams involved

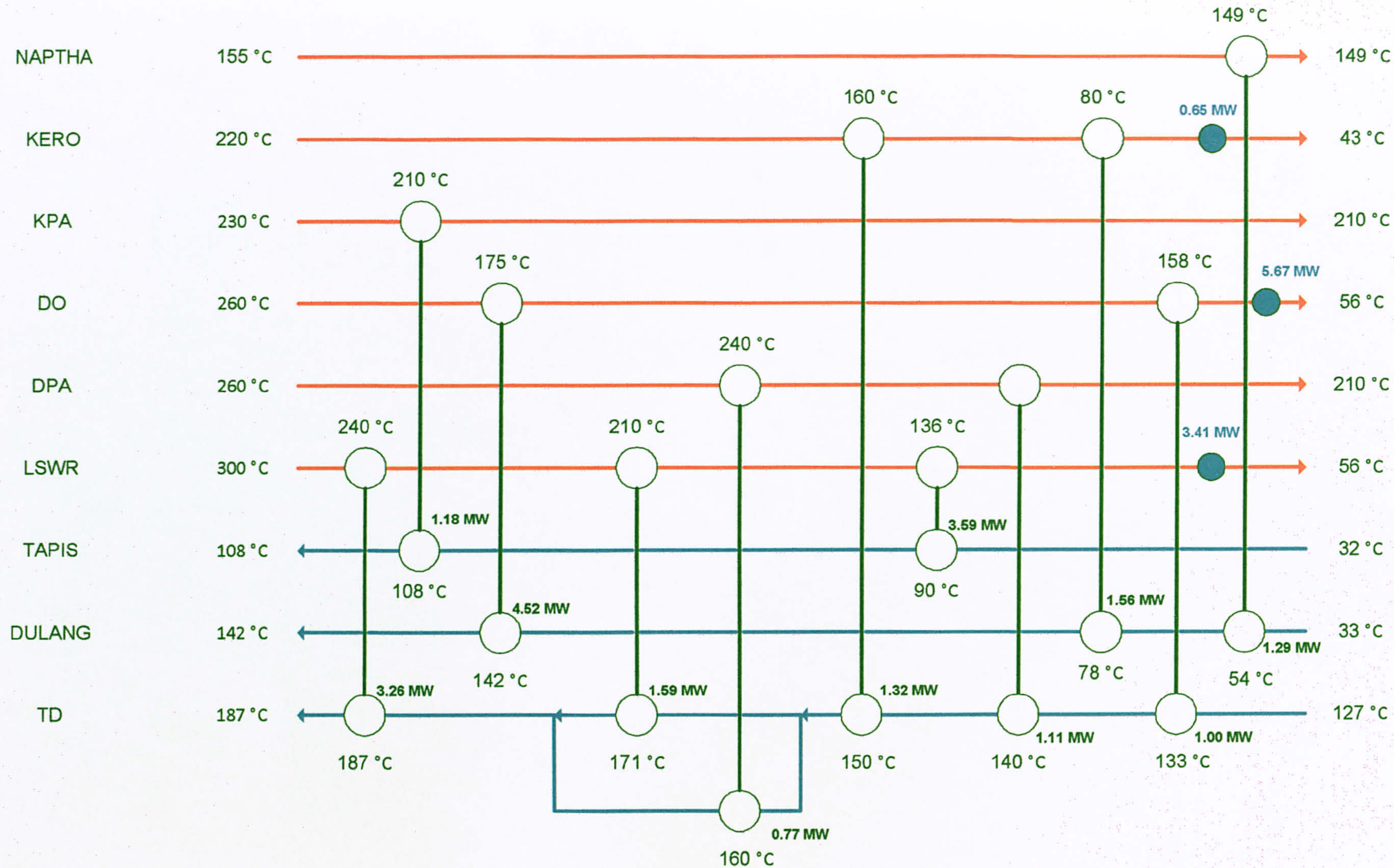

Figure 6.2: Network grid diagram actual plant design

6.1.4 Exploring the Data

From the network grid design figure 6.2, the total cold utility needed is 10.01 MW. This is base on the actual design also actual plant data. The concern here is the energy recover from the all the stream are not fully recovered. Example for diesel oil (DO) stream, the rundown temperature is about 158 deg C. This will make the cooler fan do more work to get the desired temperature to tank.

Another consideration that should be aware is the temperature to the desalter unit. The required temperature is between 135 deg C to 140 deg C. By following the data above, the crude temperature goes to the desalter unit is about 127 deg C. This will affect the operation of desalter to remove salt in crude. In a matter of concern, the salt will occasionally increase the fouling inside the tube side of the heat exchangers. Furthermore, fouling reduce the heat transfer rate thus less heat duty will be recovered.

The temperature before entering fractionators should be controlled to 195 – 210 deg C. This to ensure that the crude have a two phases flow. The two phases flow will make the separation process more efficient. Rather to use more energy on the reboiler to heat up the crude if the is low temperature crude excess from the feed. From the given data in table 2.1, the crude temperature before entering the fractionators unit is lower than range – 187 deg C. This may due to fouling on the heat exchanger especially on the tubes side also the arrangement of the heat exchanger network.

6.1.5 Result and Discussion

To cater the problem a simulation is made from crude preheat network design base on actual plant design. Basically this method is only to find the possible solution to identify or to justify the actual situation. The data given on table 6.1 was used in the simulation. From the problem above I have stated that the high diesel rundown temperature and the low temperature of Tapis blend crude entering desalter, this stream is preferred and monitor using the simulation. The streams maybe a possible solution to add another heat exchanger to solve both issues.

The output/result data of the simulation is listed in the table below:

Stream	Type	Tin (°C)	Tout (°C)	m.Cp
Tapis	C	32	108	33.6
Dulang	C	33	142	19.9
TD	C	127	186	55.6
Naptha	H	155	149	50
Kero	H	220	80	43.8
Kpa	H	220	210	118.5
Diesel	H	260	158	64.5
Dpa	H	260	210	66.9
Lswr	H	300	136	153.8

Table 6.2: Specific heat of the streams

The output of the simulation showed the specific heat of both stream can be match. Assume that the both of the streams are above pinch. Thus, the stream can be matched to exchange one and other. The rule of above pinch is Cp cold must be greater or equal to Cp hot. The Cp hot stream is the diesel oil (DO) stream and the Cp cold stream is Tapis blend crude. Now reached to the main event where instalment of a new heat exchanger. The tube temperature outlet is set 140 deg C (to satisfy the operation condition of desalter unit). The whole new diagram is illustrated to a grid network diagram (figure 6.3).

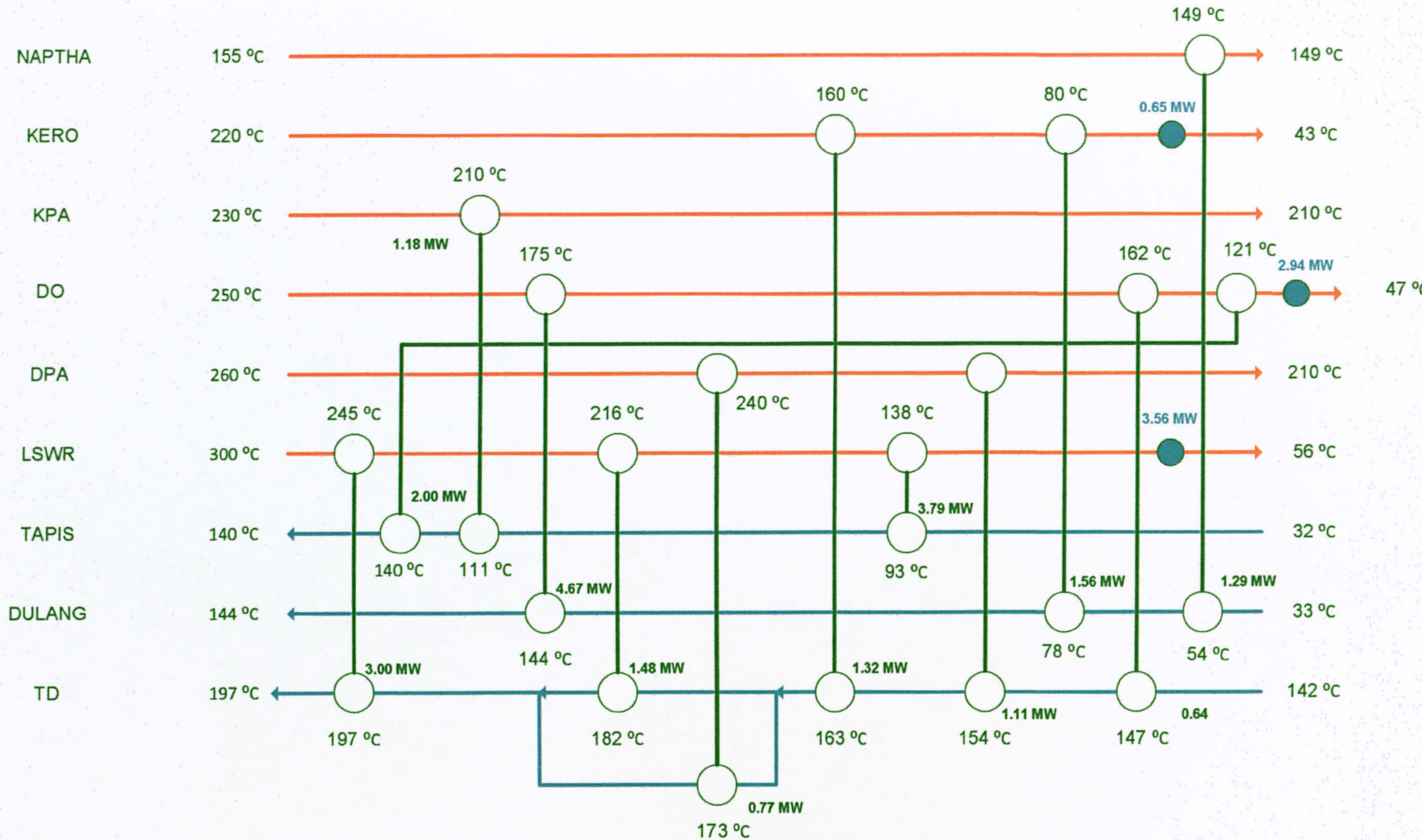

Figure 6.3: Grid diagram after pinch technology applied

As the diagram on figure 6.3 showed a whole new design layout, the thing that needs to be focused is the outcome. We can that the temperature before entering the Crude Fractionators Unit (CFU) is about 197 deg C. Compared to before is 187 deg C that means increment of 10 deg C. This is a good thing for a simple try and error solution because there is a recovery happened after the instalment of new heat exchanger.

The other stream that we concern before is the diesel oil rundown. Before this the rundown temperature is about 158 deg C, but after being exchange with the Tapis blend crude the result is 121 deg C the new rundown temperature. The energy that conserved is about 2.73 MW. This will reduce the electricity energy usage of cooling fan for cooling the rundown of diesel. In addition, the Tapis blend crude can reach it desired temperature that 140 deg C before mixing with the Dulang blend crude and entered the desalter later on.

<u>The percentage of energy recovered:</u>

Before instalment:

$$= \frac{Total\ Energy\ recovered}{Total\ Energy} \times 100\%$$

$$= \frac{21.19\ MW}{30.92\ MW} \times 100\%$$

$$= \mathbf{68.5}\ \% \sim \mathbf{69}\ \%$$

After Instalment:

$$= \frac{Total\ Energy\ unrecovered}{Total\ Energy} \times 100\ \%$$

$$= \frac{20.18\ MW}{27.96\ MW} \times 100\%$$

$$= \mathbf{72}\ \%$$

Percentage of utility energy reduce before and after instalment:

$$= \frac{Total\ Utility\ Energy\ Before - Total\ Utility\ Energy\ After}{Total\ Utility\ Energy\ Before} \times 100\%$$

$$= \frac{9.73\ MW - 7.15\ MW}{9.73\ MW} \times 100\%$$

$$= \mathbf{25.6}\ \% \sim \mathbf{26}\ \%$$

6.2 Pinch Technology Details Analysis

6.2.1 Basic Concept

Pinch technology presents a simple methodology for systematically analyzing chemical processes and the surrounding utility systems. First and Second Law's of Thermodynamics. The First Law of Thermodynamics provides the energy equation for calculating the enthalpy changes (ΔH) in the streams passing through a heat exchanger. The Second Law determines the direction of heat flow. The heat energy may only flow in the direction of hot to cold. This situation prohibits temperature crossovers of the hot and cold stream profiles through the exchanger unit.

In a heat exchanger unit neither a hot stream can be cooled below cold stream supply temperature nor can a cold stream be heated to a temperature more than the supply temperature of hot stream. In practice the hot stream can only be cooled to a temperature defined by the 'temperature approach' of the heat exchanger. The temperature approach is the minimum allowable temperature difference (ΔTmin) in the stream temperature profiles, for the heat exchanger unit. The temperature level at which ΔTmin is observed in the process is referred to as pinch point. The pinch defines the minimum driving force allowed in the exchanger unit.

6.2.2 Objective of Pinch Analysis

Pinch Analysis is used to identify energy cost and heat exchanger network capital cost targets for a process and recognizing the pinch point. The procedure first predicts, ahead of design, the minimum requirements of external energy, network area, and the number of units for a given process at the pinch point. Next a heat exchanger network design that satisfies these targets is synthesized. Finally the network is optimized by comparing energy cost and the capital cost of the network so that the total annual cost is minimized.

6.2.3 Data Extraction

The data was taken from the actual plant data. The streams involved are Tapis blend crude, Dulang blend crude, Mixed Tapis and Dulang crude (TD), Naphtha, Kerosene (KERO), Kerosene Pumparound (KPA), Diesel Oil (DO), Diesel Pumparound (DPA) and Low Sulphur Waxy Residual (LSWR). All the data were illustrated using network grid. Only this time, we are using straight forward set point of temperature or the end temperature by following the original plant design that is included with the rundown temperature. The data were manipulate using simulation software to get the energy or duty of every each streams.

Stream	Ti (°C)	To (°C)	H (MW)	m.Cp (kW/°C)
Tapis	32	135	6.6405	64.5
Dulang	33	135	6.8225	66.9
TD	140	210	10.7644	153.8
NAPTHA	155	150	0.1680	33.6
KERO	220	40	3.5751	19.9
ADO	260	50	11.6807	55.6
LSWR	310	40	13.0387	50
DPA	260	210	2.1917	43.8
KPA	220	210	1.1854	118.5

Table 6.3: Data from PPTSB

6.2.4 Problem Table Algorithm

Problem Table Algorithm (PTA) is a way to find pinch point temperature also to indicate how much cold and hot utility requirement to complete the energy recovery. The ΔTmin for this case is 10 °C. To start set a table, where Tsi (Temperature Supply Shifted) and Tti (Temperature Target Shifted).

$$T\ shifted\ for\ Hot\ Stream = T - \frac{\Delta Tmin}{2}$$

$$Tshifted\ for\ Cold\ Stream = T + \frac{\Delta Tmin}{2}$$

Stream	Type	Ti	To	Tsi	Tti	H (MW)	m.Cp
NAPTHA	Hot	155	150	150	145	0.17	33.6
KERO	Hot	220	40	215	35	3.58	19.9
ADO	Hot	260	50	255	45	11.68	55.6
LSWR	Hot	310	40	305	35	13.04	50
DPA	Hot	260	210	255	205	2.19	43.8
KPA	Hot	220	210	215	205	1.19	118.5
Tapis	Cold	32	135	37	140	6.64	64.5
Dulang	Cold	33	135	38	140	6.82	66.9
TD	Cold	140	210	145	215	10.76	153.8

Table 6.4: Shifted Temperature

Second step is finding the temperature interval heat balance. This can be carried out by using the shifted temperature and the mass flowrate heat capacity (Cp in kW/°C). The mass flowrate heat capacity was then being calculated using equation **∑Cpc -∑Cph.** The result of the Cp then carried out to find the duty or energy required by multiplying with interval temperature. For an example, temperature 255 °C and 215 °C the interval temperature between them is 40 °C. The ΔCp for temperature 215 °C is (start with cold stream) none and for the hot stream there are 56 kW/°C, 50 kW/°C and 44 kW/°C that make a total of 150 kW/°C. Then applied the equation **∑Cpc -∑Cph** that make the ΔCp equal to -150 kW/°C. After that multiply by the interval temperature (40 °C), energy or duty equal to 6000 kW. The rest of the temperature is followed and the table below showed the complete data for temperature heat balance.

	Stream m.Cp (kW/°C)											
Tshift	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**∑Cpc -∑Cph**	**ΔT(°C)**	**H(kW)**
295										0	0	0.0
255				50						-50	40	-2000.0
215			56	50	44					-150	40	-6000.0
205		20	56	50	44	119			154	-134	10	-1340.0
150		20		50					154	83.9	55	4614.5
145	34	20		50					154	50.3	5	251.5
140		20		50						-69.9	5	-349.5
45		20		50			65	67		61.5	95	5842.5
38		20		50			65	67		61.5	7	430.5
37		20		50			65			-5.4	1	-5.4
35		20		50						-69.9	2	-139.8

Table 6.5: Temperature Interval Heat Balance

Info to add, usually the negative energy is called as surplus and for positive energy value is called deficit.

6.2.5 Result on Problem Table Algorithm

From the temperature interval heat balance table 3.3, the figure below is to find the pinch point. The pinch point is important due to divide the above pinch and below pinch. Without the pinch point, basically a mistake such as cross pinch temperature (above pinch and below pinch) would make a huge penalty that need to pay.

	Temperature [C]	**Energy [kW]**	
1	295	897.1	Hot Utility
2	255	1629.1	
3	215	6337.1	
4	205	7360.1	
5	150	4060.1	
6	145	3928.1	
7	140	4397.1	
8	45	825.1	
9	38	44.6	
10	**37**	**0.0**	**Pinch**
11	35	9.8	Cold Utility

Figure 6.4: Problem table algorithm

For the result above, to identify the pinch point the energy, H (kW) will give a zero value. This showed that at that point all the energy become zero and start back from zero. Thus, in this data the pinch temperature or pinch point is 37 °C. Furthermore, from figure 4.1 the hot utility and cold utility requirement is at the top and bottom of the figure. Hot utility requirement for process integration is 897.1 kW (shown at temperature 295 °C). Thus, the heating utility needs an amount of 897.1 kW for heating usage. For cold utility, the required energy is 9.8 kW means cooling utility for cooling a hot stream.

A major mistake in this problem table algorithm is it should be zero hot utility and zero cold utility. This is because all cooling and heating utility are already being added to the data. The final temperature of the rundown of heating temperature for certain process already being satisfied with the temperature range or desired temperature.

6.2.5.1 The Hot and Cold Composite Curve

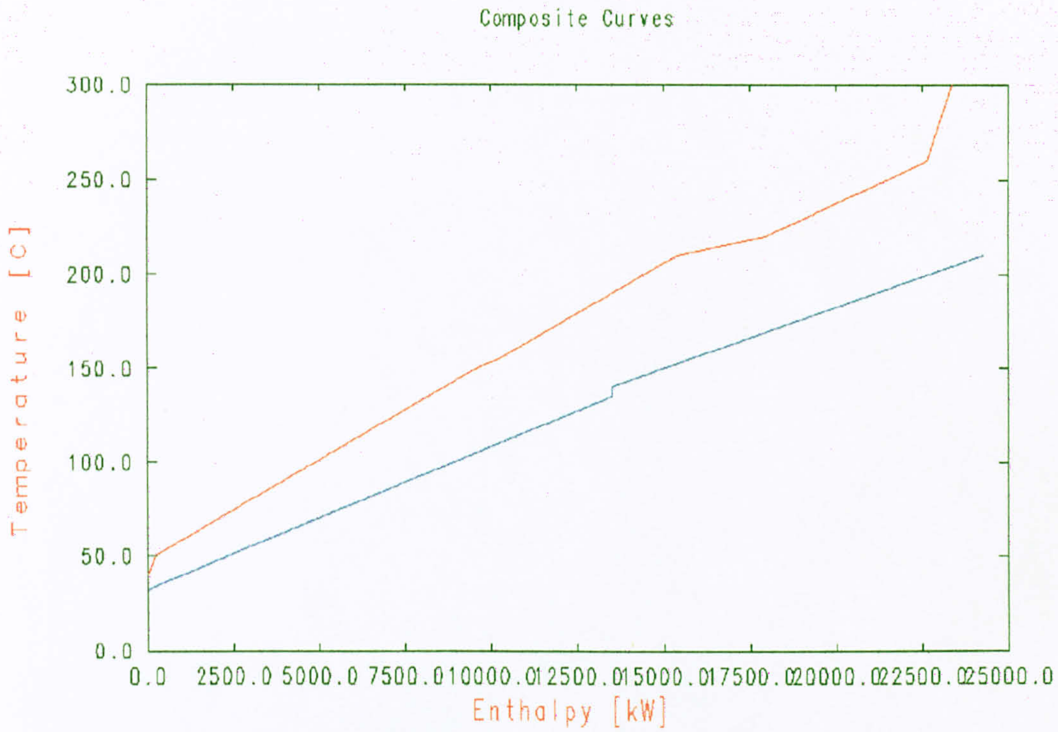

Figure 6.5: Composite curve

Temperature – Enthalpy (T – H) plots known as ***Composite curves*** have been used for many years to set energy targets ahead of design. Composite curves consist of temperature (T) – enthalpy (H) profiles of heat availability in the process (the hot composite curve) and heat demands in the process (the cold composite curve) together in a graphical representation.

In general any stream with a constant heat capacity (CP) value is represented on a T – H diagram by a straight line running from stream supply temperature to stream target temperature. When there are a number of hot and cold streams, the construction of hot and cold composite curves simply involves the addition of the enthalpy changes of the streams in the respective temperature intervals.

The concern about composite curve that it followed the previous problem table algorithm that is having the same hot utility and cold utility value. If let's say one of both not produce a same result, either one is given a wrong and correct value. The composite curve should have a threshold problems either one have zero hot utility or cold utility. But still the hot utility is ~900 kW and the cold utility ~10 kW.

6.2.5.2 The Grand Composite Curve

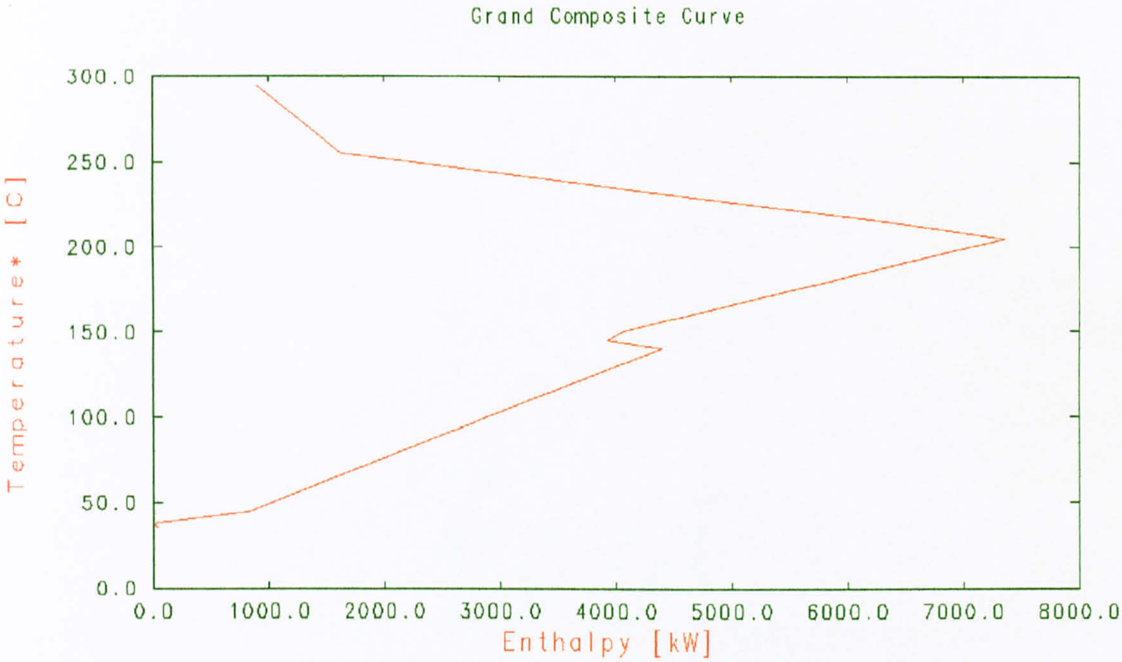

Figure 6.6: Grand composite curve

In selecting utilities to be used, determining utility temperatures, and deciding on utility requirements, the composite curves and PTA are not particularly useful. The GCC (Figure 4.3) shows the variation of heat supply and demand within the process. Using this diagram the designer can find which utilities are to be used. The designer aims to maximize the use of the cheaper utility levels and minimize the use of the expensive utility levels. Low-pressure steam and cooling water are preferred instead of high-pressure steam and refrigeration, respectively.

Base on the GCC figure 6.6, the shade area represent the energy that being recovered after the integration or most likely to say the affect of pinch technology/analysis.

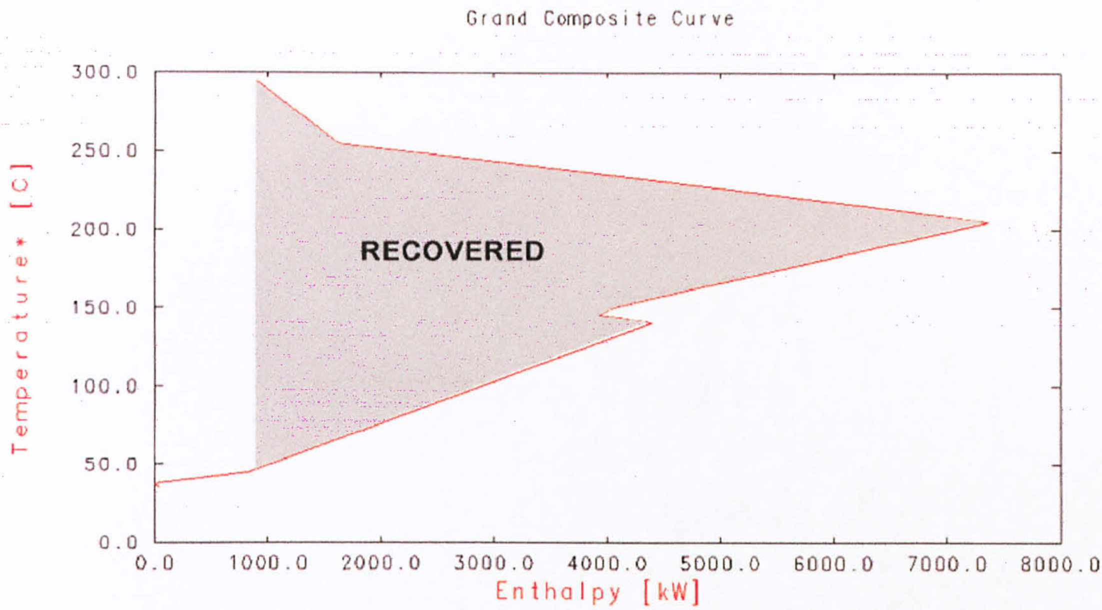

Figure 6.7: Grand composite curve recoveries

Back to the main concern again, the grand composite curve is to decide what type of utility to be used. In this case, the data are extracted from the original existing plan or base on actual plant design that already occupied with that utility thing. It should be all energy was being recovered after the heat integration.

6.3 Grid Diagram Heat Exchanger Network

See Figure 6.8, 6.9 and 6.10

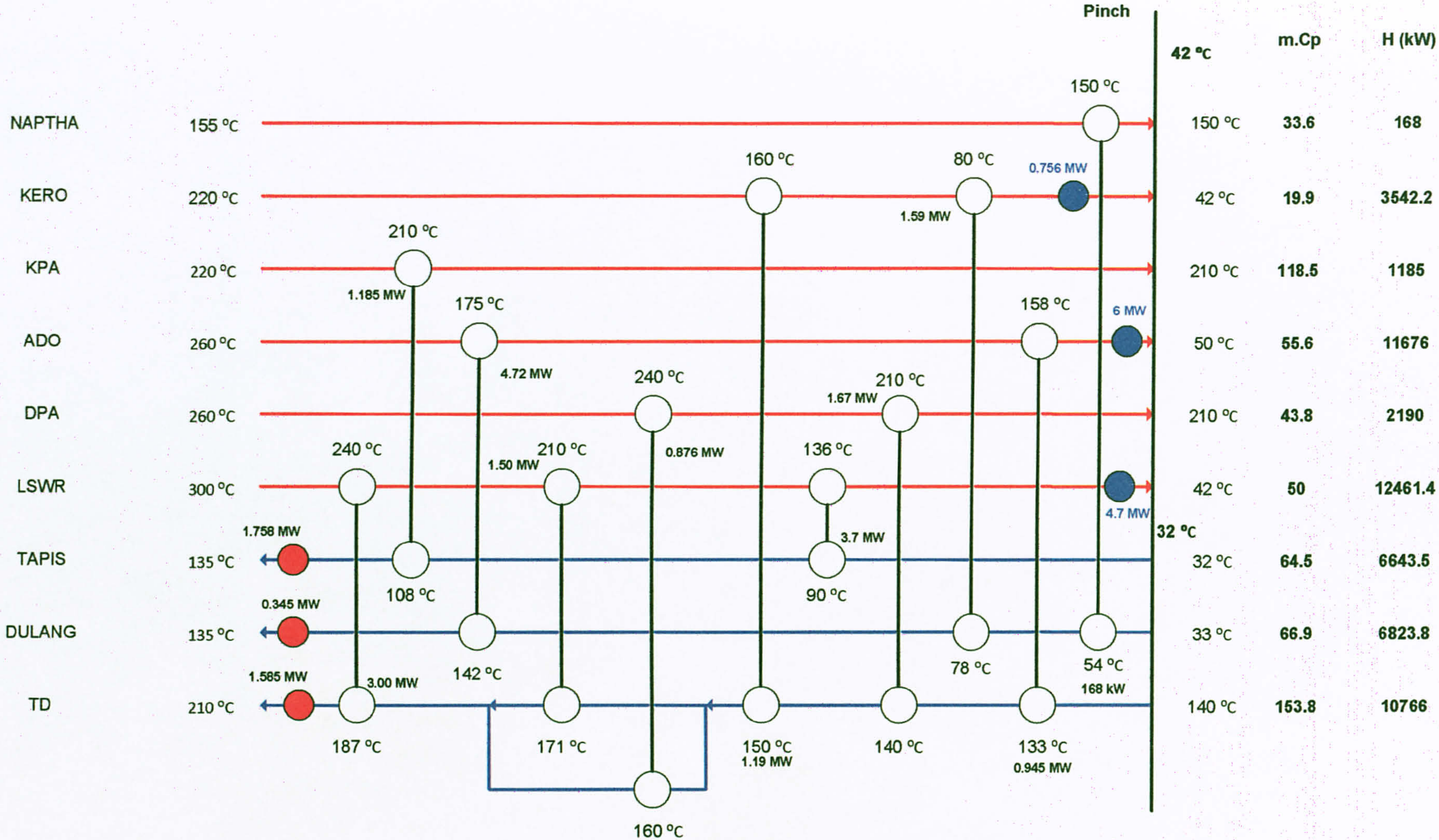

Figure 6.8: Grid diagram for existing above pinch heat exchanger network

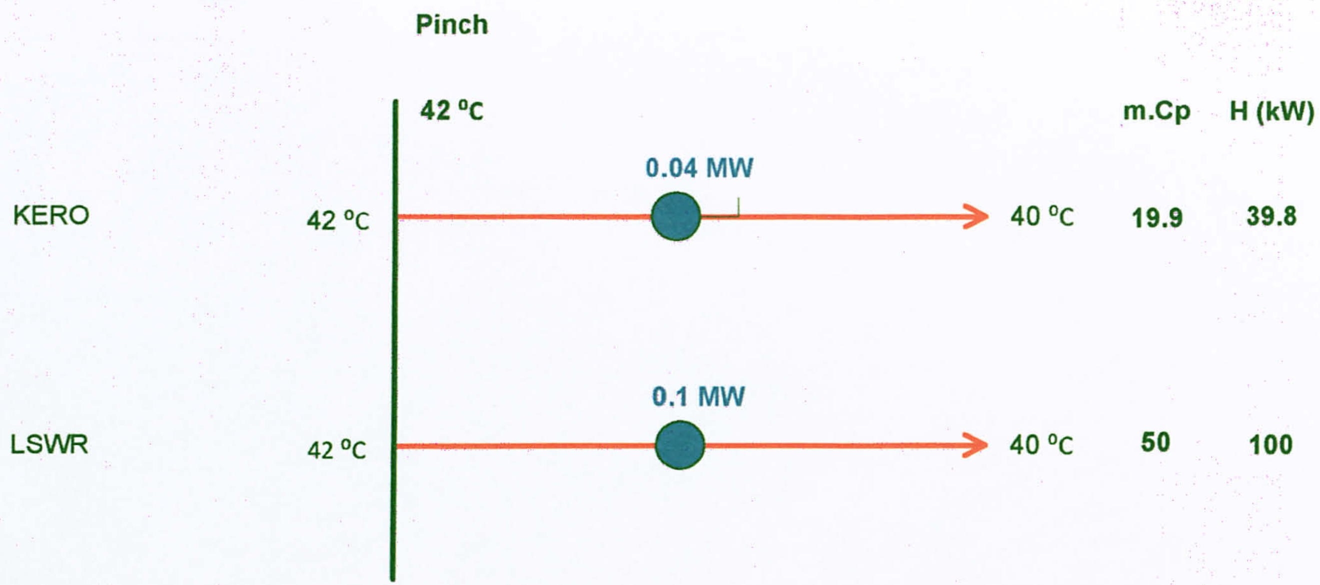

Figure 6.9: Grid diagram for existing above pinch heat exchanger network

6.3.1 Existing Heat Exchanger Network

For the existing heat exchanger network showed in figure 6.8 and 6.9, the total requirement for heat utility is 3.688 MW and the total of cold utility needed is 11.596 MW. A major energy in the cold utility proves that the recovered energy is not up to maximize because there is a huge balance. Thus, a new design should be implemented to reduce the amount of utility used also to maximize the recovered energy.

6.3.2 Proposed New Heat Exchanger Network

The proposed new heat exchanger network takes a major change in above pinch due to the un-recovered energy in the above pinch is greater than the below pinch.

Considerations:

- The rule of above pinch is Cp cold is larger or greater than Cp hot.
- Another consideration is to remove split stream due to split stream will cost from one heat exchanger to two heat exchangers.
- Change the set temperature of every heat exchanger outlet (only for stream involved).
- Try to reduce the utility requirement especially for the cold utility.
- Maximizing the heat transfers between heat exchanger by considering low fouling factor.
- Install a new heat exchanger if needed.

From figure 6.10, after a major changing on the heat exchanger network the cold utility requirement is 7.936 MW and the hot utility needed is 0 MW. Thus, the proposed design saves about 31 % cold utility and 100 % hot utility but, the major construction here to install new heat exchanger that will cost around RM 200, 000. The heat exchanger will be install in the diesel (ADO) rundown due to the current temperature is 158 deg C. It will reduce the temperature to 137 deg C and can be lowered dependent on the Tapis Blend stream set temperature to desalter unit.

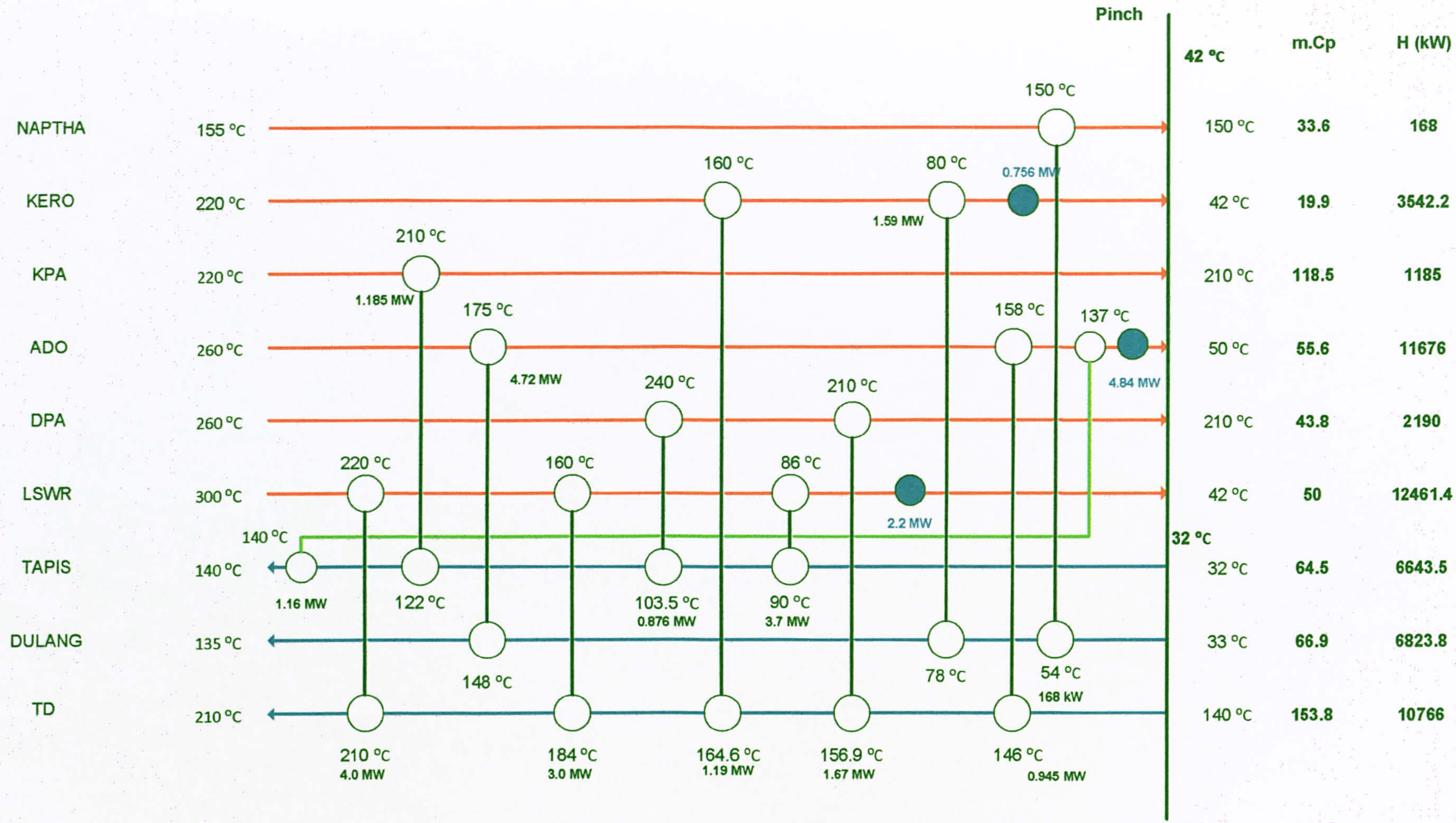

Figure 6.10: Proposed above pinch design for new heat exchanger network

CHAPTER 7
WATER WASHING FACILITIES

7.1 Overview

Basically, all chemical and oil and gas plant used heat exchanger as one o the medium to recover heat from waste or lost. The common heat exchanger used is shell and tube. This type of heat exchanger have tube side and shell side means it must have to medium to transfer from hot to cold which likely to say cold stream and hot stream. Heat exchangers are widely used in industry both for cooling and heating large scale industrial processes. The popular method use this equipment is Heat Integration. It is like a pair of chain connecting throughout the plant.

For refinery oil and gas, heat exchangers are frequently used and only stop servicing during emergency shutdown also during turnaround. Unfortunately, some of heat exchanger needs maintenance due to fouling issues. Fouling occurs when a fluid goes through the heat exchanger, and the impurities in the fluid precipitate onto the surface of the tubes. Precipitation of these impurities can be caused by:

- Frequent use of the Heat Exchanger
- Not cleaning the Heat Exchanger regularly
- Reducing the velocity of the fluids moving through the heat exchanger
- Over-sizing of the heat exchanger

Effects of fouling are more abundant in the cold tubes of the heat exchanger, than in the hot tubes. This is because impurities are less likely to be dissolved in a cold fluid. This is because solubility increases as temperature increases.

Fouling reduces the cross sectional area for heat to be transferred and causes an increase in the resistance to heat transfer across the heat exchanger. This is because the thermal conductivity of the fouling layer is low. This reduces the overall heat transfer coefficient and efficiency of the heat exchanger. This in turn, can lead to an increase in pumping and maintenance costs.

7.2 Background

Based on the monthly pressure survey and monitoring of the crude preheat train and CFU bottom exchangers, there are badly fouled among of heat exchangers involved.

This project is to create water washing facilities to clean for the heat exchangers at the tube side due to fouling always occur at the tube side. That why the pressure survey is done to check the pressure drop. A high pressure drop indicates there is a high fouling.

Piping and fittings for the heat exchangers can be carried out on-stream since 6" stubs at inlet/outlet are already installed during the previous shutdown. On-stream hot work modifications to inlet and outlet of other exchangers are possible at the expense of crude throughput reduction since these exchangers can be bypassed and the relevant spool piece can be removed. Any hot work modification then can be carried out outside battery limit.

7.3 Methodology

The exchanger's configuration will be "co-current" during cleaning as compared to "counter-current" during normal operation. This due to the normal flow makes the fouling directed as the flows. With reversing the flow during cleaning, can get rid the fouling component easier and more efficient.

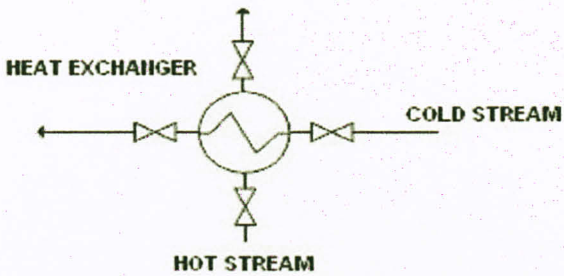

Figure 7.1: Normal operating flow counter-current

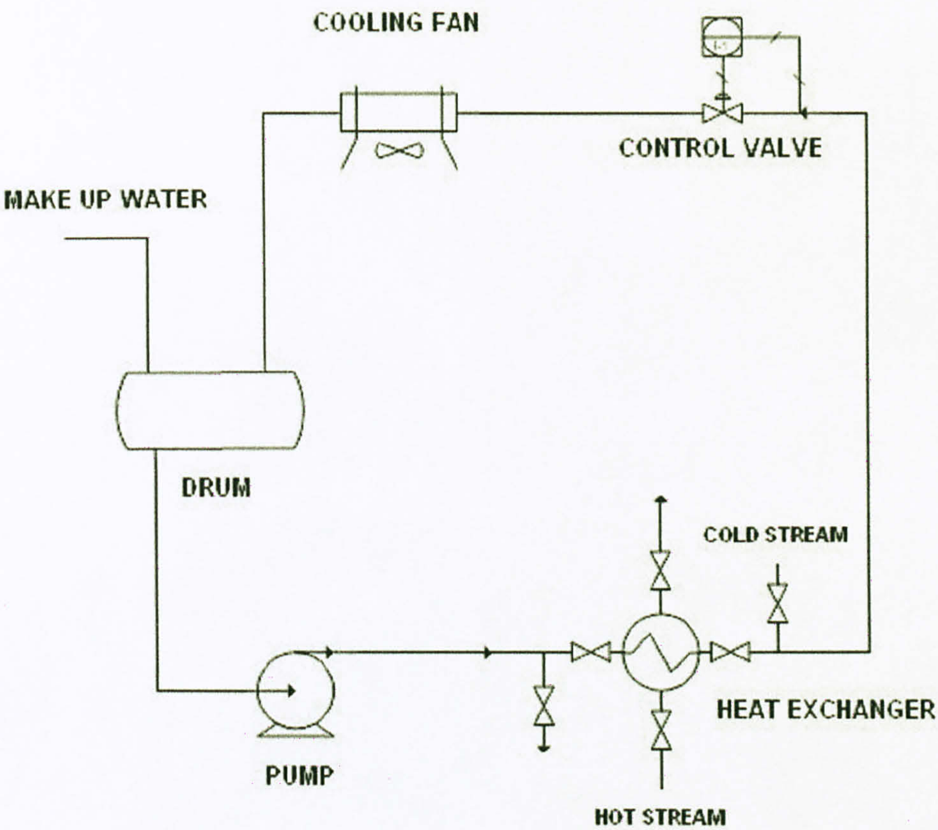

Figure 7.2: During cleaning co-current flow

7.4 Process Description

Hot water at 80 deg C is pumped to the tube side of the heat exchanger under cleaning. The water flowrate is controlled to ensure the hot water outlet is kept below 100°C. This is to avoid flashing at the downstream control valve. Some hot stream may be bypassed to ensure the outlet temperature is maintained as per normal operation. The hot water is cooled down to 70-80 deg C by an air finned cooler and returned to hot water drum. The hot water is re-circulated until completion of washing operation.

7.5 Pro II Simulation

The process flow is created by using Pro II software. The simulation is to find weather the flow of water cleaning sufficient to stabilize the shell side temperature according to the normal operation. The water outlet temperature should be less than 100 deg C. If water at 100 deg C or more, steam will be produced, thus to add more water to coop for cleaning. Example, the water rate is 250 m3/h with a temperature at 80 deg C. The hot stream temperature 300 deg C with flowrate 200 m3/h and need to be cold down to 260 deg C.

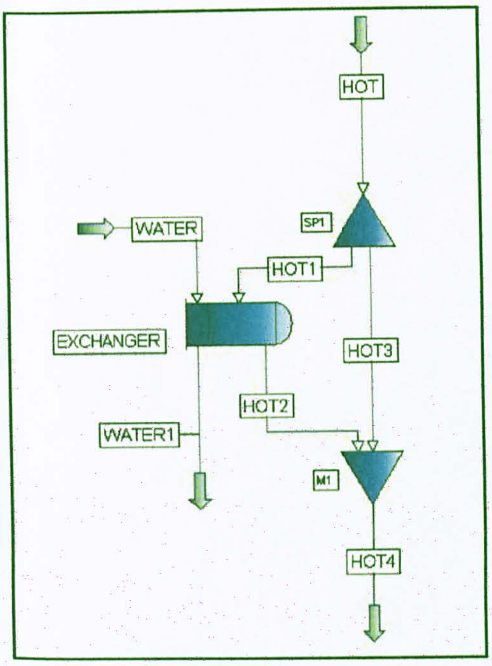

Figure 7.3: Example Pro-II simulation

From the Pro-II simulation, without bypassing the shell side the water temperature 102 deg. That means the water is in vapour phase. Thus to achieve the required temperature also the water liquid phase, some flowrate needs to bypass. About 60 % flow to the shell side is bypassed. The water state after bypass is still in liquid phase.

CHAPTER 8
CONCLUSION

Basically there are two heat exchangers that need to be check. This due to the efficiency of the exergy both heat exchangers quite high but this does not means that these exchangers are the key of the problem. This is a part of studied that viewed possible problem and the procedure to discover the part by part. Pinch analysis also needs to be analyzing for the plan heat integration to achieve better performance of heat exchanger.

The current temperature data that showed in the previous pages, the amount of heat duty done by furnace was too high. This will used a lot of fuel gas to fulfil the heat requirement for burning up the feed to Crude Tower.

Pinch Technology is a design method generated a network which was substantially better than that obtained by any previous methods of heat exchanger network design. The targeting stage gives a rapid initial assessment of the scope for change and them likely difficulties which will be encountered in obtaining a solution. The network design method can be used systematically to produce good "revamp" design, even where the existing heat exchanger network is complex. It allows a productive interaction with the engineer's experience.

All method in this report is only a **part one** of a pinch technology stage. The pinch design analysis is basically a raw solution develop from pinch grid network. By using this method we can save about 26% of utility needed for cooling and also increasing the energy recovered from 68% to 72%. Also the desired temperature of 195 -210 deg C for crude before entering Crude Fractionators Unit can be done.

The solution in this report is just theoretical overview. To explore more details about the engineering design, we should take advice from an expert or specialist because they are more experience in handling the situation or they know the design work or not.

Throughout the analysis, the assumption to have less or none utility requirement or left behind energy that has not been recovered not successfully achieved. Start from the Problem Table Algorithm (PTA), the hot utility required for heating is about 0.9 MW. This should be less than that or none. The cause for this error is due to the data given. Basically the data had been adjusted thus to fulfil the process safety requirement or follow the standard guide. But theoretically the pinch analysis for PPTSB almost proves that the result is nearing to zero or none. By looking at the composite curve and grand composite curve, the margin of energy left are not a large different. Pinch analysis would be 80 % accurate about the integration of plant network for this case.

After a major changing on the heat exchanger network the cold utility requirement is 7.936 MW and the hot utility needed is 0 MW. Thus, the proposed design saves about 31 % cold utility and 100 % hot utility but, the major construction here to install new heat exchanger that will cost around RM 200, 000. The heat exchanger will be install in the diesel (ADO) rundown due to the current temperature is 158 deg C. It will reduce the temperature to 137 deg C and can be lowered dependent on the Tapis Blend stream set temperature to desalter unit.

The Water Washing facility is a great investment due to it can be used for several time. Also if some heat exchanger have high fouling factor or high pressure drop or less heat transfer the heat exchanger can possibly be cleaned in short time even though it take one day. By using the method stated that is to use co-current or reverse flow for cleaning can reduce the fouling more efficient. Through bypassing, we can control the two considerations that the temperature of the outlet shell required also the water temperature.

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