Studies on Heat Integration in Crude Preheat Train and the Effect of Fouling

By

Imran Abdul Halim Zaki

Dissertation submitted in partial fulfillment of

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

DECEMBER 2010

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.

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Imran Bin Abdul Halim Zaki

ABSTRACT

This report is on the performance of heat exchanger in Crude Preheat Train and the effect of fouling. For years refinery had been struggling with various operational problem due to fouling. This project uses two different Crude Preheat Train design. The simulation work will study the difference in the performance of each heat exchanger in the preheat train both under clean and fouled condition. This project use Aspen Hysys 2006 software. The importance data in this project is the overall heat transfer coefficient and the duty of the heat exchangers. The result shows the advantage and disadvantage of both preheat train design. This project also looks into the economic impact of fouling on the preheat train. Results show the advantage and disadvantage both preheat train design. Simulation and calculation data are documented to provide a base for future work on possible reallocation of streams in the existing Crude Preheat Train.

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ABBREVIATION AND NONMENCLATURE

A	Heat transfer area of a heat exchanger (m^2)
h_i	Film coefficient for fluid inside the tube ($W/m^2.K$)
h_{fi}	Fouling resistance for fluid inside the tube ($m^2.K/W$)
h_{fo}	Fouling resistance for fluid flow inside shell ($m^2.K/W$)
h_o	Film coefficient for fluid inside the shell ($W/m^2.K$)
k_w	Thermal conductivity of heat exchanger material
Q	Heat exchanger duty (kW)
ΔT	Mean temperature difference between the hot and cold end of the exchanger
U	Overall heat transfer coefficient ($W/m^2.K$)

CHAPTER 1
INTRODUCTION

1.1 Background of Study

1.1.1 Crude Distillation Unit (CDU)

Crude distillation is a highly complex process. The process has undergone relatively little improvement for the past 70 years (Ji, 2001) (Liebmann, 1998). The design of CDU is basically the same with a column and several side strippers and pump around. For some refineries that process light crude blending they might have preflash drum to separate the liquid and vapor prior entering the furnace.

Factors such as crude mixture, large production quantity and large temperature variation result in limited improvement in the process technology. There are about 1000 distinguishable components with boiling temperature varying from room temperature to over 550^{o}C (Ji, 2001). Any changes that take place in the design will affect the distillation process. In order to maintain the sharp of distillation process, engineers stick with the previously outline design.

Crude oil distillation is an energy-intensive process consuming as fuel 1 to 2% of the crude oil processed (Liebmann, 1998) (Ji, 2001). Energy extracted directly from burning of fuel. Energy use to heat process stream and to generate steam both for process use and to generate electric. The distribution of the energy requirement for a typical refinery was reported to be as follow: 65% of the total energy used for process heat, 28% accounts for steam generation and only 7% for electrical power generation (Mujtaba, 2007).

Since 1970s, the increased in energy cost, most of attention had been paid to energy conservation issue (Mujtaba, 2007) (Ji, 2001). Due to increase in energy cost, energy consumption played more significant role in process economics. As a result process design today paid a lot of attention on energy conservation. An energy-integrated distillation scheme with maximum heat recovery can be achieve. With maximum heat recovery, there will be significant reduce in utility consumption in the process.

Figure 1-1 below shows that crude oil price consistently increasing from 1998 to 2009. With high utility required for heating purpose, significant increment on operating cost will take place. The consequence of low energy efficient process can strike both refiners and customer. While refiners might want to maintain the product margin, customer might struggle with higher price for gasoline and other refinery product. Energy efficient process is very important in order to keep a competitive market for products.

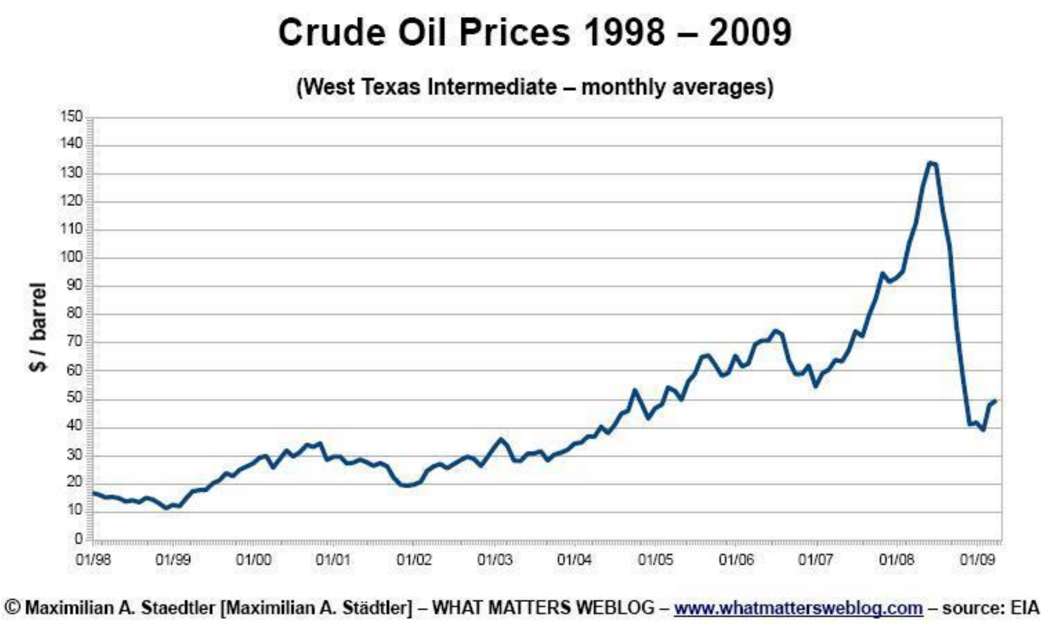

Figure 1-1: Crude Oil Price 1998-2009

1.1.2 Crude Preheat Train (CPT)

CPT is a sub unit of CDU. It is located at the beginning of a CDU as shown in Figure 1-2 below. The train is divided into two parts which are cold preheating and hot preheat. Cold and hot preheat is separated by a desalter. After CPT, preheated crude will enter furnace before entering the distillation column.

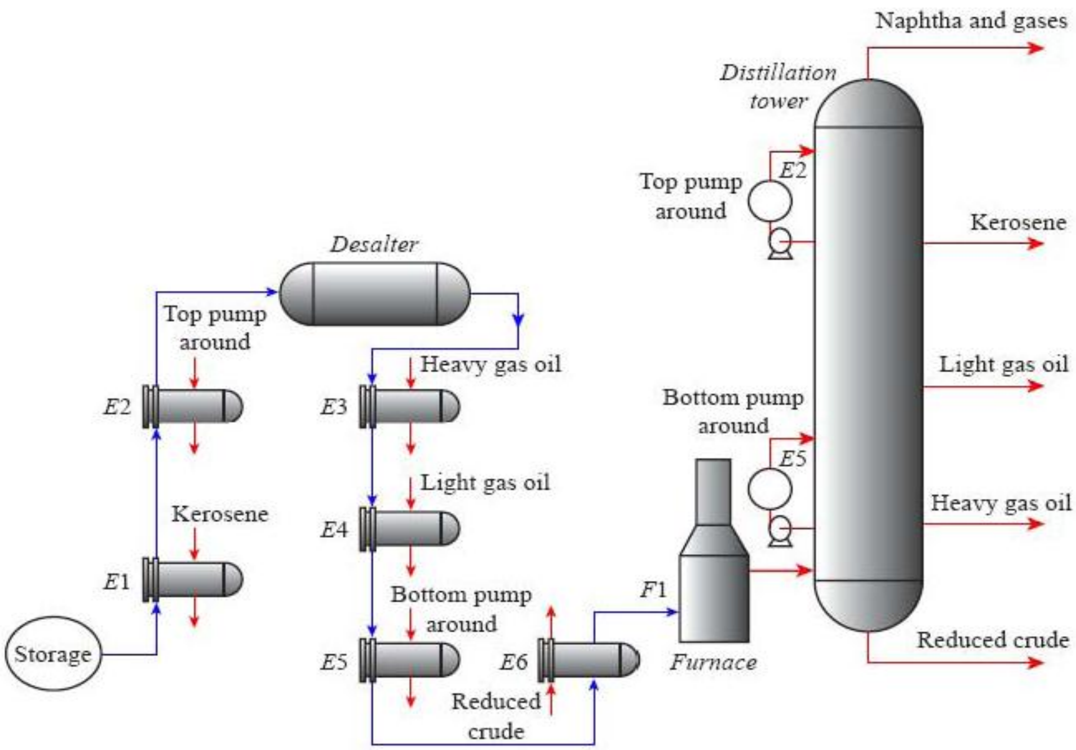

Figure 1-2: Crude Preheat Train Overview

Through CPT energy from high temperature streams leaving the crude distillation column are used to preheat the feed streams. The preheat train of a CDU is regarded as the most critical system in reducing the energy consumption, through the heat integration (Silva). In (Watkins, 1979) and (Mujtaba, 2007), pointed out “optimizing the crude preheat-tower heat exchange train is the heart of crude unit design, and each case must be studied on an individual basis in order to arrive at the most economical processing scheme”. Optimum heat recovery will give a better result in utility savings rather than increasing the energy efficiency of the column alone.

1.1.3 Fouling

Fouling is defined as the deposition of undesirable materials on the tube and shell side of the heat exchanger (Mujtaba, 2007). There are 6 types of fouling which are particulate fouling, bio-fouling, corrosion, precipitation, chemical reaction and coking.

Particulate fouling is accumulation of suspended solid in process stream while precipitation is a result of precipitation of dissolve substance in the process stream. Coking is a general term to describe organic fouling. Corrosion fouling is a result of corrosion on the heat transfer surface itself which later promote attachment of other fouling. Bio-fouling involve attachment of macro or microorganism along with adherent slime often generated by the latter.

Fouling has an adverse impact both on capital and operational cost. For heat exchanger, larger surface area is an option to overcome fouling problem. This means higher capital cost for a larger equipment. There also higher operational cost for downtime and maintenance. The effect of fouling also includes loss of throughput. As a result of fouling in CPT lower heat recovery and higher utility consumption. Under severe condition it may led to equipment rupture. As a measure to minimize the impact of fouling, chemical injection such as antifouling was introduce.

1.2 Problem Statement

CPT was designed to achieve efficient energy recovery and excessive heat-exchanger fouling results in low heat recovery in crude preheat trains (Wagensveld, 2007).However the magnitude of the impact is unknown. In this project the focus will be on the impact of fouling on the performance of heat exchanger.

1.3 Objective

The objective of this project is to study the heat integration in crude preheat train of a distillation unit and the impact of fouling for two different CPT configuration. In the first part a model of crude preheats train will be constructed using the simulation software to study the performance of the train which is the amount of duty of each heat exchanger. In the second part focus will be on studying the effect of fouling on the train performance. Fouling will provide resistant that result in drop of heat transfer coefficient. As a result the amount of heat recovered will be lower. Additional utility required can be calculated from the amount of energy loss due to fouling in the heat exchanger.

1.4 Scope of Study

Scope of this project can be divided into 3 major parts. The first part will be on research. Through research it helps to enhance the understanding on the crude distillation and crude preheat train especially. In the first part also suitable model will be selected to be modeled using Hysys software. The first part will be the base for comparison to study the effect of fouling. The second parts of this project will be on the modeling the preheat train and to observe the heat integration and the impact of fouling. The key parameters will be the duty of heat exchangers and the heat transfer coefficient. It includes the analysis in term of duty loss and the impact on economics due to the fouling.

CHAPTER 2
LITERATURE REVIEW

2.1 Literature Review

2.1.1 Preheat 1

The base case, Preheat 1 is similar a conventional refinery CPT design. As in the Figure 2-1, crude from storage exchange heat at E1 against Top Pump around (TPA). In E2, crude exchange heat with Kerosene stream from heat exchanger E1106. At the next heat exchanger, crude exchange heat with Heavy Naphtha Pump around (HN P/A) from heat exchanger E5. Crude then flow through the shell side of E4 to exchange heat with residue stream from E8. Crude then flow into desalter (TEE-100) where desalted crude will enter E5 to exchange heat with HN P/A from the column. Desalter effluent will flow to the water treatment system.

Desalter is use to extract salt and base sediments that can result in fouling, corrosion and catalyst poisoning. Effluent is removed at a rate of 194 kg/h. At E6 crude exchange heat with Kerosene stream from column and later with Atmospheric Gas Oil (AGO) stream at E7. At E8 crude receive heat from residue stream from E11. At E9 crude exchange heat with Diesel Pump around (DPA) and with AGO Pump around at E10. At E11, crude exchange heat with Residue from column.

In Preheat 1, the configuration will ease the process cleaning as high fouling streams flow through the tube side of heat exchanger. Crude is allocated on the tube side against pump around and product streams as it heavily fouled compared to hot streams while Residue is high fouling stream compared to crude oil stream. Except for heat exchangers where heat is recovered from Residue, crude oil stream flow through the tube as it has higher pressure compared to other process streams. High pressure streams on the tube side means only tubes and tube fitting need to be built to withstand the pressure instead of whole heat exchanger (Wol10).

Preheat 1 come with setback as stream with lower heat transfer coefficient has smaller surface area for heat exchange. Crude has lower heat transfer coefficient than the pump around and products streams while Residue is lower than crude. This results in poor heat exchanger performance. Preheat 1 configuration both ease the built of heat exchanger and the cleaning process with trade-off on the heat exchanger performance.

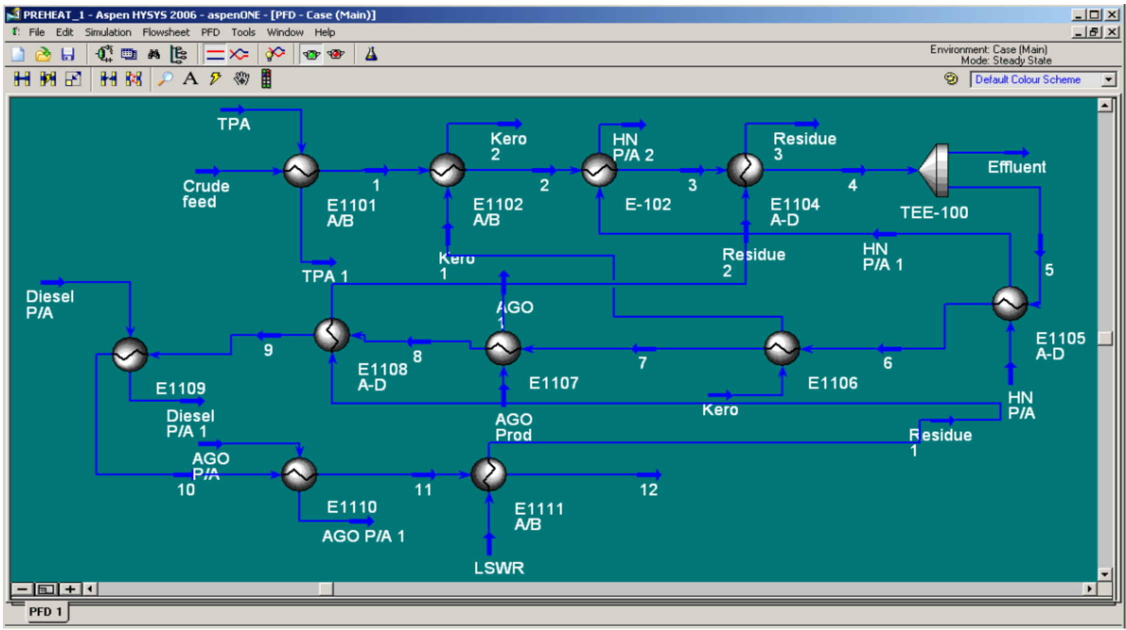

Figure 2-1: Preheat 1

2.1.2 Preheat 2

In an article title Redesign Crude Preheater Train for Efficiency (Wagensveld, 2007), they come with a new design of crude preheat train. It was done under key consideration of reducing risk of fouling in the preheat exchangers at design capacity and achieve increased in unit throughput. (Wagensveld, 2007) first suggestion is two allocate all pump around streams in the heat exchanger tube with optimum tube side velocity. Suggested configuration allows better flexibility for tube side capacity to cope with variation in column throughput or product distribution. In the new CPT design, low sulfur waxy residue (LSWR)/Residue are allocated on the exchanger shell side.

This new preheat train will be the Preheat 2 in the project. Compared to the conventional approach as in Preheat 1, it is different in several ways. Preheat 2 allocate low fouling streams in the tube side while Preheat 1 on the shell side. The suggested allocation provides extended surface area for low heat transfer coefficient stream. This will result in a better heat transfer across the heat exchanger. With similar operating conditions to Preheat 1, Preheat 2 is safer as hot streams are in the tube side for pump around streams.

Despite the advantages, there are couples of setback for Preheat 2. As crude at higher pressure than other streams, both tubes and heat exchanger need to be built to withstand the fluid pressure. This will result in higher capital cost. With high fouling on the shell side, it will provide extra challenge when it comes to cleaning process. As the spaces between tubes are very small, cleaning process might not be done by water jet alone. Other treatment might also be needed to ensure the outer side of tubes is totally clean especially tubes at the center of the bundle.

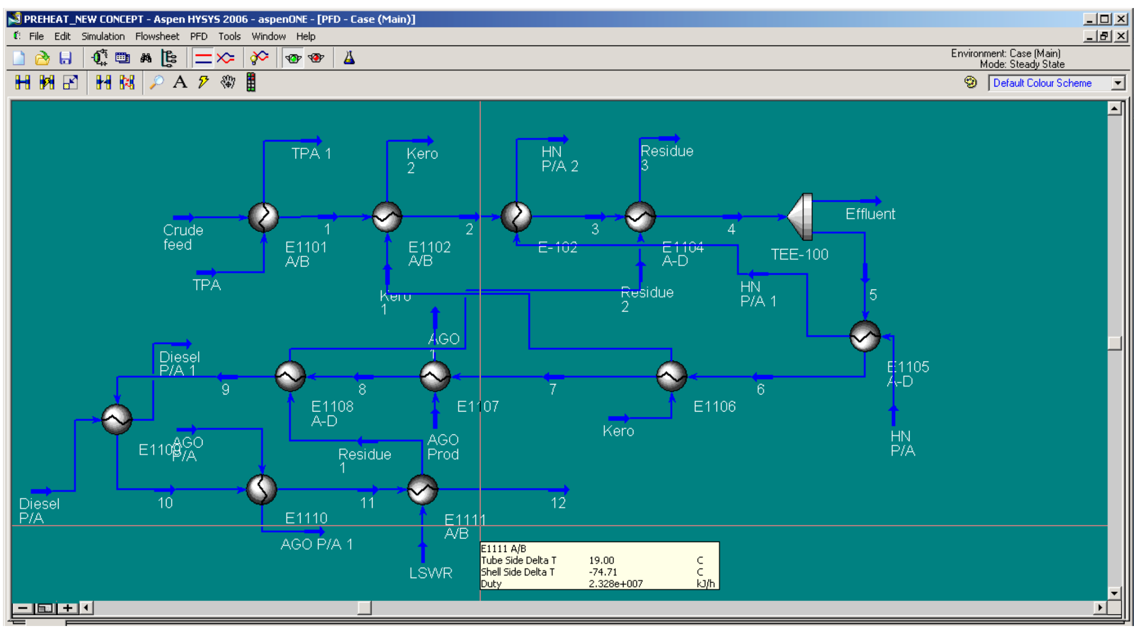

Figure 2-2: Preheat 2

As in the Figure 2-2 above, crude enter the shell side of E1 to exchange heat with TPA stream. Then flow through the shell side of E2. Here crude will exchange heat with Kerosene stream from E6. At the next heat exchanger, crude flow on the shell side of the exchanger as it exchange heat with HN P/A stream from E5. At E4, crude flow on the tube side while residue on the shell side. Crude then enter the desalter before entering E5. Here crude exchange heat with HN P/A stream from column.

Crude enter E6 to exchange heat with Kerosene stream. At E7, crude exchange heat with AGO product stream from column. Residue from E11 exchange heat with crude from E7 at heat exchanger E8. Here crude flow on the tube side of the heat exchanger. Crude then exchange heat with Diesel P/A stream and AGO P/A stream. At E9, against Diesel P/A stream crude flow on the shell side. The configuration is similar for E1110. E11 is the last heat exchanger in the stream where Crude flow on the tube side of the heat exchanger. Crude will exchange heat with Residue stream.

2.2 Theory

The focus in this project is the performance of the exchanger both under clean and dirty condition. To achieve this data on amount of heat transferred across and the temperature at both ends for both streams will be recorded for evaluation. The most fundamental equation for heat transfer is;

$$Q = U^{*} A^{*} \Delta T_m$$

For heat transfer across cylindrical tubes in a exchanger;

$$Q = \frac{\Delta T_m}{\frac{1}{h_i A_i} + \frac{\ln(r_0/r_i)}{2\pi L k_w} + \frac{1}{h_o A_o}}$$

Comparing 1st and 2nd equation and we get;

$$U^{*} = \frac{1}{\frac{A^{*}}{h_i A_i} + \frac{A^{*}\ln(r_0/r_i)}{2\pi L k_w} + \frac{A^{*}}{h_o A_o}}$$

Under dirty condition, the fouling factor will be taken into consideration. The equation for overall heat transfer equation;

$$U^{*} = \frac{1}{\frac{A^{*}}{h_i A_i} + \frac{A^{*}}{h_{fi} A_i} + \frac{A^{*}\ln(r_0/r_i)}{2\pi L k_w} + \frac{A^{*}}{h_{fo} A_o} + \frac{A^{*}}{h_o A_o}}$$

For $A^{*} = A_o$,

$$U_o = \frac{1}{\frac{A_o}{h_i A_i} + \frac{A_o}{h_{fi} A_i} + \frac{A_0\ln(r_0/r_i)}{2\pi L k_w} + \frac{1}{h_{fo}} + \frac{1}{h_o}}$$

$$A_{*} = 2\pi r_{*} L$$

$$A_o = 2\pi r_o L$$

$$A_i = 2\pi r_i L$$

$$U_o = \frac{1}{\frac{r_o}{h_i r_i} + \frac{r_o}{h_{fi} r_i} + \frac{\mathrm{r_o} \ln({}^{r_0}/_{r_i})}{k_w} + \frac{1}{h_{fo}} + \frac{1}{h_o}}$$

Base on the series of equation given we can see the relation between overall heat transfer coefficients, U^* and fouling heat transfer coefficients both for fluid inside and outside of tube,$h_{fi} and h_{fo}$. Fouling will come and provide extra resistance on both side of the tube. As a result there will be decrease in the U_o value. Given the same value for A, lower U_o value will require larger driving force.

Base on the theory, it justifies the reason some heat exchanger being over design. Extra area available will compensate the reduction in overall heat transfer coefficient. The new heat exchanger area, A_2 will be equal to $\frac{U_o}{U_f} \times A_1$. However under severe fouling condition, this might not work as U turn to be very small. As a conclusion fouling is something refineries try to avoid. In addition to additional capital to be invested on equipment, it brings up various operational issues to be deal with.

CHAPTER 3
METHODOLOGY

3.1 Project Activities

The first step in this project is to do research (Figure 9) on related subject to the problem. The research part is divided into several keywords which are Crude Distillation Unit (CDU), Crude Preheat Train (CPT), heat integration in refinery and refinery fouling. To understand the CDU and CPT also refer to several presentations on PETRONAS Penapisan (Melaka) Sdn. Bhd., PP (M) SB.

For simulation purpose, I am using Hysys 2006 using and as a revision, I used Aspen Hysys Crude Distillation Tutorial as the guideline. Since that I did not find adequate Crude Assay for Bintulu condensate, Tapis and Miri light condensate, this project will be using the crude assay given in the tutorial. Streams use in the CPT simulation are define base on the product streams from the simulation tutorial. The initial CDU setup has 5 products which are Naphtha, Kerosene, Diesel, Atmospheric Gas Oil (AGO) and Residue.

Preheat 1 as in Figure 2-1 is the base case in this project. Flow rate, pressure and temperature of the streams will be similar to the literature. The target is to preheat crude oil stream from 39^{o}C to 232^{o}C. For simulation of CPT, instead of attaching the heat exchangers directly with the distillation simulation feed and product streams, streams involve will be created explicitly. This is because the temperature is different. Simulation is done under steady state condition with heat exchangers sizing similar to heat exchangers in the literature

The required information from the steady-state simulation is the duty, stream heat transfer coefficient and the mean temperature difference, $\Delta T_{m.}$ Use the data obtain from the steady-state simulation; the heat transfer coefficient under fouled condition is calculated. Value for carbon steel thermal conductivity and crude oil fouling resistance is obtain from and engineering site (10Au). Fouling coefficient for product and pump around streams are taken from Chemical Engineering book (Sinnott, 1998).

Preheat 1 under fouled condition simulation; heat exchanger model selected is Exchanger Design (Weighted). Selected model allow user to insert the value of overall heat transfer coefficient and mean temperature difference. Key in all heat exchangers overall heat transfer coefficient and mean temperature difference and run the simulation. Then record the heat exchanger duty and the crude outlet temperature at E11.

Simulation is done for both clean and dirty condition. Figure 6-1 shows the simplified process flow. The similar approach was taken for the suggested new design concept from the literature. From the simulation we can have data on the heat exchanger duty, process streams inlet and outlet temperature and Mean Temperature Difference.

3.2 Project Gantt chart

3.2.1 Semester 1

Refer to Table 6-1 in Appendices

3.2.2 Semester 2

Refer to Table 6-2 in Appendices

CHAPTER 4
RESULT AND DISCUSSION

4.1 Crude Preheat Train Performance

4.1.1 Graph Overall Heat Transfer Coefficient, U_o vs. Heat Exchanger

Figure 4-1 below show the overall heat transfer coefficient of each heat exchanger in both Preheat 1 and Preheat 2. Overall heat transfer coefficient of heat exchanger plotted against the heat exchanger. The value is calculated using the overall heat transfer coefficient equation. Under clean condition, fouling resistance is neglected so the fouling resistance value is set to zero.

Fluid heat transfer coefficient, h_i and h_o are obtained from the simulation. The unit for the heat transfer coefficient is W/m^2K. Tube length and diameter is taken from literature. Both parameters unit are in meter. Tube wall thermal conductivity is taken from engineering site (10Au)and in W/mK. Higher heat transfer coefficient, the better heat transfer process through a surface.

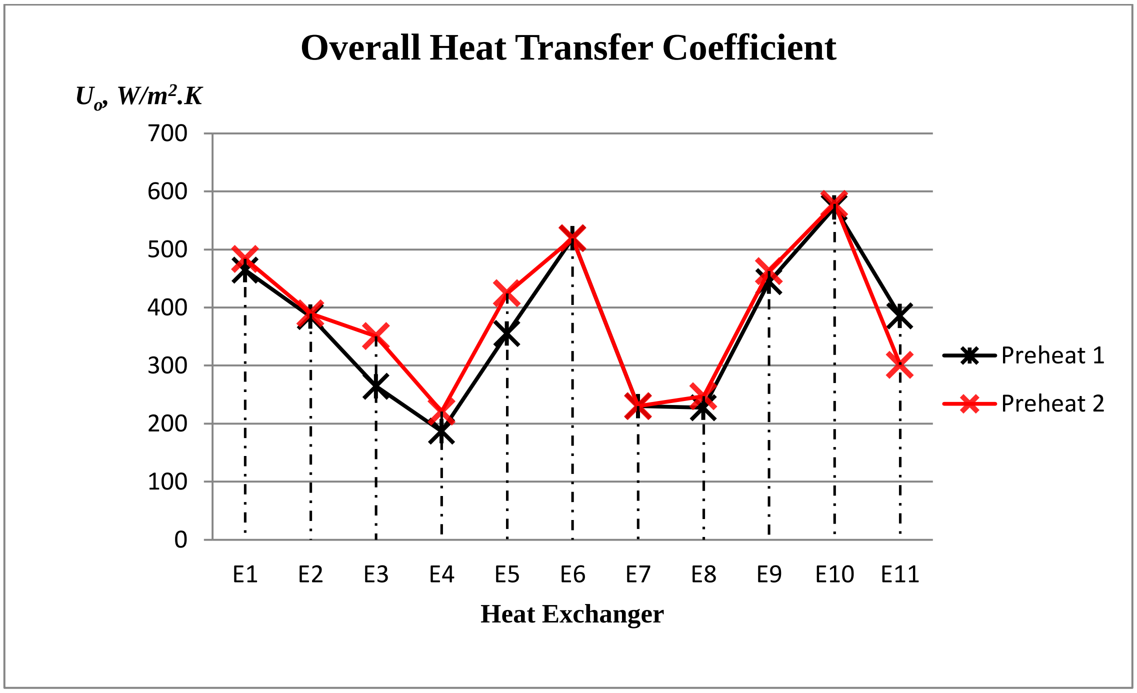

Figure 4-1: Heat Exchanger Overall Heat Transfer Coefficient

4.1.2 Graph Heat Exchanger Duty vs. Heat Exchanger

As in Figure 4-2 below show the duty of heat exchanger in the preheat train for a year of operation. To find the heat exchanger duty the simulation is done with the existing heat exchanger size and mean temperature difference, ΔT_m for both trains. The ΔT_m use is taken from the first simulation. The value can be found at the performance tab of heat exchanger details in Hysys.

The annual duty for heat exchanger is equal to heat exchanger duty, Q in kilowatt multiply by operating time. Kilowatt is equal to kilo Joule per second. To find the annual duty for each heat exchanger the operating time will be converted from days per year to seconds per year. For calculation purpose the operating days for a year is assume at 330 days with 30 days spend for maintenance purpose. Multiply the energy transferred per second with the operating time to get the annual duty of all heat exchangers in both preheats trains.

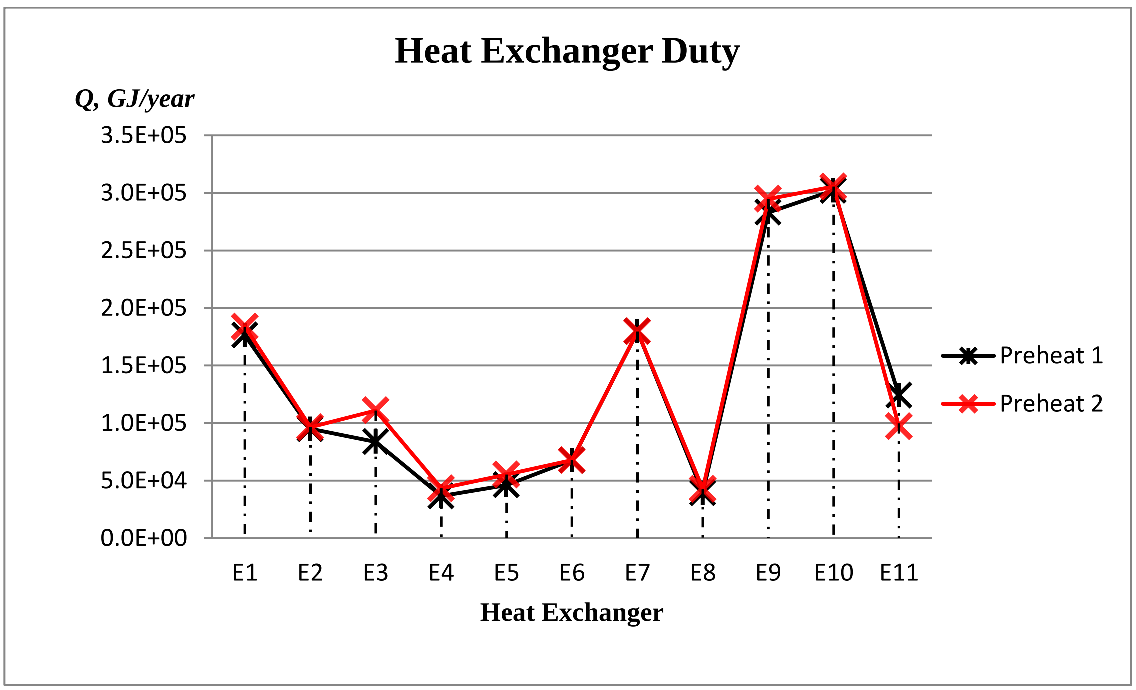

Figure 4-2: Crude Preheat Train Heat Exchanger Duty

4.1.3 Performance of Preheat Train for Clean Heat Exchanger

In Figure 4-1, the results show that the overall heat transfer coefficient of heat exchanger in Preheat 2 is higher compared to Preheat 1. Higher heat transfer coefficient will help to ease the heat transfer across the heat transfer surface. As a result, more energy transferred through the surface from hot stream to cold stream. This will improve the heat exchanger performance.

To study the heat exchanger performance, the manipulated variable is the overall heat transfer coefficient. Heat exchanger area and the mean temperature difference are kept constant. Re-allocation of stream in Preheat 2 involve pump around, crude and Residue streams. Low heat transfer coefficient streams are allocated on the shell side of the heat exchanger. In general, the new configuration in Preheat 2 results in higher heat transfer coefficient for heat exchanger in the train.

The new configuration does not include any changes on heat exchanger that recover heat from products streams. E2, E6 and E7 are the heat exchangers that use products streams as the heat source to heat the crude. In Figure 4-1, all three heat exchangers have the same value for coefficients in both preheat trains. The result in Figure 4-2 shows that the annual duty all three heat exchangers is the same.

There are 6 heat exchangers that is use to recover heat from pump around streams. From Figure 4-1 the results show that Preheat 2 heat exchangers have higher overall heat transfer coefficient after the re-allocation of stream. As a result the heat transfer to crude is easier and more energy recovered. Values in Figure 4-2 reflect the theory as area and the mean temperature difference are constant; all respective heat exchangers duty in Preheat 2 is higher than Preheat 1.

In the preheat train there are 3 heat exchangers use to recover heat from Residue stream. Residue stream first enter E11 before exchange heat at E8 and the last heat exchanger is E4 before it flows to the storage tank. In Preheat 1, the allocation of stream want to ease the cleaning job as Residue, high fouling stream flow in the tube side. E4 and E8 give a better result in Preheat 2. From Figure 4-1, the value for E4 and E8 is higher in Preheat 2 than Preheat 1. Results in Figure 4-2 show that both heat exchangers transfer more heat from Residue to crude feed.

From the simulation, E11 gave a different result. Figure 4-2 shows that the energy recovered through E11 in Preheat 2 is smaller than Preheat 1. This is because the heat transfer coefficient of Residue stream on the shell side is too low. As a result, the overall coefficient drop compared to Preheat 1. This further affecting the amount of energy recovered as the resistance to transfer heat is higher.

Table 4-1 is the summary of the heat exchanger performance under clean condition. For clean heat exchanger condition, Preheat 2 recovers more heat than Preheat 1. Preheat 2 can recover additional 43090 GJ of energy in term of heat per year.

Heat Exchangers	U_o, W/m^2.K		Q, GJ/year	
	Preheat 1	Preheat 2	Preheat 1	Preheat 2
E1	464.329	483.693	1.763E+05	1.837E+05
E2	384.047	389.581	9.497E+04	9.634E+04
E3	264.276	350.612	8.371E+04	1.111E+05
E4	186.739	220.764	3.667E+04	4.336E+04
E5	355.297	424.424	4.623E+04	5.523E+04
E6	519.293	519.293	6.777E+04	6.777E+04
E7	230.063	230.072	1.796E+05	1.796E+05
E8	227.381	247.170	3.935E+04	4.277E+04
E9	444.133	462.603	2.831E+05	2.948E+05
E10	572.449	578.538	3.022E+05	3.054E+05
E11	385.100	301.178	1.242E+05	9.716E+04
Total			1.434E+06	1.477E+06

Table 4-1: Preheat Train Performance under Clean Condition

4.2 Effect of Fouling on Crude Preheat Train

4.2.1 Graph Heat Loss vs. Heat Exchanger

Figure 4-3 shows the duty loss due to fouling. Duty loss indicates the different in duty of heat exchanger under clean and fouled condition. Fouling provide resistance for heat transfer and result in drop in heat transfer coefficient. The layer of resistance occurred both on tube and shell side Fouling will reduce the amount of energy recovered from the hot stream. Often to reduce the impact of fouling equipment is overdesign so that there will be larger surface area for heat transfer.

Crude fouling coefficient in general divided into two which is wet crude and dry crude. Wet crude contains salt water while desalted crude is the dry crude. For each type it can be divided according to temperature range. The first temperature range from 0-95^{o}C, second range between 95^{o}C to 160^{o}C and the last temperature range from 160^{o}C to 260^{o}C. Crude fouling resistance increases as temperature increase. Fouling coefficient value for hot streams is taken from a handbook (Sinnot, 1998). Hydrocarbon streams is divided into two which are light and heavy hydrocarbon.

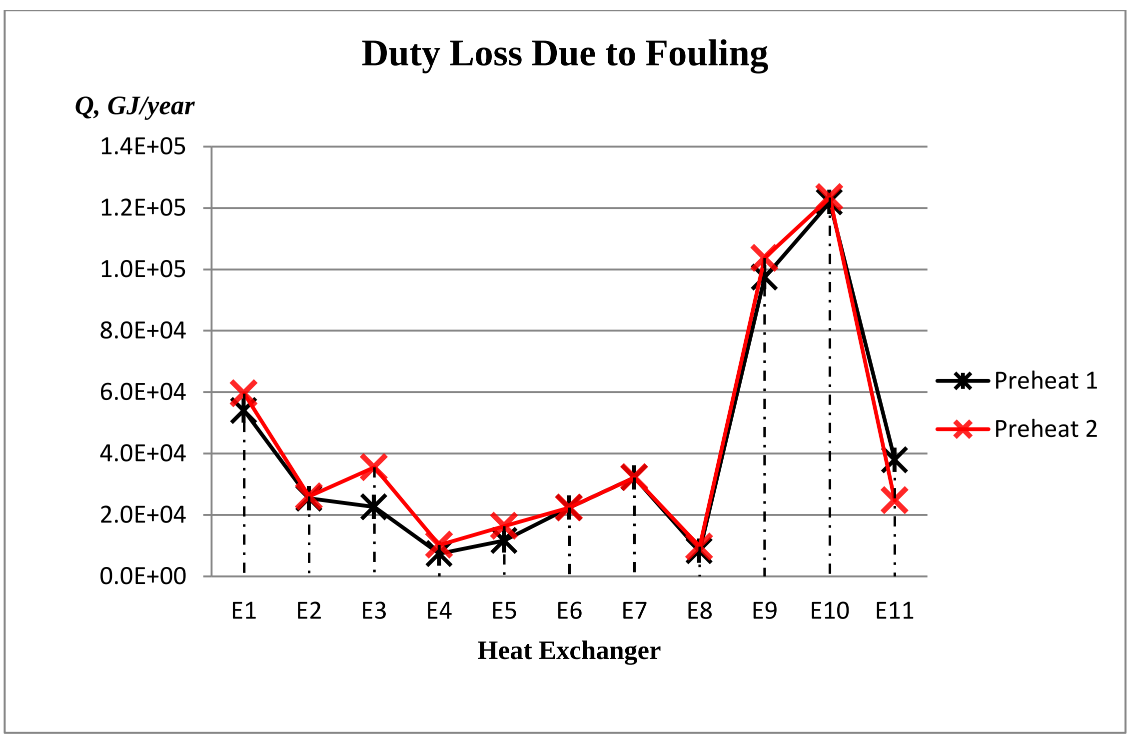

Figure 4-3: Duty Loss due to Fouling

4.2.2 Graph Economic Loss vs. Heat Exchanger

As a result of loss in heat exchanger duty due to fouling, more utilities required for heating purpose. Figure 4-4 shows the economic loss for each heat exchanger in the train. Heat can be supply by steam or fired heater. Steam is produce from boiler feed water and heater required to vaporize the water. Through fired heater, fuel is burned to provide heat to heat up the process stream.

Term economic loss can be defined as the incurred cost for utility due to fouling on heat exchanger. This cost fall into the operating cost for the refinery. As cost increase the refinery margin decrease. Economic loss is calculated by multiplying duty loss per year (kJ/year) with price of fuel per energy produce (RM/GJ). Fuel is priced at RM 12 /GJ.

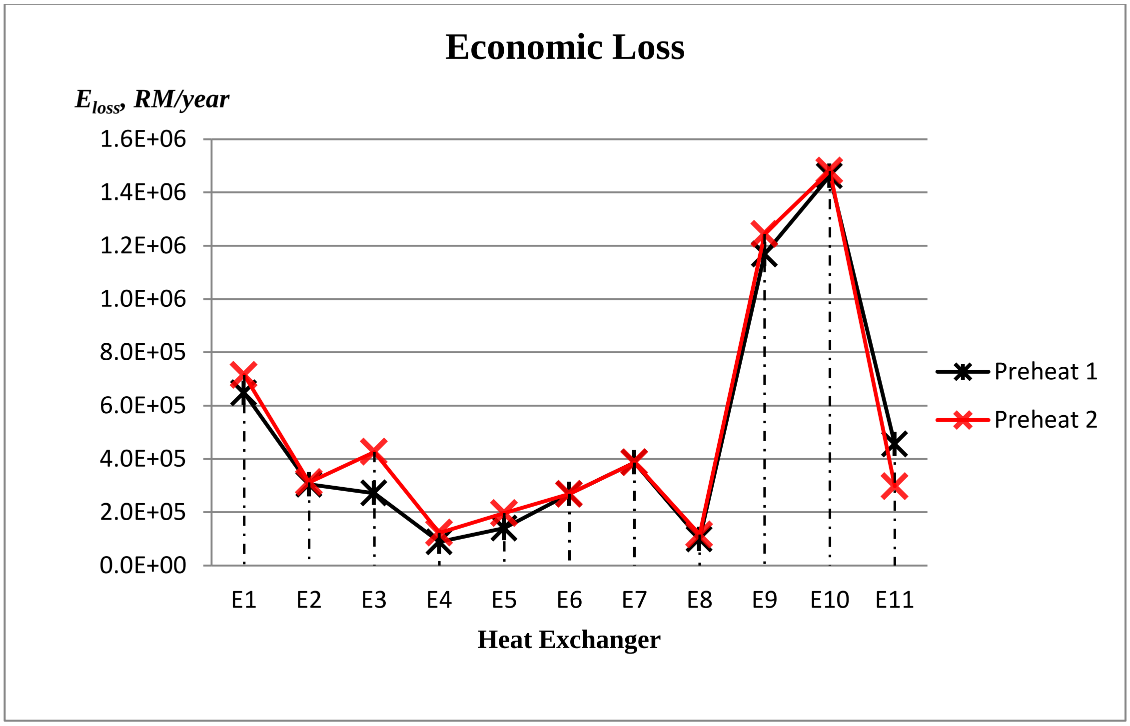

Figure 4-4: Economic Loss due to Fouling

4.2.3 Performance of Preheat Train during Fouled Condition

Figure 4-3 shows the loss of duty for heat exchanger under fouled condition. Heat exchanger that is severely foul will experience significant drop in the duty and large heat loss. Drop in heat transfer coefficient due to fouling result in less efficient heat transfer. With constant surface area and mean temperature difference, the amount of energy recovered will be less during fouled condition.

In Crude Distillation Unit (CDU) before entering the column crude will be further heat using fired heater. Loss of duty in the preheat train can be covered by the heat supplied from the heater. However it comes with additional fuel cost. Severe fouling may led to excessive load on the heater. This is one of the factor that may led either reduce in throughput or unit shutdown.

The effect of fouling on Preheat 2 is more severe compared to Preheat 1. In Figure 4-3 shows that Preheat 2 has larger duty loss compared to Preheat 1 except for E2, E6, E7 and E11. The first three heat exchangers do not have any change on Preheat 2 as the hot stream is other product streams so the result is the same.

High duty loss for heat exchanger in Preheat 2 means the allocation of high fouling stream on the shell side results in large drop in the overall heat transfer coefficient. The resistance due to fouling in Preheat 2 is larger compared to Preheat 1. As the ease of heat transfer dropped, amount of energy recovered from hot stream is smaller.

The larger economic loss for Preheat 2 is explained by the loss of duty for the heat exchanger. More fuel required to produce the energy to cover the duty loss. Table 4-2 gives the summary on the effect of fouling on the heat exchanger performance and the economics. As a result of fouling refinery need to spend not less than RM 5 million per year for fuel. Minimizing the effect of fouling will help to reduce the additional utility consumption.

Heat Exchangers	Q_{loss}, GJ/year		Economic Loss, RM/year	
	Preheat 1	Preheat 2	Preheat 1	Preheat 2
E1	5.395E+04	5.956E+04	6.474E+05	7.147E+05
E2	2.538E+04	2.602E+04	3.045E+05	3.122E+05
E3	2.260E+04	3.554E+04	2.712E+05	4.265E+05
E4	7.350E+03	1.023E+04	8.820E+04	1.228E+05
E5	1.166E+04	1.637E+04	1.400E+05	1.964E+05
E6	2.238E+04	2.238E+04	2.686E+05	2.686E+05
E7	3.220E+04	3.221E+04	3.864E+05	3.865E+05
E8	8.281E+03	9.663E+03	9.937E+04	1.160E+05
E9	9.738E+04	1.037E+05	1.169E+06	1.244E+06
E10	1.219E+05	1.234E+05	1.463E+06	1.481E+06
E11	3.793E+04	2.475E+04	4.551E+05	2.970E+05
Total	4.410E+05	4.638E+05	5.292E+06	5.566E+06

Table 4-2: Effect of Fouling on Crude Preheat Train

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the results, under clean condition Preheat 2 can recover more energy compared to Preheat 1. Reallocation of crude streams to shell side against all pump around streams and residue to shell side against crude stream improve the overall heat transfer coefficient.

Under the fouled condition, loss of duty in Preheat 2 is larger compared to Preheat 1. However the total energy recovered in Preheat 2 remain larger than Preheat 1 but the difference is smaller compared to under clean condition. Allocation of high fouling stream on shell side result in large drop in heat transfer coefficient for heat exchanger in Preheat 2. The configuration fails to reduce the impact of fouling on heat exchanger performance.

Reallocation of streams in Preheat 2 can help refinery to reduce in their annual operating cost both under clean and fouled condition of heat exchanger. This is because in comparison to total energy recovered in Preheat 2 is larger compared to Preheat 1 in both condition. In order to preheat crude from 39^oC to 232^oC, Preheat 2 is a better configuration compared to existing Preheat 1.

From the simulation result we can conclude that fouling is seriously affecting the performance of CPT. Fouling may result in more than 25 percent loss of heat exchanger duty in CPT. With the new concept there is opportunity to recover more heat both under clean and fouled condition. However the severity of fouling on the surface area will be higher as high fouling fluid is allocated on the shell side. An extensive study should be done before any changes were made.

5.2 Recommendation and Future Work

With the objective to study the performance of heat exchanger and the effect of fouling on Crude Preheat Train (CPT) is successfully achieved, there are a lot of work can be done on the issue relating to fouling in Crude Preheat Train. From the two available CPT designs, study can be done on the fouling accumulation rate and the pressure drop across heat exchanger as a result of fouling.

The faster fouling accumulate the shorter life-cycle of heat exchanger. The larger the accumulation the larger pressure drop across heat exchanger. Both topics are inter-related and the result will complete the finding from this project. As this project show the loss of economics for additional fuel, extensive study on the accumulation and pressure drop will show the additional energy for pumping required and threshold period before the pressure drop become too large.

In order to help the project to have a smooth progress, students choosing this topic should have a short stint in the real plant. This will help their understanding on the unit itself. It also provides them with the ease of real time data. With a real time data, the simulation and calculation is more accurate and the impact observes will be the same.

CHAPTER 6

REFERENCES

(n.d.). August 31, 2010, *http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html*

Wolverine Tube Inc, *Heat Transfer Databook*, *http://www.wlv.com/products/databook/ch1_4.pdf*, 2 December 2010

A. S. ,Mujtaba (2007). Minimisation of fuel energy wastage by improved heat exchanger network desin -an industrial case study. *ASIA PACIFIC JOURNAL OF CHEMICAL ENGINEERING*, 575-584.

C.D.S.Silva, F. E. (n.d.). Fouling Model For Real Time Heat Exchanger Fouling. *4th Mercosur Congress on Process Systems Engineering*, (pp. 1-10). Rio de Janeiro.

C. V., Krishna M. Yerramsetty (2008). Synthesis of cost-optimal heat exchanger networks using differential evolution. 1861-1876.

D. I., K. P. Papalexandri (1998). Heat Integration Aspects in a Crude Preheat Refinery Section. 141-148.

D. S., Wagensveld (2007, May). HYDROCARBON PROCESSING. *Redesign crude preheater train for efficiency*. West Melbourne, Victoria, Australia.

M. B. , Ji (2001). Rigorous Procedure for the Design og Conventional Atmospheric Crude Fractionation Units. Part 1:Targeting. *Ind. Eng Chem. Res.*, 617-626.

M. F., R. Mohammadhasani Khorasany (2009). A novel approach for synthesis of cost-optimal heat exchanger networks. 1363-1370

R. K. Sinnot (1998). *CHEMICAL ENGINEERING, Vol 6, 2nd Edition.* Butterworth Heineman.

R. N. Watkins (1979). *Petroleum Refinery Distillation.* Texas: Gulf Publishing Company.

S. S., Ebrahim Rezaei (2009). Heat exchanger network retrofit by coupling genetic algorithm with NLP and ILP methods. 1451-1459.

Z. H. Li, B. H. (2000). Modeling and optimizing for heat exchanger network synthesis based on expert system and exergo-economic objective function. 1223-1228.

CHAPTER 7
APPENDICES

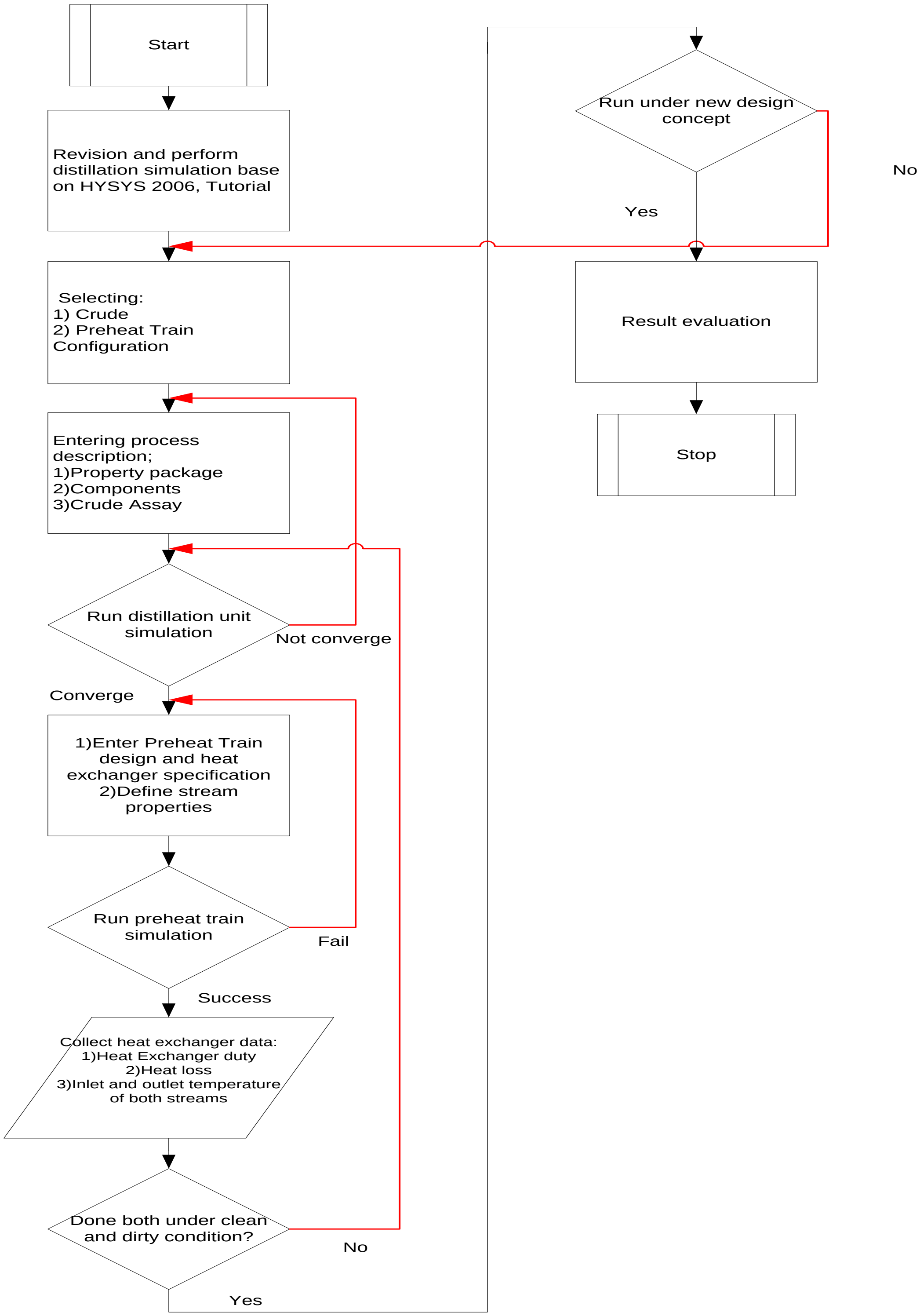

Figure 7-1: Project Flow

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic	■	■													
2	Literature Review and Theory		■	■	■											
3	Submission of Preliminary Report					■										
4	Seminar 1						■	■								
5	Project Work					■	■	■								
6	Submission of Progress Report										■					
8	Project work continues									■	■	■	■	■		
9	Submission of Interim Report Final Draft															■
10	Oral Presentation															■

Table 7-1: Milestone 1

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Preheat 1 Simulation															
2	Submission of Progress Report 1															
3	Preheat 2 Simulation															
4	Submission of Progress Report 2															
5	Preheat Fouling Analysis															
6	Poster Exhibition															
7	Submission of Dissertation (soft bound)															
8	Final Oral Presentation															
9	Submission of Project Dissertation (Hard bound)															

Table 7-2: Milestone 2