MODELING AND SIMULATION OF CRUDE DISTILLATION UNIT (CDU)

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ABSTRACT

There is rapid growth in the usage and demand of crude oil in various industrial fields. Thus, the price of the petrol is rising due to the stronger-than-expected demand for petroleum products. Nowadays, simulation has become an important tool in the behavior study of almost all chemical processes. A proper modeling can bring great advantages to an industry, among them, the increase in knowledge about the process without the need to carry out the real processes. A good model is necessary to develop a proper control strategy for crude distillation unit (CDU) as it can provide more accurate behaviour study of the real system. Due to the lack of proper simulation of CDU, this research is aimed to develop modeling and simulation of CDU. Data of crude oil, the operating conditions of the involved units, and other essential data were collected and entered into the simulation software, Aspen Plus to generate the CDU model. The completed simulation of CDU was run and the results were studied. By solving model equations, the effect of different operating conditions of petroleum refining towards the yield and composition of petroleum products was determined. The higher the feed flow rate, the higher the products feed flow rates. To ensure the simulation is working, the results obtained were compared to previous works done by other researchers and were proven to be valid. Various information about the system under study were obtained easily using the CDU simulation model. The objectives of this research were accomplished.
ABSTRAK

PEMODELAN UNIT PENYULINGAN MINYAK MENTAH

Penggunaan dan permintaan terhadap minyak mentah semakin meningkat dalam pelbagai industri. Justeru, harga petrol turut meningkat disebabkan permintaan yang lebih tinggi daripada penghasilan produk petroleum. Pada masa kini, simulasi telah menjadi suatu alat yang penting bagi mengkaji sistim pelbagai proses kimia. Suatu model yang baik akan membawa kebaikan kepada sesuatu industri, seperti menambahkan ilmu berkaitan suatu proses tanpa menjalankan proses tersebut. Model yang baik diperlukan untuk mengembangkan strategi kawalan yang sesuai untuk unit penyulingan minyak mentah kerana ia dapat memodelkan keadaan sistem yang dikaji dengan lebih tepat. Disebabkan kekurangan model unit penyulingan minyak mentah yang tepat, kajian ini bertujuan untuk menjana model unit penyulingan minyak mentah.

Data minyak mentah, keadaan operasi bagi unit yang terlibat dan data penting yang lain telah dikumpulkan dan dimasukkan ke dalam perisian simulasi, Aspen Plus untuk menjana model unit penyulingan minyak mentah. Simulasi yang telah siap telah diujii dan keputusan yang diperoleh telah dianalisis. Dengan menyelesaikan persamaan model, kesan keadaan operasi yang berbeza dalam penapisan petroleum terhadap hasil dan komposisi produk petroleum telah dikaji. Semakin tinggi kadar aliran masuk minyak mentah, semakin tinggi kadar aliran keluar produk petroleum. Bagi memastikan model yang dijana berkeses, keputusan yang diperoleh telah dibandingkan dengan kajian-kajian yang pernah dijalankan oleh penyelidik lain dan telah terbukti sah. Pelbagai maklumat mengenai sistem yang dikaji dapat diperoleh dengan mudah dengan menggunakan model simulasi unit penyulingan minyak mentah ini. Objektif kajian telah tercapai.
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<td>Atmospheric distillation unit</td>
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<td>AE</td>
<td>Algebraic equations</td>
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<td>AGO</td>
<td>Atmospheric gas oil</td>
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<td>API</td>
<td>American Petroleum Institute</td>
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<td>ASTM</td>
<td>American Society for Testing and Materials</td>
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<td>BK10</td>
<td>Braun K10</td>
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<td>CDU</td>
<td>Crude distillation unit</td>
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<td>CS</td>
<td>Chao-Seader</td>
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<td>English Engineering units appropriate for Petroleum applications</td>
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<td>Pumparound</td>
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<td>PC</td>
<td>Pseudocomponent</td>
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<tr>
<td>PID</td>
<td>Proportional Integral Derivative</td>
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<td>True boiling point</td>
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CHAPTER 1

INTRODUCTION

1.1 Background of Study

A model is a representation of a real object or system of objects for visual or behavior analyzing purposes. Simulation is the transition of a mathematical or computer model to a description of the system behavior based on sets of input parameters (Barr, 2007). Modeling and simulation are important in engineering because description of system behavior by experimentation might not be feasible due to inaccessible inputs and outputs, experiment is too dangerous, very high experimentation cost, experimental behavior might be obscured by disturbances and/or time constants of the system may not be compatible with human dimensions.

There are two types of modeling, namely steady state modeling and dynamic modeling. The models for chemical processes are generally developed for steady state and dynamic modes (Goncalves, Martins, & Feyo de Azevedo, 2010). Steady state models can generally perform steady state material and energy balances, determine different plant scenarios, and optimize capital and equipment costs to obtain best profits, which is very useful in project stage. However, steady state models are of limited use because chemical plants do not operate in steady state. This is where dynamic models come in
vital need. Dynamic models describe the change of system properties over time. Dynamic modeling can provide users a better understanding and operational capabilities of dynamic processes. Therefore, nowadays dynamic simulation has become an essential tool in behavior study of almost every process.

Crude distillation units (CDU) are fractional distillation columns for the distillation of crude oils. A CDU is also known as an atmospheric distillation column (ADU) as it operates at atmospheric pressure. It is the first major unit in refineries for crude oil processing, the central, and the most important unit of all crude oil refineries (Goncalves et al., 2010) because distillation is the first step in the processing of crude oil. CDUs are key process plants in petroleum refinery because they produce intermediate streams that are used in downstream process units. In the CDU, crude oil, which is a mixture of many types of hydrocarbons, is boiled and condensed to separate the crude oil into various components such as naphtha, kerosene, diesel and gas oil, based on the boiling points of the respective components. Figure 1-1 shows the basic flow diagram for conventional distillation and associated unit operations. PA in Figure 1-1 stands for pumparound while HEN stands for heat exchanger network.

Changes in CDU have great impact on product yields and quality (Lopez, Mahecha, Hoyos, Acevedo, & Villamizar, 2009). Therefore, CDUs are recommended to be operated at optimal conditions from technical and economical aspects.

Many types of commercial process simulators are available in the market today. In this research, Aspen Plus will be used to develop the steady state CDU simulation.
Crude oil or petroleum is a complex mixture of carbon and hydrogen, which exist as a liquid in the earth's crust (Ophardt, 2003). Crude oils vary in colour, from clear to tar-black, and in viscosity, from water to almost solid. Crude oils need to be refined before it is further processed into various products for human daily usage such as vehicle petrol and plastic chairs.

In crude oil distillation process, crude oil is desalted in a Desalter and then heated to about 350°C-400°C in a series of heat exchangers before being piped into a CDU. Figure 1-2 shows the fractionation column and trays. In the CDU, the liquid falls to the bottom and the vapor rises, passing through a series of perforated trays called sieve trays. Heavier hydrocarbons condense faster than the lighter ones and will settle on lower trays while lighter hydrocarbons condense on higher trays. The liquid fractions are then drawn out from the unit. Light gases, methane, ethane, propane and butane are collected from the top of the column, petrol is formed in top trays, kerosene and gas oils in the middle, and fuel oils at the bottom (Refining of Petroleum, n.d.). The residue
drawn from the bottom may be processed into lubricants, waxes and bitumen, burned as fuels or used as feedstock for cracking units. Crude oil products obtained after the distillation in the CDU can be further processed into various useful products for human daily life usage, for example, vehicle petrol, chemicals in skincare products and lubricants in factories.

Figure 1-2 Fractionation Column and Trays

1.2 Motivation and Problem Statement

There is rapid growth in the usage and demand of crude oil in various industrial fields such as plastic industry, synthetic rubber industry and pharmaceutical industry. The crude oil refining process should be studied more carefully so as to provide more information to engineers to upgrade or enhance the efficiency of the various equipments required. This is where the dynamic modelling and simulation of CDU comes in useful.

Dynamic models allow us to understand the behavior of the dynamic system of study besides resolving industrial problems or processes that are of immediate and contemporary interest. Although distillation is a widely used unit operation in chemical
process industries, the development of dynamic models continues to be an active research area (Wong & Seborg, n.d.). In crude oil distillation process, when the feed flow rate or feed composition in altered, the product compositions will change as well. According to Radulescu (2007), due to the importance of CDU and its complexity as well as high energy consumption involved, it is very important to have powerful instruments to intimately study it. Since the dynamic modeling of CDU is quite difficult due to process complexity and problems affecting the numerical integration of the model equations, there is no proper dynamic model and simulation of CDU (Radulescu, 2007). A proper dynamic simulation of CDU can provide the people working with this system a wider knowledge about its behavior besides serving as a demonstration during trainings for new engineers in the industry. Therefore, it is necessary to have an accurate dynamic modeling of a CDU in order to have full control over the unit after it is built.

1.3 Research objective

The objectives of this research are:

i) To develop a model of CDU

ii) To study the effect of different operating conditions of petroleum refining toward the yield and composition of petroleum products by solving model equations

1.4 Scope of Study

The scopes of this research have been identified in order to achieve the research objectives. The scopes are:

i) To develop a model of CDU based on the component and overall mass balance, enthalpy balance, and vapor-liquid equilibrium equation by building up a mathematical model for the crude oil refining process

ii) To validate the model by comparing the model results and the data obtained from previous researches done by other researchers
1.5 Main Contribution of This Work

The followings are the contributions that this study could provide:

i) Improve previous researches on dynamic modeling and simulation of CDU

ii) Solve problems faced by crude refining industries

1.6 Thesis Organisation

The structure of the remainder of the thesis is outlined as follow:

Chapter 2 presents the review of previous studies done related to this research. This chapter discusses in detail about the mathematical model for CDU, thermodynamic method which will be chosen, types of mathematical model available, the simulation software which will be used for this study, which is Aspen Plus (for steady state CDU model simulation), the boiling point analysis, as well as the assumptions and simplifications that will be made for this study. A summary of past researches is included in this chapter.

Chapter 3 gives an overview of the simulation environment. This chapter introduces the general procedure in developing a dynamic model, starting from the very first step, which is to define the objectives of the research. Besides that, the steps involved in developing a simulation of CDU model using Aspen Plus are described in this chapter.

Chapter 4 presents the result obtained from the completed simulation of CDU, which are illustrated in the form of graphs and tables. Comparisons of result obtained with past researches are also discussed in this chapter.

Chapter 5 consists of the summary made for this research, together with the recommendation for future research related to this research topic.
CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter presents the detailed information and classification of crude oil, as well as the details about the CDU besides describing the importance of modeling and simulation. This chapter also discusses about the mathematical model for CDU in detail. Next, this chapter also reviews the thermodynamic methods, types of mathematical model and the modeling software which are involved in this study. Lastly, this chapter includes the boiling point analysis, the assumptions and simplifications which need to be considered in this study, and the summary of past researches done by other researchers.

2.2 Introduction

Different regions on earth tend to have different types of crude oil, so crude oil is often classified based on where it comes from. Crude oil quality is measured in terms of density and sulfur content. Its density is classified as light, medium or heavy according to its measured American Petroleum Institute (API) gravity. API gravity is a measure of how heavy or how light a petroleum liquid is compared to water at a temperature of
15.6°C (Facts About Crude Oil, 2000). Light crude has API gravity higher than 38°API, medium crude has API gravity between 22.3°API and 31.1°API, and heavy crude has API gravity below 22.3°API. If its API is greater than 10, it is heavier than water and therefore, sinks. Most values fall between 10°API and 70°API. Lighter oils are more valuable than heavy oils because more gasoline can be created from a smaller amount. According to Facts about Crude Oil (2000), crude oil with sulfur content less than 0.5% is commonly defined as sweet crude, while sour crude has sulfur content greater than 0.5%. To extract the maximum value from crude oil, it first needs to be refined into petroleum products.

There are different types of CDU model available for the distillation of crude oil. To achieve a good separation between the different products, the CDU is designed to have 30 or more trays. A CDU can be divided into two sections: rectifying section and stripping section. The rectifying section of the CDU uses heat to separate the components of crude oil based on their volatilities. The temperature of each tray decreases as the vapor proceeds up the CDU, allowing only the more volatile components to continue travelling upwards through the CDU (Brunetti, Howard, & Bagajewicz, n.d.). There is a condenser on top of the column, which condenses the exiting overhead vapor stream. The condensate is parted into two portions: one will be refluxed as a liquid phase that cascades down the column while the other will exit the condensate as distillate. According to Brunetti et al. (n.d.), the stripping section is similar to the unit operation of stripping. In conventional distillation model, steam enters the bottom tray in the CDU and rises through the trays below the feed, stripping the lighter components to the rectifying section. The crude oil components are separated by the stripping action of the steam. Besides having strippers, the CDU also consists of pumarounds, which are required to ensure liquid reflux within the column. According to Hovd, Michaelsen & Montin (1997), the upper and lower pumarounds are where liquid is withdrawn from the column and heat exchanged before being returned to the column. These pumarounds and the capacity of the condenser for the top product are important constraints when maximizing throughput and optimizing energy efficiency, but are not used for control of product quality or yield (Hovd et al., 1997). In order to recover as much heat as possible from the distilled units, pumaround streams and product streams recover heat in the preheat trains for the column feeds. The complex heat integration schemes and the interactive nature of the process due to the presence of
pumparound and side-stripper distillation features make it difficult to operate at the optimal conditions (Robertson, Palazoglu & Romagnoli, 2011). According to Robertson et al. (2011), the decision variables of the operational level are the stripping steam mass flow rates, product flow rates, pumparound flow rates, overhead column flow rates, and atmospheric and vacuum furnace outlet temperatures.

Dynamic models allow us to examine relationships that could not be sorted out by purely experimental methods, and to make forecasts that cannot be made strictly by extrapolating from data (Ellner & Guckenheimer, 2006). Dynamic simulation allows the prediction of dynamic behavior of the process and also assists in evaluation or design of the control strategies (Bezzo, Bernardi, Cresmonese, Finco & Barolo, 2004) besides being an essential prerequisite for a project engineer attempting to design new units or rate existing units (Kumar, Sharma, Chowdhury, Ganguly & Saraf, 2001). Using modeling and simulation software to construct a model for the system of study can save the time by 80% compared to constructing an actual working model, besides saving cost (Guven, n.d.). According to Guven (n.d.), by using a software prototype and testing the model under computerized simulation conditions, it enables users to quickly and easily find out the problem encountered by the model. With computer modeling and simulation, engineers do not need to retest the same part of operation with thousands of different configurations, which would cost thousands of dollars as well as hours to accomplish, because a computer software prototype can be easily used to test it on thousands of different conditions.

### 2.3 Mathematical Model for CDU

Mathematical model is an abstract model that uses mathematical languages to describe the behavior of a system. Mathematical modeling can be used in many cases, for example, to develop scientific understanding through the quantitative expression of current knowledge of a system, to test the effect of changes in a system, and to aid decision making (An Introduction to Mathematical Modelling, n.d.).

According to Doust, Shahraki & Sadeghi (2012), the appropriate way to solve a problem involving multiple-stage separation for systems in which different phases and different components play their parts, is to resort to simultaneous or iterative solutions of hundreds of equations. It is necessary to specify a sufficient number of design
variables so that the number of unknown quantities, the output variables, is exactly the same as the number of equations, the independent variables (Doust et al., 2012). This set of equations can be found and counted in a mathematical model.

The model equations for an ordinary equilibrium stage of a simple distillation column, namely mass balance, equilibrium, summation and enthalpy balance (MESH), need to be solved first as mathematical modeling is an important part of economic design. These are the fundamental material and energy balance equations which can facilitate numerical stability and ease of convergence (Kumar et al., 2001). For dynamic modeling, the ordinary differential equations (ODE) and algebraic equations (AE) will need to be solved too, as they are important to show changes within the process with time. According to Kumar et al. (2001), from a practical viewpoint, it is not possible to represent the crude oil feed or its distillation products in terms of actual component flow rates or mole fractions since crude oil is a mixture of several hundred constituents which are not easy to analyze. A general practice is to express the composition of crude oil in terms of a finite number of pseudo-components and each pseudo-component is characterized by an average boiling point and an average specific gravity and is treated as a single component (Kumar et al., 2001).

According to Haydary & Pavlik (2009), theoretical stage method is usually used for mathematical description of a distillation process in refining columns. The real number of stages might need to be multiplied by column efficiency in order to find the number of theoretical stages of an existing column (Doust et al., 2012). The mass balance for individual components or pseudo-components, enthalpy balance, and vapor liquid equilibrium equation can be written for each theoretical stage. The sum of these equations creates the mathematical model of a theoretical stage which in turn makes up the mathematical model of a column.

2.4 Thermodynamic Method

One of the fundamentals to process simulation is to select a suitable thermodynamic model for the prediction of the enthalpy (H) and the phase equilibrium (K) (Edwards, 2008). The appropriate thermodynamic method is the most essential step in developing an accurate simulation without errors. The selection of appropriate thermodynamic model depends on the detailed knowledge of thermodynamics and practical experience.
Guidelines for thermodynamic method selection includes the process species and compositions, pressure and temperature operating ranges, system phases involved, nature of the fluids, and the availability of data (Edwards, 2008). There are four categories of thermodynamic models or four main types of Property Methods and they are Ideal, Equations-of-State (EOS), Activity Coefficient, Empirical and Special System Specific. Petroleum-tuned EOS are used at high pressures. The hydrocarbons can be from natural gas or crude oil, that is, complex mixtures that are treated using pseudo-components.

According to Kumar et al. (2001), computation of equilibrium constants of various components present and enthalpies of different streams as the function of temperature and composition are essential for a distillation column simulator. Empirical or semi-empirical correlations are commonly used in estimating these thermodynamic properties (Kumar et al., 2001). The four categories of thermodynamic Property Methods mentioned in the paragraph above are available in Aspen Plus. However, there are only two groups of methods suitable for crude oil refining process. One is based on the EOS of gas while the other is specially developed for hydrocarbon mixture. The state of equation of gases is suitable for real components. Peng-Robinson (PR) and Redlich-Kwong-Soave (RKS) are examples of state equations. The group which is specially developed for hydrocarbon mixture is suitable for pseudo-components. Examples are Braun K10 (BK10) and Chao-Seader (CS). Kumar et al. (2001) stated that the thermodynamic properties of vapor-liquid mixtures are usually predicted by calculating deviations from ideality of both the vapor and liquid phases by using any of the EOS. Another method is to apply the EOS only to the vapor state while the liquid phase deviations from ideal behavior are calculated using thermodynamic excess functions.

Doust et al. (2012) and Haydary & Pavlik (2009) stated that the unit that should be used in CDU modeling is the thermodynamic model BK10 because it is suitable for mixtures of heavier hydrocarbons at pressures under 700 kPa and temperatures from 170°C to 430°C. BK10 is used primarily for crude and vacuum columns operating near atmospheric or subatmospheric pressure (Thermodynamic Data Section, n.d.). The BK10 model can only be used to predict the properties of heavy hydrocarbon systems at low pressures (Doust et al., 2012). According to Aspen Physical Property System (2009), K10 values can be obtained by the Braun convergence pressure method using tabulated parameters for 70 hydrocarbons and light gases. K value is calculated at
system temperature and 10 psia using the Braun convergence pressure method by the model at the given normal boiling point of a component. Then, the K10 value is corrected for pressure using pressure correction charts. K values for any components that are not covered by the charts at 10psia and corrected to system conditions using the pressure correction charts can be found using the modified Antoine equation (Aspen Physical Property System, 2009).

2.5 Types of Mathematical Model

Mathematical modeling problems are often classified into black box or white box models, depending on how much information is available for the system. It is important to choose the right model type when modeling a chemical process so that accurate results can be obtained without wasting computing power and time. Model set selection is determined from the information available. The more the available information, the better the construction of the model and the more the model would resemble its system (Ablameyko, 2003). When choosing the right model type, the flexibility of the model is considered, whether how changes in the design could affect certain aspects of its behavior. A good model designed for long term project needs to be flexible so as to keep up with unexpected design changes. The availability of resources needs to be considered too. In cases where the type of model used is limited by the available computing power, the model needs to be simplified. Finally, the number of approximations that can be safely made must be taken into consideration. Appropriate approximations can greatly increase the efficiency of a model, provided that the approximations do not reduce the model accuracy (Tarr, n.d.). There are three types of modeling, namely black box, grey box and white box.

According to Ablameyko (2003), the black box model is also known as input-output model or empirical model. It is characterized with its input-output behavior without any detailed information about its structure. The elements of a black box model structure have no physical meaning as the model structure does not reflect on the structure of the physical system. Tarr (n.d.) stated that a pure black box model does not describe the internal workings of a device, and that it only solves a numerical problem without reference to underlying physics. Usually, a set of transfer parameters or empirical rules are taken to relate the output of the model to a set of inputs. When the response of a
system is not broken down into its underlying mechanisms, a black box model is used. Black box models are easy to optimize, can run very rapidly and do not require huge computing power as it is a relatively simple model. However, black box model is lacking in flexibility. A lot of work need to be done to determine any new rules or bulk parameters if the model needs to be changed to describe something physically only slightly different. Black box model is also lacking in any form of physical meaning, making it hard to relate the model to the actual device which is being modeled. Black box models come handy when an answer to a specific problem is required while the flexibility to change aspects of a model to see the effect is not required. This model is suitable to be used to provide quick, approximate answers, based on a pre-determined set of input parameters because flexibility is not required as the overall design has already been fixed.

Grey box model is basically the combination of both black box and white box. It provides a physical representation but with some of the physics is approximated (Tarr, n.d.). Most simulation models are grey box models. Grey box model provides more flexibility and enables the use of modeling to optimize a design instead of just providing data based on a fixed design. The internal workings of the design are partly known. Grey box models can be used for design sensitivity analysis, whereby the sensitivity of a design towards a particular aspect is determined.

According to Robinson (2004), a black box model is often the primary test for simulation and its validation should not be relied upon solely. On the other hand, white box model provides a simulation closest to the real behavior of the design being studied. Tarr (n.d.) stated that the white box model is the most detailed type of model and is close to provide a full description of the real device. The method of presentation of a model to its eventual user depends to an extent on how much the knowledge the user knows about the model (An Introduction to Mathematical Modelling, n.d.). Since much information on CDU is obtained through literature, the white box model simulation is used for this research. The physical processes are described at low levels as possible, with no approximations or bulk parameters used so that the simulation would model the actual process accurately. The advantage of using white box models is that they are extremely flexible as everything is modeled at low level. The behavior of the model can be changed in minute detail according to the actual physics. Another advantage is that white box models provide closest match to the real device and models the behavior of a
real device closely to its actual behavior. However, white box models are the most complex types of model to be set up and implemented, which also renders them the slowest running type of model. The complexity of the model requires fast running computers and large memory space. White box model can be used for the same applications as a grey box model but it provides greater realism.

2.6 Modeling Software

There are many commercial process simulators available in the market today. In this research, Aspen Plus will be used in the modeling and simulation of CDU. Aspen Plus is one of the most widely used simulators (Yela, 2009). The steady state model and simulation requirements will be fitted into Aspen Plus. The specification of crude oil and CDU was designed where the model simulation will be done using Aspen Plus (Haydary & Pavlik, 2009).

2.7 Boiling Point Analysis

Petroleum refining industry deals with boiling point ranges. The temperature at which the first vapor formed is called the ‘initial boiling point’ which corresponds to the bubblepoint of a mixture of specific chemical components (Luyben, 2006). The material will vaporize more if sample heating is continued. The ‘5% point’ is the temperature at which 5% of the original sample has vaporized (Luyben, 2006). The liquid volume percents are more commonly used. The ‘95% point’ is the temperature at which 95 liquid vol% of the original sample has vaporized (Luyben, 2006).

There are three types of boiling point analysis, namely ASTM D86 (Engler), ASTM D158 (Saybolt) and true boiling point (TBP). ASTM D86 is the standard test method for distillation of petroleum products at atmospheric pressure (ASTM International, n. d.). According to Luyben (2006), ASTM D86 and ASTM D158 are similar to the boiling point off vapor as described in the previous paragraph, while in TBP, the vapor from the container passes into a packed distillation column and some specified amount is refluxed. Thus, the TBP analysis exhibits some fractionation while the ASTM analysis is just single-stage separation (Luyben, 2006). ASTM analysis is easier and faster to run while the TBP analysis gives more detailed information about the contents of the crude (Luyben, 2006). Therefore, TBP will be used in this research. Ali & Yusoff (2012)
stated that refining engineers analyze the TBP curves of the ‘cuts’ present to determine the behavior of the crude distilled and various saleable products. ‘Cut points’ define the range of boiling points in a given product (Dave, Dabhiya, Ganguly & Saraf, 2003).

Ali & Yusoff (2012) also stated that the TBP curve is one of the most significant characteristic features of the feedstock which decides the amounts of various fractionation products available from the crude as well as the composition and properties of these products. The accuracy and success of property prediction depends mainly on the accuracy of the TBP curve used. Therefore, it is an integral part of the property prediction procedure (Ali & Yusoff, 2012). Commonly, the TBP data of pure crude is available from the crude assay which may not represent the crude being processed at a later time because these deviations may arise due to various reasons like blending of different crudes, contamination of one crude with another in storage tanks or the crude being produced from a different section of the reservoir at different times (Ali & Yusoff, 2012).

2.8 Assumptions and Simplifications

Professional engineering judgment and decisions are important when it comes to making assumptions related to chemical processes. Assumptions are made in order not to complicate matters unnecessary. The followings are assumptions that apply to CDU simulation based on Kumar et al. (2001), Luyben (1990) and Gabriel (2007):

i) Crude oil compositions are expressed in terms of pseudo-components
ii) Dynamic component of condenser and reboiler are negligible
iii) Ideal heat rate balance in absence of interface resistance
iv) Equilibrium temperature is dependent variable
v) Perfect mixing in column and the fluid is incompressible
vi) Heat of mixing is negligible
vii) Fluids are in thermal equilibrium but not phase equilibrium

2.9 Summary of Past Researches

Table 2-1 shows the past researches done related to modelling and simulation of CDU. These past researches done by various researchers are useful in this research as they
provide much information which is used as reference needed in succeeding this research.

Table 2-1 Summary Table for Researches

<table>
<thead>
<tr>
<th>No.</th>
<th>Research</th>
<th>Validation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dynamic Simulation of Crude Oil Distillation Plant</td>
<td>Close to real system behavior</td>
<td>Radulescu, G. (2007)</td>
</tr>
<tr>
<td>2</td>
<td>CDU Simulation (includes Pre-flash column)</td>
<td>No research data to be compared</td>
<td>Haydary, J., &amp; Pavlik, T. (2009)</td>
</tr>
<tr>
<td>4</td>
<td>Modeling of Diesel Distillation</td>
<td>Close to lab results</td>
<td>Kumar, S. S (n.d.)</td>
</tr>
<tr>
<td>5</td>
<td>Simulation Models in Operations</td>
<td>Close to real system behavior</td>
<td>Schumann, D., Davis, G., &amp; Shah, P. (n.d.)</td>
</tr>
<tr>
<td>7</td>
<td>CDU suitable for online applications</td>
<td>Valid</td>
<td>Kumar, V., Sharma, A., Chowdhury, I. R., Ganguly, S., &amp; Saraf, D. N. (2001)</td>
</tr>
<tr>
<td>8</td>
<td>Simulations of Kaduna Refining &amp; Petrochemical Company CDU Using Hysys</td>
<td>Column need to be optimized</td>
<td>Jibril, M., Folorunsho, A. D., &amp; Manasseh, A. (2012)</td>
</tr>
</tbody>
</table>

2.10 Summary

This chapter presented the detailed information about crude oil and its classification, the design of CDU, and the importance of models and simulation. The mathematical model
and process simulation involved in this study are discussed. The selection of thermodynamic method is included in this chapter as well. Next, the model types for mathematical model problems and the modeling software, Aspen Plus is reviewed. Then, the boiling point analysis and the assumptions made for this research are also included in this chapter. Lastly, this chapter presented the summary table for the past researches done by other researchers.