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DETERMINATION OF OPTIMUM OPERATING PARAMETERS OF CRUDE OIL DISTILLATION UNIT

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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SALWAN KANAAN ALWAAN AL-AJEELE

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DETERMINATION OF OPTIMUM OPERATING PARAMETERS OF CRUDE OIL DISTILLATION UNIT

By Salwan Kanaan Alwaan AL-AJEELE

July 2023

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

Advisor : Assoc. Prof. Dr. Barış ŞİMŞEK
Co-Advisor : Assoc. Prof. Dr. Ömer Faruk DİLMAÇ

Examining Committee Members:

Chairman : Assoc. Prof. Dr. Uğur ÖZVEREN
Chemical Engineering
Marmara University

Member : Assoc. Prof. Dr. Ömer Faruk DİLMAÇ
Chemical Engineering
Çankırı Karatekin University

Member : Asst. Prof. Dr. Semahat DORUK
Chemical Engineering
Çankırı Karatekin University

Approved for the Graduate School of Natural and Applied Sciences

Prof. Dr. Hamit ALYAR
Director of Graduate School

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Salwan Kanaan Alwaan AL-AJEELE

ABSTRACT

DETERMINATION OF OPTIMUM OPERATING PARAMETERS OF CRUDE OIL DISTILLATION UNIT

Salwan Kanaan Alwaan AL-AJEELE
Master of Science in Chemical Engineering
Advisor: Assoc. Prof. Dr. Barış ŞİMŞEK
Co-Advisor: Assoc. Prof. Dr. Ömer Faruk DİLMAÇ
July 2023

The operational conditions together and the study of their impact make engineers provide more products in less quantities and less time and increase the efficiency of operational and production units. The purpose of the study is to obtain the ideal results for the products coming out of the distillation tower and to analyze the difference of some information by increasing or decreasing in some operational conditions on the products and their quantities. The results of the simulations are compared with the results of the real unit in the oil refineries. During the process, the variables that directly affect the results of the treatment, such as temperature, pressures, and concentrations, are closely monitored because they affect each other, so the modification of one variable affects the course of the entire process. The simulation process was used using the PRO// program to study the effect of changing some operating conditions on the products in the oil distillation unit. in the program that several adjustments can be made in the quantities of the required products by controlling the operating variables. It is worth noting that the variables were set according to the ideal operating system to obtain the required quantities. The results were compared to the results of the AL-Dora refinery / crude oil distillation unit. It can be noted in the program that several adjustments can be made in the quantities of the required products by controlling the operating variables. It is worth noting that the variables were set according to the ideal operating system to obtain the required quantities, but due to Depreciation of the equipment's and too long uses in the refinery plant, the operating capacity does not exceed 60%. Therefore, the idea of improving distillation processing will show the way to other simple and practical solutions to obtain products in controlled quantities. Performance design was conducted based on the physical properties of chemical compounds, as the Pro program is an ideal simulation environment to serve the manufacturing and production industries and has many options to expand industrial capabilities. Monitoring, error detection and repair, operational improvement and business planning can also be performed using the Pro //program.

2023, 71 pages

Keywords: Pro//, Simulation, Optimization, Crude distillation unit

ÖZET

HAM PETROL DİSTİLASYON ÜNİTESİNİN OPTİMUM ÇALIŞMA PARAMETRELERİNİN BELİRLENMESİ

Salwan Kanaan Alwaan AL-AJEELE
Kimya Mühendisliği, Yüksek Lisans
Tez Danışmanı: Doç. Dr. Barış ŞİMŞEK
Eş Danışman: Doç. Dr. Ömer Faruk DİLMAÇ
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Operasyonel koşulların ve etkilerinin incelenmesi, mühendislerin daha az miktarda ve zamanda için daha fazla ürün sağlamasını, operasyonel ve üretim birimlerinin verimliliğini artırmasını sağlar. Çalışmanın amacı, distilasyon kulesinden çıkan ürünler için ideal sonuçların elde edilmesi, ürünler ve miktarları üzerinde bazı çalışma koşullarında artma veya azalma ile bazı bilgilerin farklılığının analiz edilmesidir. Benzetim sonuçları petrol rafinerilerindeki gerçek birim sonuçları ile karşılaştırılmıştır. İşlem sırasında sıcaklık, basınç ve konsantrasyon gibi işlem sonuçlarını doğrudan etkileyen değişkenler birbirini etkilediği için yakından takip edilir, bu nedenle bir değişkendeki değişiklik tüm sürecin seyrini etkiler. Yağ damıtma ünitesindeki bazı çalışma koşullarının değiştirilmesinin ürünler üzerindeki etkisini incelemek için PRO// programı kullanılarak simülasyon işlemi kullanılmıştır. Programda, çalışma değişkenleri kontrol edilerek gerekli ürünlerin miktarlarında çeşitli ayarlamalar yapılabilir. Gerekli miktarları elde etmek için değişkenlerin ideal işletim sistemine göre ayarlanmıştır. Sonuçlar AL-Dora rafinerisi / ham petrol damıtma ünitesi sonuçları ile karşılaştırıldı. Programda, çalışma değişkenleri kontrol edilerek gerekli ürünlerin miktarlarında çeşitli ayarlamalar yapılabileceği söylenebilir. Değişkenlerin istenilen miktarları elde etmek için ideal işletim sistemine göre ayarlanmıştır. Ancak ekipmanların amortismanı ve rafineri tesisinde çok uzun kullanımlar nedeniyle işletme kapasitesi %60’ı geçmemektedir. Bu nedenle, damıtma işlemini iyileştirme fikri, ürünleri kontrollü miktarlarda elde etmek için diğer basit ve pratik çözümlere yol gösterecektir. Pro 2 programı imalat ve üretim endüstrilerine hizmet etmek için ideal bir simülasyon ortamı oluşturduğundan ve endüstriyel yetenekleri genişletmek için birçok seçeneğe sahip olduğundan, performans tasarımı kimyasal bileşiklerin fiziksel özelliklerine dayalı olarak inşa edilmiştir. İzleme, hata tespiti ve onarımı, operasyonel iyileştirme ve iş planlaması da Pro 2 programı kullanılarak gerçekleştirilebilir.

2023, 71 sayfa

Anahtar Kelimeler: Pro//, Simülasyon, Optimizasyon, Ham distilasyon ünitesi

PREFACE AND ACKNOWLEDGEMENTS

After a year of hard work, I am happy to finally have come to an end with this thesis. It was an amazing experience, and I will remember it for a long time.

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Last but not the least, I would like to express my endless thanks to my family who always stood by me and encouraged me throughout my life, especially my parents, to whom I am grateful for their support, motivation, and encouragement to reach my goals and achievements.

Salwan Kanaan Alwaan AL-AJEELE
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CONTENTS

LIST OF SYMBOLS

°C	Celsius degree
cm	Centimeter
m^3	Cubic meter
kg	Kilo gram
L	Liter
mm	Millimeter
mL	Milliliter
m^2	Square meter
%	Percentage

LIST OF ABBREVIATIONS

ASTM	American Society of Testing and Materials
Atm	Atmospheric
APC	Advanced process control
API	American Petroleum Institute
Fcc	Fluid creaking catalyst
HGO	Heavy gas oil
IC4	Isobutane
IC5	İsopentane
Kero	Kerosene
LGO	Light gas oil
LPG	Light petroleum gas
C2	Methane
Mmcal	Milimilcalulize
Fg	Off gas
NC5	Propane
C3	Propane
ppm	Part per million
ppt	Part per thousand
PFD	Process flow diagram
PTB	Part per thousand barrels
Rc	Residue
SPPS	Software package process simulation
Vol	Volume
VOL%	Volume percent
WT%	Weight percent
V/V	Volume per volume
W/V	Water per volume

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1. INTRODUCTION

1.1 Literature Review

One of the most important tools that have been introduced into the engineering system in general and especially in chemical engineering are computer programs, which have a wide scope for developing engineering work by providing software services that facilitate and assist in the work of many experiments and designs of models of industrial facilities by entering operational information and operational conditions such as pressure and temperature. Crude distillation is the oldest and most important part of any industry. using many of the tools and techniques currently employed in modern refineries. Opening educational courses to engineers in the early stages of their engineering practice reduces the complexity they face in simulating the original design of a job site and provides develop ideas for engineering work into the reality available today. These simulation programs are essential for understanding practical interaction and communication (Chang *et al.* 2013).

The operational conditions together and the study of their impact make engineers provide more products in less quantities and less time and increase the efficiency of operational and production units. The student should never use a computer unless he knows exactly how the machine is doing. Therefore, he should always be required to do process design calculations by hand. The use of simulation saved time and reduced the risk of lab experiments that were required for engineers to get the best results. The chemical engineering design student is required to calculate the material and energy balance, the size and cost of equipment, the operating cost, and some profitability criterion for each process he studies. One of the tasks of the chemical engineer in engineering design operations is to calculate the balance of energy, materials, volumes, equipment costs, operating costs, and profit returns (Gaddy 1974). In repeated uses, there is experience in manual calculations, but it requires a long period and a little time available to make perfect designs. Therefore, it is necessary to provide educational design courses to apply basic technology in heat and mass transfer processes. Chemical systems are not limited to chemical processes, but to economic analysis of the process that leads to optimal design. Modern programs and methods are always being invented to develop new designs at more economic costs.

That these programs

- Provides learners with further study of engineering processes
- Giving more chances to reach the perfect design
- The engineering class is acquainted with the electronic design methods used in different industries (Gaddy 1974).

The distillation process is one of the most important oil separation processes in oil refineries. Crude oil is a complex mixture of hydrocarbons with varying small amounts of sulfur, nitrogen, salt, and metals such as nickel, vanadium, and copper. The crude points are entered into the distillation unit to separate compounds and molecules through several interactions affected by temperature and pressures to separate compounds into liquids with multiple uses. In general, crude oil consists of several hydrocarbon compounds, sulfur, nitrogen and multiple atoms of salts and minerals. It is extracted mainly from refining processes from the ground, to be sent through multiple tankers such as ships or pipelines to oil refineries to conduct several separation operations to obtain the needed products (Young 2006).

As a general idea of the distillation unit, the most strategic units for the processing of the crude oil. it is considered the most effective unit in the treatment of crude oil, as it consists of a main tower, to which the crude oil enters through heat exchangers previously before it enters the distillation tower and passes through the salt liquids and the thermal furnace. Then it goes out to several separation columns units to obtain kerosene, naphtha, light and heavy diesel products, gas oil and asphalt. Experienced empirical methods are used to obtain the best improvements in the products .it work by the process in the units involves passing the crude oil through preheat trains of exchangers prior to the main distillation or fractionation and the products are also cooled before sending to storage units (Jibril *et al.* 2012).

The separation method depends on the pressures and boiling point of each component in the crude oil, which is mainly composed of several hydrogen and carbon compounds. To improve the performance efficiency of the distillation units, obtain more pure and concentrated components and reduce waste, the designers devised several mathematical methods depending on the number of theoretical stages of the distillation tower, and components and pseudo-components, included to characterize the crude oils stream that were applied to the distillation unit in a simple way in the past in laboratories. Its efficiency is more accurate, simplified, and easy by creating a graphical model, designing the unit, determining the quantities entering and leaving the unit, and stabilizing temperature, pressure and flow rates (López *et al.* 2013).

Crude oil flow consists of the input to the products mainly from: gasoline, kerosene, and asphalt mixture of hydrocarbon compounds. It is useless to make analytical processes for these compounds based on their components. Usually, petroleum consists of small petroleum fractions or similar components resulting from distillation. Similar components are determined from boiling point and gravity, where these two properties are exploited to know the properties of other components required to perform the calculation (Al-Assady 2009).

Distillation is a physical process for the separation of liquid mixtures, based on differences in the boiling points or relative volatility of the constituent components. Although the distillation process is more widely used in oil refineries, it has significant drawbacks represented by high costs due to the size of the basic equipment and costly operational conditions. Therefore, the main incentive for companies is to reduce costs by being guided by energy, reducing conditions, integrating several liquidations, or using alternative sources of energy. The efficiency of the process can be improved through the safe and efficient use of materials and energy, the conservation of water resources, and the creation of a healthy and environmentally friendly environment (Kiss and Biotechnology 2014).

After several successful uses of modeling and simulation programs, administrators have the experience to extend the benefits of simulation to provide a highly perfect refining industry, impacting competition between companies and modern technology by bringing about industrial changes. Such as evaluating the crude, respecting the environmental standards, the capabilities of the oil sites, and the maintenance procedures and sites. The economics of the supply chain are dictated by accurate demand forecasting and crude valuation. One of the most important obstacles in expanding technology and spreading its success is that most of the oil industries are still in the process of planning, prospecting, and providing products (Forrest and Oettli 2003).

simulation systems have become a major means of obtaining and improving results through the application of modern programs on them, especially those that cannot be obtained identically or directly. As well as a knowledge tool for every process in manufacturing units, especially oil refineries. Most of the applications of the model are in the separation units, especially the distillation units, which are the main element in oil refineries, which have several interactions with a large non-linearity, the behavior of the processes is analyzed in standard conditions that facilitate their study (Gonçalves *et al.* 2010).

One of the most important principles of chemical engineering that apply to analysis, design, development, and simulation with its current programs is the best way to use time and make several models for a particular unit with high efficiency and with more accurate results and increase knowledge of chemical engineering work in general and oil refining units in particular. Several simulation programs have been designed and developed such as (chem share, hyses, aspen plus, pro//) for the distillation unit which made mathematical improvements by building models for each of the distillers (Ghasem 2021).

On the other hand, optimization is meeting a goal and finding the values of the variables in the process, which yield the best value of the performance criterion., to reduce costs and meet the environmental regulations. In recent years simulation programs have been used in separation operations due to the benefits mentioned in the calculations. Programs have been developed to improve industrial processes and keep pace with development.

Among these programs are Chem Cadr, Plus R, Hyses R, Super Designer R, Aveva Pro//. Simulation can be described as addressing challenges and seeing prospects in the field of separation operations (Kancherla *et al.* 2021).

In any simulation case, all feeds flowrates into the distillation column must be known and pre-defined before the simulation process .The use of simulation shows the possibility of finding the parameters of the distributed heat in the oil refinery and forming a picture of the improvement of the products, where the simulation revealed that the real production rates match with the simulation data. In some products there were shown some differences in the flow rates.

The reason for this is due to the mixing of some oil fields with crude oil coming from several sources or locations, which leads to a difference in the graphs of the real temperature in the distillation tower. Simulation is an effective way to understand the nature of products and their concentrations according to their original boiling point (Khalaf 2018).

The basis of simulations is to know the differences in production rates and their impact on operational conditions and compare them with the real production reality and to identify defects and reasons for the decline in production in some crude oil products. As any manipulation in any source of the main conditions such as heat and pressure affect the distillation column as a whole and affects the production rates. The use of simulation provides the way to obtain the ideal results required and provides the fuel that meets the market need for industrial and industrial operations. Naphtha and kerosene are products with much needed uses. Therefore, knitting provides the ideal environment to learn how to obtain the highest percentages at the lowest costs and time (Ahmed 2018).

One of the environmental disadvantages of the distillation process is the carbon emissions associated with processing crude oil. Simulations provide an ideal environment to reduce energy consumption and Co2 emissions. Simulations provide the construction of an ideal distillation unit based on the operational conditions adopted at the plant. The simulations affected the cash disbursement and were shortened to several steps after making a package of modern modifications and saved more than 300 thousand US dollars per year (Wang *et al.* 2016).

Several studies were conducted in which some types of simulation operations were used to improve the performance of the work of distillation units, as they proved their effectiveness in improving energy and production performance, reducing production costs, and reducing investment expenses. Reducing costs, improving energy efficiency by 1.6%, reducing polluting emissions from the distillation process, and saving in expenses for more than 1.5 million dollars annually (Waheed and Oni 2015).

As a result of the current climatic conditions of global warming, high temperatures, increased carbon emissions and pollution, scientists have found alternatives to save energy and reduce consumption in oil refineries by providing environmentally friendly industrial capabilities by exploiting solar and wind energy to shorten some parts of oil refineries and treating fluids such as using transformers for the purpose of solar heating. Technicians used advanced simulation software to save energy consumed annually. A study started using solar heating inverters, to save 23% of the energy consumed. And provide an economic cost for the refining industries and reduce most of the maintenance costs (Kwiatkowski *et al.* 2006).

The current studies in the simulation systems of the oil refinery units. The differences between the simulated process and the real process on the ground and according to the traditional conditions are analyzed. It showed differences in the ability to improve outputs and control energy consumption by specifying conditions to obtain optimal results. The effects of the temperature of the kerosene removal plate, the cap temperature of the distilling tower, the stripping steam flow, and the top pressure of the tower on the distillation products were determined for the aim of increasing yields of some variable products (Kamışlı *et al.* 2019).

Then the results of the simulations are compared with the results of the real unit in the oil refineries. During the process, the variables that directly affect the results of the treatment, such as temperature, pressures, and concentrations, are closely monitored because they affect each other, so the modification of one variable affects the course of the entire process. The focus, especially in the distillation towers, is on increasing kerosene and naphtha products in particular because of the multiple uses of these products. The simulation resulted in an improvement in the production of naphtha between 27-29% and kerosene 2-6%, and they were tested in several operating conditions, and the program proved a rapid convergence of the models use (Kamışlı *et al.* 2019).

1.2 Crude Oil Products

After refining oil, we get oil products such as light gas oil (LGO), heavy gas oil (HGO), liquefied petroleum gas (LPG), asphalt, and naphtha in both types: heavy and light naphtha, asphalt, wax (Table 1.1). Some of these products are raw materials that are processed to enter the petrochemical industries, the production of plastics, rubber, chemical detergents, chemical fertilizers, and some of them are used as fuel for cars, machines, aircraft, and oil. Gas in cook or to generate heat energy for engines used in the production of electric power. The products are not used directly after refining, as they need to be processed and some auxiliary additives added to improve performance and raise the efficiency of the product, such as antioxidants and freezing point, rust inhibitors (Dilmaç 2011).

Table 1.1 Carbon number and boiling point values of refinery products (Dilmaç 2011)

Refinery Products	Carbon Count limit	Initial temperature boiling point	Final Temperature boiling point
Kerosene	C8-C18	135	250
Heavy Naphtha	C5-C17	90	178
Light Naphtha	C4-C12	35	120
Heavy gas oil	C12-C20	355	420
Light gas oil	C4-C17	200	350
LPG	C3-C4	-42	1
Reduce crude	>C20	>345	

It should be clear that it is very difficult to determine the carbon number and boiling point, the values given are given as an example.

1.3 The Aim of This Study

The study aims at the possibility of using the simulation program such as Aveva PRO // Program to simulate the distillation tower in the AL-Dora refinery and compare the results through the program with the real results of the refinery. In process design, it is important that models used to simulate design options are sufficiently realistic to deliver feasible solutions. The purpose of the study is to obtain the ideal results for the products coming out of the distillation tower and to analyze the difference of some information by increasing or decreasing in some operational conditions on the products and their quantities. The program provided the possibility of obtaining detailed information for the distribution of product parts and the distribution of temperatures on the trays in the distillation tower. In this study, detailed information was obtained for the quantities of products such as Naphtha, LGO, HGO, HG and Kerosene. Given the importance of naphtha and kerosene and their multiple uses and requirements in different industries, the modeling program aims to improve the performance of the distillation tower to obtain the highest concentrations and quantities of these two materials.

2. OVERVIEW OF DISTILLATION PROCESS

The distillation process has been known for thousands of years, as it was limited to some simple craft industries to produce alcohol or perfumes through separating membranes, then it developed over time to include several fields in many industries that require integrated and intensive precise separation processes with a commitment not to use boiling the mixt. The scale of distillation operation in industry is continuously increasing and has resulted in larger and larger distillation column configurations. Boiling the mixture loses or destroys some of the basic ingredients. Distillation processes evolved from their simple form to many chemical industries, which led to the formation of larger quantities in the distillation column (Sørensen *et al.* 2014)

The distillation process is a major process in the distillation tower, which is intensive and complex. Some of distillation towers contain several pumps, side salt removers, cooling and heating equipment, and side strippers. The main purpose of the distillation process is to separate compounds dissolved in crude oil through several heating processes and exposure to pressures into main products that are used in several fields in the industry. Distillation units use approximately 35-40% of the total energy of the oil refinery (Ibrahim *et al.* 2017).

The principle of the distillation process is based on heating crude oil to a boil. Crude oil consists of several liquid and gaseous hydrocarbon compounds, many sulfur minerals, nitrogen, and water. The composition of crude oil and the concentrations of compounds in it differ according to the oil field coming from it, as gaseous components such as methane, ethane, and hydrocarbons, which are in solid form and remain in the distillation tower (Jones and Pujadó 2006).

The distillation method is based on the process of separating the components in the crude oil in some balanced phases in the equilibrium vapor and liquid phase method. Where the volatile parts have a lower boiling point than the components with a high boiling point. The distillation process is affected by the main variables such as temperature, pressure and concentrations of materials entering or dissolved in the crude oil (Perry *et al.* 1999).

According to wang the process simulation system PRO/II is used to build a rigorous model for the crude oil distillation unit based on the conventional furnace and three column process flow in refinery that addresses both the distillation columns and the heat exchanger network (HEN) simultaneously It is necessary that shaft control systems with the presence of a dynamic control system should be able to reduce energy consumption. Sometimes even simple single-feed bars present a multivariate problem. So it is important to controlling in variable pairing, and controller device tuning (Wang *et al.* 2016).

2.1 Process Description

When the main task of the distillation unit is to separate the components dissolved in the crude oil, it is necessary to know the main parts of the distillation unit that affect the separation process. As it consists of a series of parallel parts that depend on temperatures pressure and concentration and increase them to separate the components, and when the effects increase, the separation efficiency increases, and we get more useful amount of the compounds.

2.1.1 Preheat train

Crude oil is heated by several heat exchangers to a sufficient vaporization temperature to enter the distillation column .There are several thermal currents that enter the initial heating to increase the efficiency of evaporation and increase the materials required for distillation. The process must be carefully observed to conserve energy in the distillation tower.

2.1.2 Atmospheric and side products stripping columns

The distillation column separates the crude oil into the upper part of the naphtha and from the lower part of the asphalt, and from the sides according to the boiling point of each compound comes out of the trays to side strippers through side streams to give kerosene products, heavy oil gas and light oil gas before it enters heat exchangers that heat before entering the side to remove any light components.

2.1.3 Pump around

By means of the side pumps, the heat is recovered to the main tower through a system called pump around reflux system. The currents are drawn from the trays in the towers and exposed to several coolers. So, if we increase the heat recovery in the pump around as much as possible within operating constraints, we could save heat duty for crude oil, which in turn can reduce the heat load of the overhead condensation unit and its size and reduce the diameter of the column by controlling the vapor and liquid traffic in particular zones.

2.2 Principles of Crude Oil Distillation Units

Crude oil contains several hydrocarbon compounds that have different boiling points, so the distillation process enables the separation of compounds depending on their boiling point. There are two types of distillation units in oil refineries.

1) Atmospheric distillation

2) Vacuum distillation (Gorak and Schoenmakers 2014)

The crude oil entering the refinery is heated using hot streams. As for the main heating processes, it takes place in an oven before entering the main distillation tower, then it moves to three side strippers that produce kerosene, light gas oil, heavy gas oil, and asphalt from the bottom of the main tower (Figure 2.1).

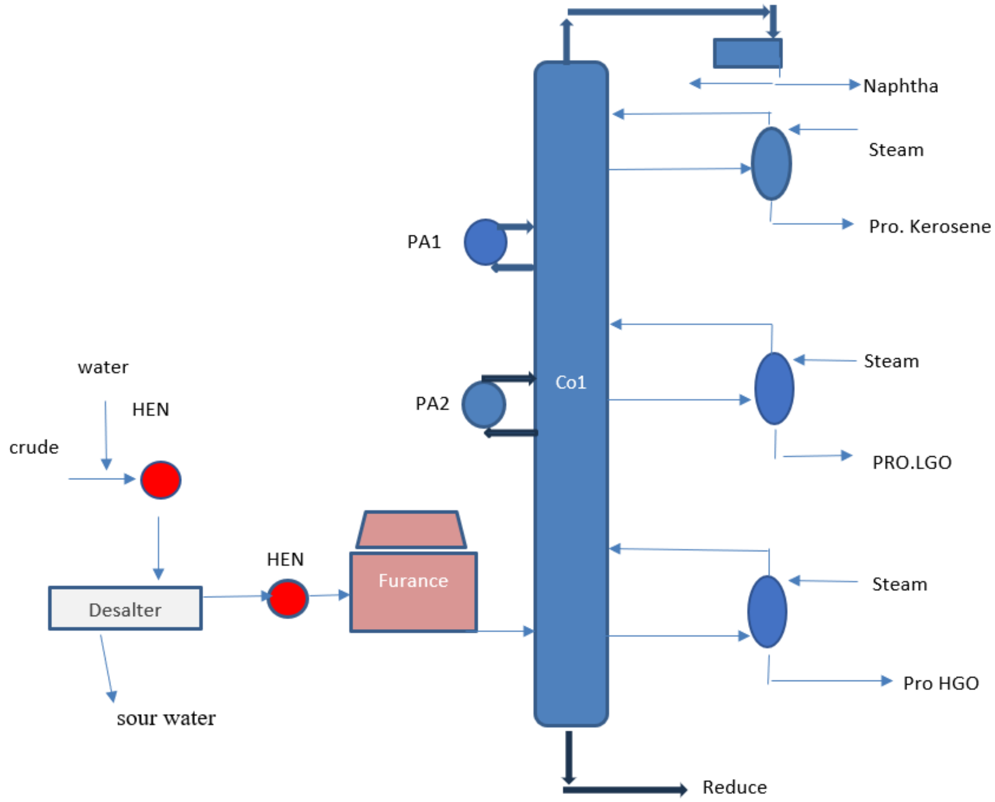

Figure 2.1 Simplified model of distillation unit (Khalaf 2018)

2.2.1 Component properties

From the properties of the components present in the flowing oil, the equilibrium rates of materials and energy are calculated, and the flow characteristics are solved from the calculations of the material and energy balance equations, where the pseudo-components are estimated from the boiling point temperature and specific gravity. The properties of the components are known (Molecular weight, critical constants, eccentricity factors, latent heat, ideal internal gas temperature, and vapor pressures) (Al-Assady 2009).

2.2.2 TBP distillation

Almost all the components of the compounds in crude oil are measured by measuring the true boiling point (TBP), which is considered the basis for batch distillation. One of the most important product features in crude oil is the TBP curve, which determines the quantities and behavior of distillate crude products which is usually applied to crude oil under vacuum and atmospheric pressures and calculating the boiling rate in the petroleum fractions (Figure 2.2). Usually, the percentage is given based on weight or moles. The real boiling curve is used according to the relationship between the temperature boiling point and the percentage weight or the percent moles ratio as the temperature increases, the percentage of the product increases until it exceeds the temperature of evaporation. The product is pulled to the side stripper (Ali and Yusoff 2012).

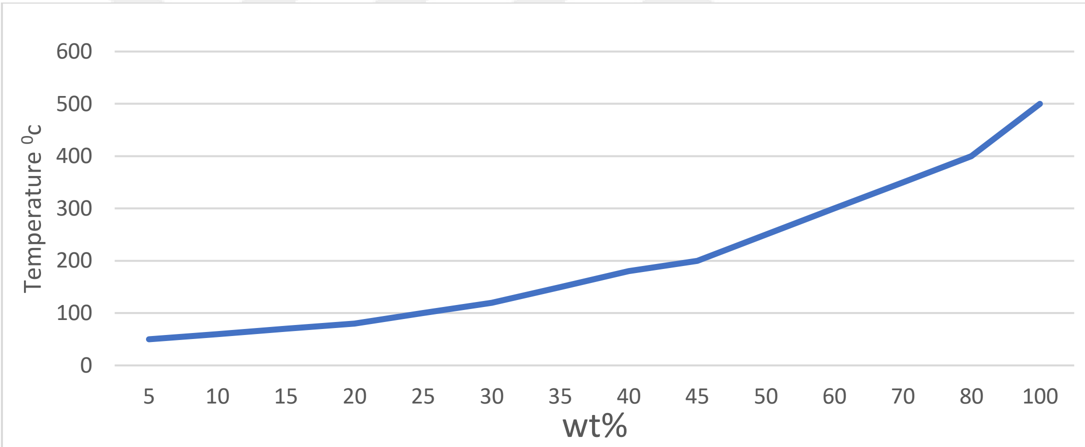

Figure 2.2 True Boilng Point Temperature Curve and weingt percentage relationship (Ali and Yusoff 2012)

2.2.3 ASTM distillation

ASTM is terming The American Society for Testing Materials (ASTM) for Advanced TBP Distillation Processes. There are several types and methods of testing, the mostمy used are D86 and D1160. It is a quick distillation without the use of trays, retrieval, or packaging between the bottom and condenser. In the ASTM there may be residue in the distillation unit equipment. This residue left may be the difference between the volume of the inlet material the unit and the distillate material, this difference is called "loss”. it is thought as volatile components of the inlet material which have not been re condensed (Table 2.1) (Perry *et al.* 1999).

Table 2.1 Approximate ASTM boilng point temperature (operation manual of Aldora refinery)

Fractions	Apparatus	Boiling Point Temp. Rang °C	Uses
Light Naphtha	D86	50-104	Home and tourist heaters, lighting and lighters Camping stoves
Heavy Naphtha	D86	116-169	Reduced for paints and varnish Lubricant heating
Kerosene	D86	176-250	Performing petrochemical feed
Light gas oil	D86	242-337	Fuel for cars
Heavy gas oil	D1160	335-350	Fuel for airplane
Reduce crude	D86	>355	Road surface

2.2.4 Cuts liquid volume percent boiled in assay

When crude oil contains a group of desirable products, each product contains cuts that are either paraffins or olefins with carbon chains that are affected by temperature, and the carbon and hydrogen bonds are affected by a non-linear relationship. As studies have shown that the increase in cuts is with the rise in temperature, as the more the temperature increases Evaporation The droplets increased after the pressure and the inlet flow rate are constant (Table 2.2).

Table 2.2 Liquid volume percent boiled in assay

Cuts	Light Naphtha	Heavy Naphtha	Kerosene	Light Gas Oil	Heavy Gas oil
Volume Percentage	Temperature °C	Temperature °C	Temperature °C	Temperature °C	Temperature °C
Initial Boiling Point	35	90	135	200	355
5%	48	118	177	242	
10%	52	122	185	251	
50%	75	143	205	279	
90%	100	163	226	320	
95%	104	170	234	330	420
End Boiling Point	120	178	250	350	

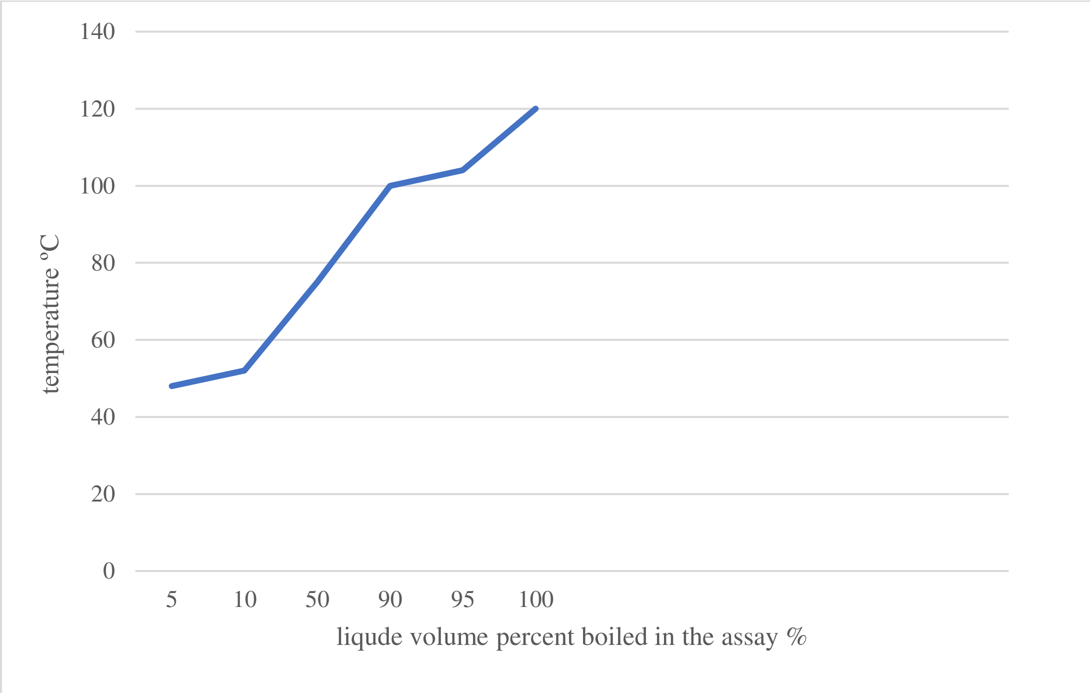

Figure 2.3 Light Naptha ASTM D86

From the above Figure 2.3, it is possible to notice the relationship between the liqude volume percent and its increase with the increase of temperature, as it began to form light naphtha at the beginning of the temperature of 35°C, and it condenses on the trays of the separation tower until it reaches the end of its concentrations in the oil entering the distillation unit at a temperature of 104°C and with a separation rate of 95%, as it is the 5% The remaining is considered a loss or very small that does not affect the quantities.

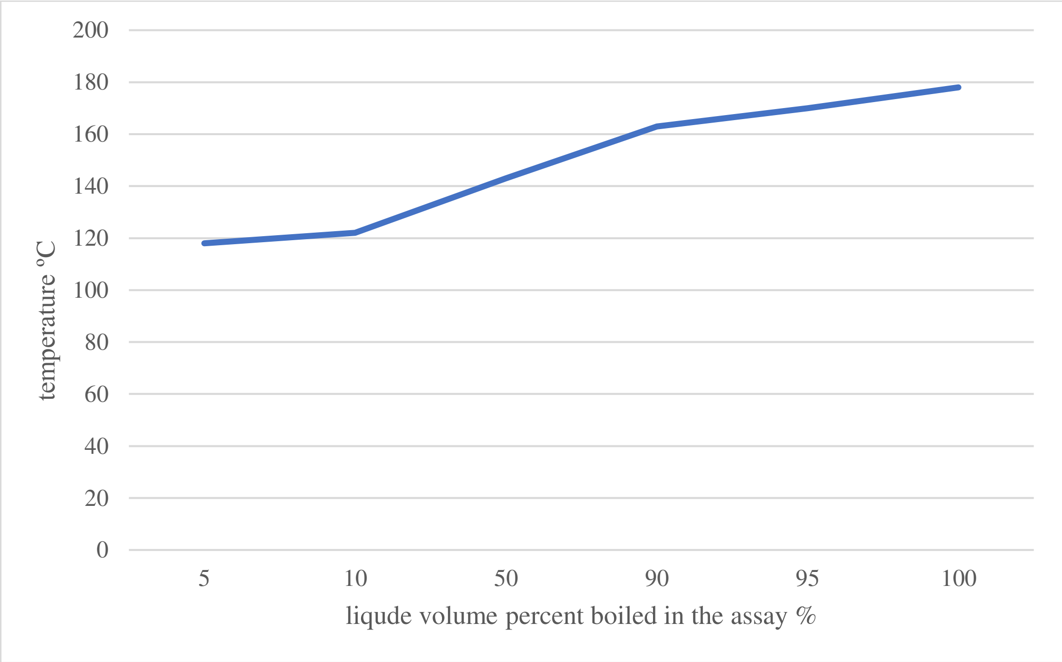

Figure 2.4 Heavy Naphtha D86

All the naphtha is steam extracted to the separation column, where the naphtha is condensed and separated into light and heavy naphtha, where after raising the temperature to more than 104°C, which is the last degree of carrying light naphtha and its presence in crude oil, we get the beginnings of a volumetric concentration of heavy naphtha at a temperature of 90°C, where From the above Figure 2.4, the relationship between the increase in the concentration of naphtha is the increase in temperature until reaching higher concentrations at a temperature of 170°C where both light and heavy naphtha are considered light compounds due to their evaporation at lower temperatures than the rest of the products.

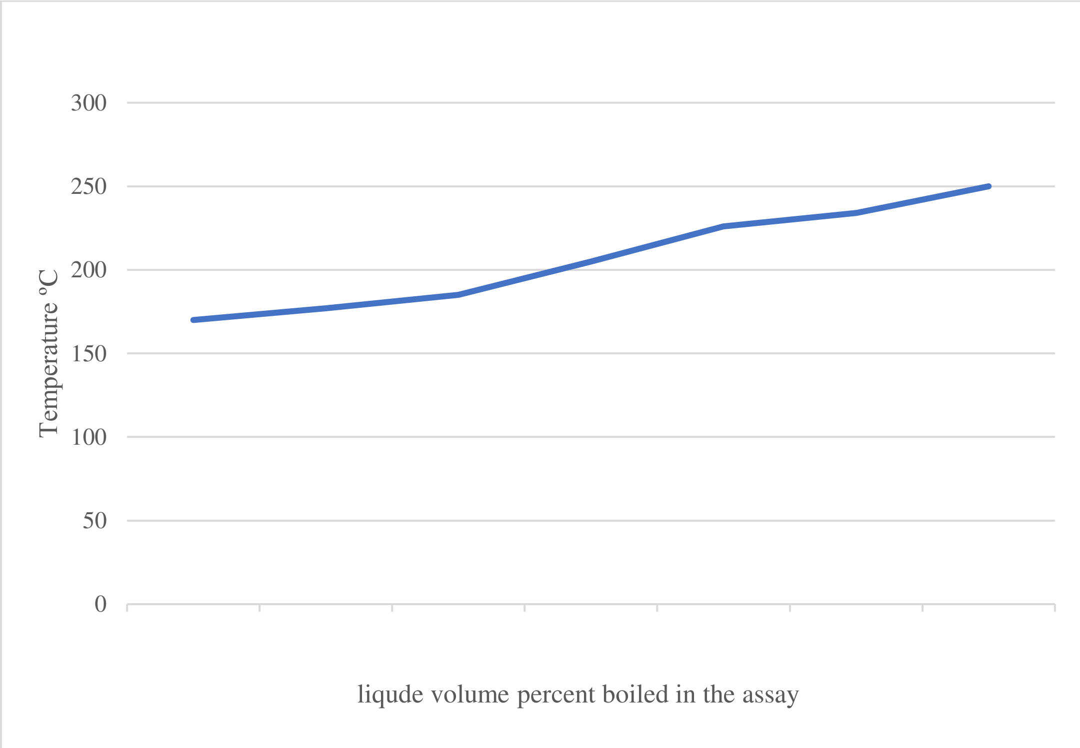

Figure 2.5 Kerosene ASTM D86

Kerosene is one of the light compounds, so the process of condensing it in the upper trays of the distillation column and with temperatures that are average in relation to the temperature from the bottom of the tower to the top, where the process of condensing kerosene takes place from temperatures starting from 170°C, where the first cuts of the product can be observed until reaching the temperatures that implement the kerosene product of feed flow at a temperature of 234°C (Figure 2.5). Kerosene is considered one of the dominant products in the industrial and operational fields, so most of the economic demand is concentrated on it.

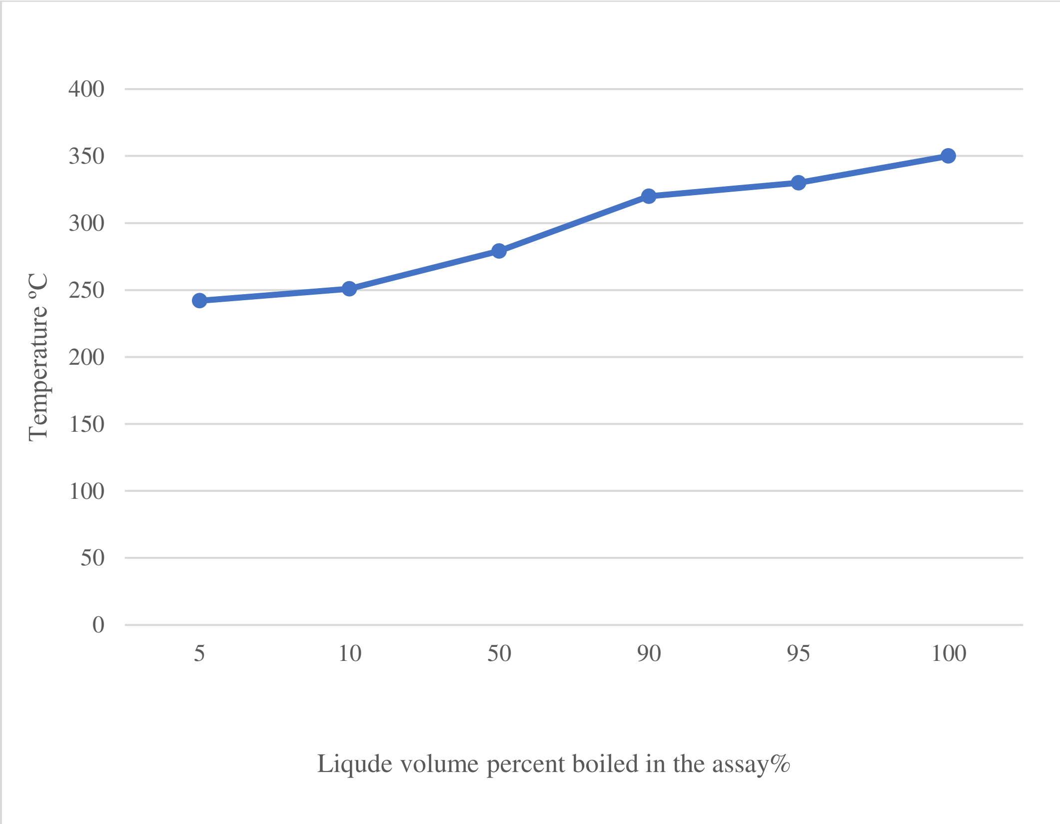

Figure 2.6 LGO ASTM D86

After reaching medium temperatures in the tower, the formation of heavy compounds begins, including light gas oil, which is formed after the crude oil temperature reaches 242°C and is withdrawn from the tray to the side stripper and it disappear after that at a temperature of 330°C, and the percentage of its presence in crude oil is 95% (Figure 2.6).

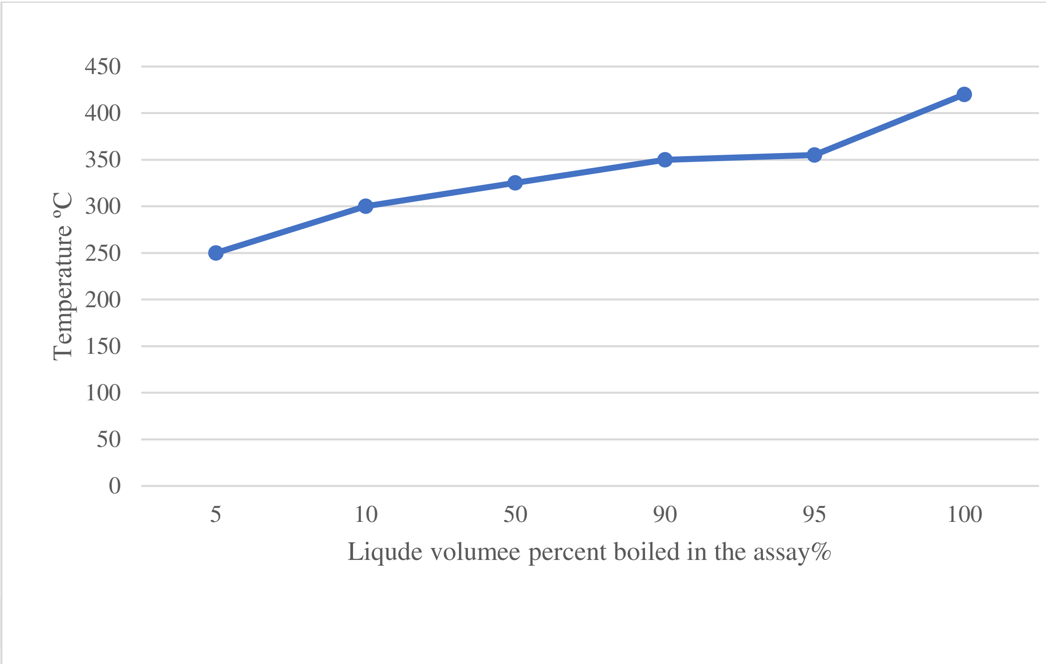

Figure 2.7 HGO ASTM D116

Heavy gas oil is one of the heavy compounds that has the highest degree of evaporation among the components of crude oil, so it is below the side columns and higher than the asphalt, which is the rest of the undesirable crude oil deposits in the separation process, and the temperature of condensation of the heavy gas oil is between 335°C to 420°C. Through these curves, the quality of oil products is known, and the degree of separation between products is determined and according to the measurement method, 95% of the products are evaporated. Figures 2.2-2.7 show the simulated ASTM curves for Light Naphtha, Heavy Naphtha, Kerosene, LGO, and HGO.

2.3 Introduction and Overview of The Unit Distillation in AL-Dora Refinery

This unit was designed to refine the crude oil entering the refinery at a pressure close to atmospheric pressure, so it was called the atmospheric pressure refining unit. Previously, the internal oil of the refinery was through 3 lines.

1. Iraq Kirkuk
2. Iraq Basra
3. Iraq Central Basra

To obtain major and important products that include both

- LPG (Light Petroleum Gas)
- LGO (Light Gas Oil)
- HGO (Heavy Gas Oil)
- Light Naphtha
- Heavy Naphtha
- Kerosene
- R.C

The unit is designed to work on refining crude oil with a capacity of 70,000 bbl./ day and with a factor that takes 8000 hours / year, and 60-105% of the design capacity. The tower consists of a thermal unit that heats the oil entering the refinery, then it passes through the salt removers. After passing through the main distillation tower, it exits according to the boiling degrees into three side strippers with the required products. Connected to the main tower are pumps feeding towards the heat exchangers.

The main tower contains 46 trays with partial condenser. the crude oil after heating supply and desalt and the furnace will be entering the distillation tower in the 41 trays. And the steam to the bottom of the column. Vapors entered at a rate 3400 kg/hr. with temperature 340˚C and pressure with 3.2 kg/cm^2 (g). The pressure at top of the CDU is 1.3 kg/cm^2 (g) and bottom stage pressure of 1.6 kg/cm^2 (g).

Table 2.3 Pump specification

Pump number	Location with the trays	Return temperature °C
Pa1	3-1	85
Pa2	26-24	198

Table 2.4 Stripper specification

STRIPPER NAME	TRAYS	FLOW RATE OF THE STEAM kg/hr.	PRO.kg/hr.	PRO TEMP. °C
KEROSEN	4	500	39710	187
LIGHT GAS OIL LGO	5	1100	70290	251
HEAVY GAS OIL HGO	8	800	12740	298

2.3.1 Material balance and method distillation unit

Perry also added that the basis of the separation process for the distillation tower depends on the balance between the vapor and liquid phases, as they must reach the saturation stage and be separated depending on the boiling point. The distillation mechanism takes heat, which in turn affects the balance (Perry *et al.* 1999).

Table 2.5 Material balance of AL-Dora Crude Oil

Fluid	wt.%	kg/hr.	vol%	m^{3}/hr. at 15 °C
FUEL GAS	0.08	350	-	-
LPG	1.39	5620	2.18	10.1
LIGHHT NAPHTHA	4.96	20900	6.49	30.1
HEAVYNAPHTHA	9.28	37600	10.93	50.7
KEROSENE	9.99	40500	11.11	51.5
LIGHT GAS OIL	15.6	63230	16.28	75.5
HEAVY GASOIL	3.2	12970	3.15	14.6

2.3.2 Oil characterization

In all simulations, the materials included in the crude oil are introduced to the distillation column and identified before starting the simulation. From the information included in the program, it is introduced from the operating manual in the refinery plant. Hydrocarbon compounds and unknown substance and substances dissolved in crude oil are known according to the boiling temperature point, and the heavy and light components are determined. All equations for calculating energy, momentum and material balance are prepared in the simulation program (Leelavanichkul *et al.* 2004).

Table 2.6 AL-Dora Crude Oil assay data

Temperature boiling point TBP		Light End Hydrocarbons	
TEMPERATURE °C	WT%	COMPONENT	WT%
50	4.34	C2	0.01
60	5.61	C3	0.36
70	7.09	IC4	0.19
80	8.35	NC4	0.91
100	11.3	IC5	0.89
120	14.89	NC5	0.97
150	19.97	PROPERTIES	
180	26.01	API AT 15°C	30.4-30.5
200	29.32	SPECIFIC GRAFITY	0.872
250	38.85	SULFER CONTENT	2.8-3 %
300	47.86	KINEMAT VISCOSIT	
350	58.8	AT 10°C	29.34
400	64.61	AT 21.1°C	19-20
500	77.09	AT 37.8°C	9-11

2.4 Fractional Distillation

It is known that industrial distillation columns have a several units in which partial vaporization and condensation processes occur at the same time, as liquids move from top to bottom in contact with the rising steam, and this contact is present along the distillation column. To make mass and energy balances in the distillation column for ease of calculations, it is divided into three sections:

-The top section presents the operating line correction.

-The bottom section gives the peeling running line.

-The feeder section gives the equation of the feed line.

With this division, it is possible to make calculations for the incoming and outgoing lines in the column. McCabe-Thiele method used to analyze distillation column which is the most popular method (Vasconcelos *et al.* 2008).

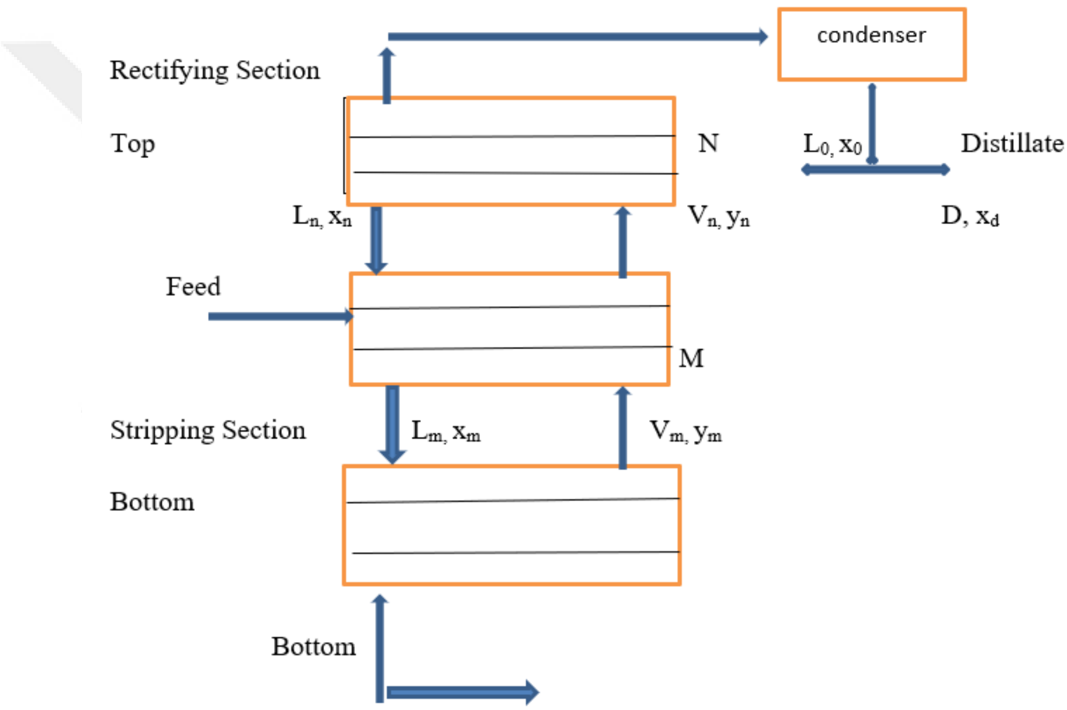

Figure 2.8 Fractional distillation column (Vasconcelos *et al.* 2008)

- The overall material balance of the distilling column results equation (Equation (2.1) and Equation (2.2)):

Overall material balance

$$F=V_n + L_n \tag{2.1}$$

$$V_{in,i,bot}+L_{in,imb} =V_{in,mb}+ L_{in,ibot} \tag{2.2}$$

The mechanism of mass transfer between liquid and vapor is equimolar. The molar flow rate of liquid and vapor in each section are constant (Equation (2.3) and Equation (2.4)). So:

$$V_n=V_m \tag{2.3}$$

$$L_n=L_m \tag{2.4}$$

F=The Feed

i=component

n = the bottom part of the top section

m= the top of the bottom section

L = the overall liquid molar flow rates

V = the overall vapor molar flow rates

Calculate the Number of Stages

To determine the number of stages, Equation (2.5):

$$N = \frac{L}{V} * x - Bx\frac{b}{v} \tag{2.5}$$

B – Bottom flow rate

L – Liquid flow rate below the feed stage

xb - Bottom product mole fraction

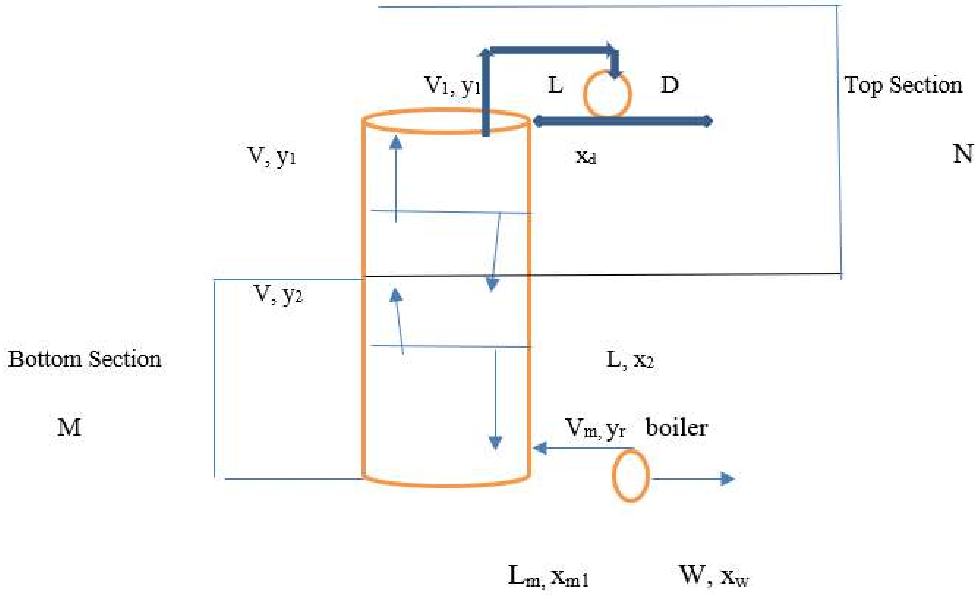

Figure 2.9 Top and bottom section (Vasconcelos *et al.* 2008)

For top section

$$V=L + D \tag{2.6}$$

$$V * y_2 = L * x_1 + D * x_d \tag{2.7}$$

From Equation (2.6), Equation (2.7), Equation (2.8) and Equation (2.9) are given,

$$y_2 = \frac{L}{D} * x_1 + \frac{D}{V} * x_d \tag{2.8}$$

for any stage in N

$$y_2 = \frac{L}{L+D} * x_1 + \frac{D}{L+D} * x_d \tag{2.9}$$

For Bottom Section

$$L_m = V_m + W \tag{2.10}$$

$$L_m * x_{m1} = V_m * y_r + W * x_w \tag{2.11}$$

From Equation (2.10) and Equation (2.11), Equation (2.12) is given,

$$Y_r = x_{m1} * \frac{Lm}{Vm} - x_w * \frac{W}{vm} \qquad \text{for any stage in M} \tag{2.12}$$

Calculate the Reflux Ratio

$$R = \frac{L}{D} \tag{2.13}$$

Operating line Equation (2.13) of top section is straight line Equation (2.14),

$$Y_{n+1} = \frac{R}{R+1} * x_d + \frac{xd}{R+1} \tag{2.14}$$

Y_{n+1} = minimum reflux ratio at any stage

xd= distillate mole fraction.

R = Reflux Ratio (Gavhane 2008)

3. MATERIALS AND METHODS

3.1 Distillation Process and Simulation Programs

Simulations are a tool for the development and practical planning of all industrial and technical processes that develop with the progress of technological and the need to reduce costs and time. It is involved in several processes of chemical, physical, biological, and alternative technical processes or unit operations in software package. The simulation process is mainly based on clear data and information about the chemical and physical properties and mixtures in the factory, which helps the mathematical operations in calculating the simulation (Robertson *et al.* 2011).

The simulation process relies on real models to create a simulation application with high accuracy to obtain reliable results effectively. And because the simulation process relies on skilled users to control performance and ensure the flow of the standard sequence and develop a correct answer towards the equation to reach the largest model suppliers in simulation technology (Perry *et al.* 2010).

The simulation gives a model of the performance of the relationship between the supplier and the refinery and can be applied to several industries and the extent of its impact on the relationship between all parties involved in the business of the industry (Lestari *et al.* 2016).

The programs used in the simulation process contain packages that are used all over the world to design factories, evaluate their performance, and conduct analysis on oil industrial units, especially the distillation tower. To create a distillation unit, the program uses the design data of the refinery and the definition of components and thermodynamic fluids to create a simulation system. The evidence affecting the simulation results is defined as the critical temperature, pressure, viscosity, density, number of trays, reflux rate, and monitoring the directions and positions included in the tower (Beshir *et al.* 2014).

The simulation uses assumptions and estimates that are close to real, covering the full cycle of the industrial process, all the way to the final design and operation of the plant. The simulation process is a main tool for the chemical engineer to understand the functioning of the technical and dynamic processes of the plant, and the biggest challenge in this process is to install the main data in the design of the application, provide a complete picture of the operation, present a comprehensive picture of the plant simulation, and understand its complex operation method, which in turn leads to an improvement in future design and development.

3.2 Benefit of Simulation

The simulation system was used to reduce energy consumption, reduce several units, and increase production, which saves large economic resources by entering data in detail to obtain a perfect match between the program and reality. The simulation system has been tested with several programs and used in many industries and environmental treatments, especially that the cost of environmental treatment as a result of pollution associated with industrial processes consumes a lot of time and material resources, which negatively affects the general profits of the investor, especially in light of the current climatic conditions of global warming and other problems (Davarpanah and Mirshekari 2018).

The distillation process requires a high consumption of energy because it consists of a group of heat exchangers, cooling, and pre-flashing. Therefore, simulations are made to reduce energy consumption, increase production, and reduce operating costs. Simulation is used to find the possibility of exploiting interactions between the separation units and the heat recovery system, while ensuring the quality of and quantity of production. The foundations of the simulation are based on choosing the ideal values for operating variables such as pressure and temperature (Ledezma-Martínez *et al.* 2017).

The simulation process takes care to establish the steady state and flow rate in all engineering phases. Simulation is used as a training method for some operators in laboratories and factories, and to demonstrate the possibility of improving operations through computer systems and the Internet. Simulation is also based on reducing risks from conducting laboratory operations in realistic factory units. It is possible to produce software systems to monitor the mechanical work and train the equipment and prepare multiple users for one simulation.

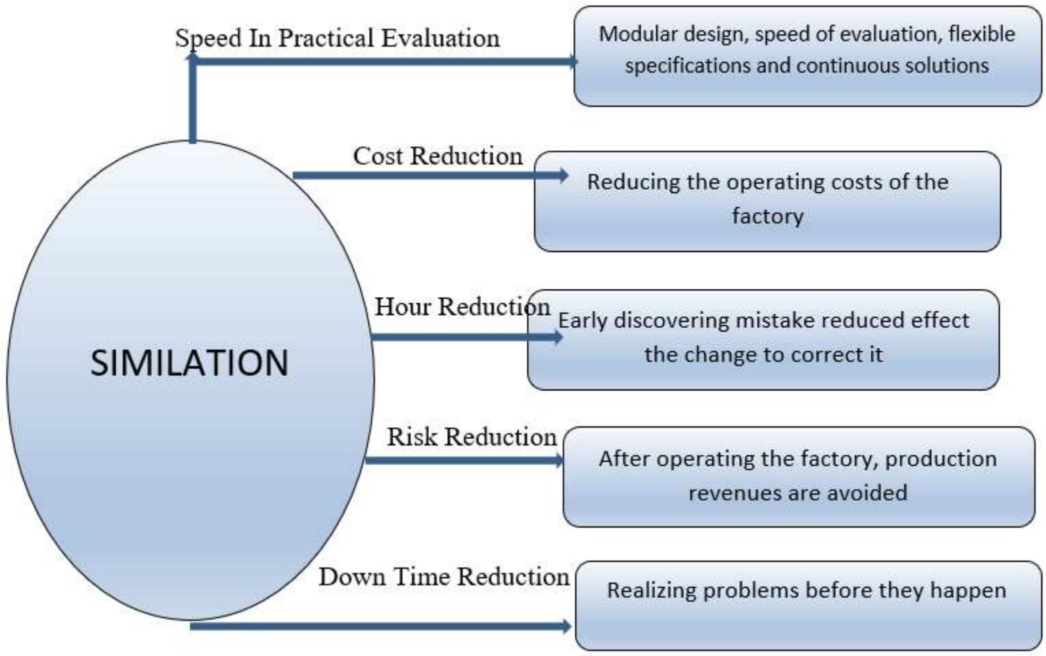

Figure 3.1 Benefit of simulation (de Beer *et al.* 2021)

3.3 Fundamental and Principles of PRO// Simulation Program

The PRO// program is considered one of the important programs in the field of energy, oil, and gas industries, and it is spread in several countries around the world. help save, reduce technical consumption, reduce cost, improve production, and achieve excellence through sustainability throughout the life of operations. The software streamlines the data-driven design and engineering process and reduces the risk of project delays. PRO// software process simulation is a valuable tool for engineers and workers in industrial sites in general, energy, gas, and oil in particular, and the need for such software leads to the innovation of chemical alternatives in the oil industry. Simulation software offers:

1. Offers a wide range of applications PRO// simulation can be used in every oil and gas industry and production, refining, petrochemical, chemical, pharmaceutical, and polymer plants. PRO// Simulation offers a comprehensive library of components, thermodynamics, material properties data, and unit operations due to its ease of use in design, training, and other operations.
2. The PRO// simulation improves plant performance by optimizing process design, operational analysis, and engineering studies. PRO// Simulation is designed to perform accurate heat and material balance calculations for a wide range of chemical processes, optimizing process and procedures from inception to final production stages.
3. Ensure the integrity of the relief system through dynamic technical simulation through understanding the process and the ability to control.
4. Simplified IT Support This new infrastructure allows for secure control of user access, seamless maintenance, streamlining of IT expenditures, and monitoring of equipment performance, allowing multidisciplinary engineers to work together effectively to reach the ideal destination in production.
5. Integration with other computer programs You can create custom forms and prepare reports via Microsoft Excel. Import screening information via unified supply chain management.

The current research focuses on field research referring to improve the performance of Crude Distillation Unit by simulation. according to pinto a short time ago, scientists believed that the industrial problem could be solved by mathematical methods or published research on the process. However, with the expansion of the argument to the development of production, the need for continuous work emerged by pelletizing the dynamic nature of the petrochemical industries with scheduling tools by computer. In the oil industries, important places such as distillation and FCC area units are essential for the effective operation of the oil company There are still some other events required and related to logistics, planning and scheduling, as well as more efficient modeling and solution techniques (Pinto *et al.* 2000).

Stacy E. Mcmanus defined field research “as systematic studies that rely on the collection of original data—qualitative or quantitative—in real organizations” because of that, the study is named as field research because the data will be obtained directly from reality namely AL-Dora Refinery site that belongs ministry of oil (Edmondson and McManus 2007).

That evaluation studies aim precise study for accomplishment of event determination at standard conditions according to E Svensson, Morandin, 2020 the study can be done by using virtual parameters taken from real field data Where the state of the oil refinery data is taken, the data are determined and the methods of entering them in each section, and hypothetical experiments are conducted to find out the differences between the data coming out of the simulated program and the real data. Determine the goal of improvement (Svensson *et al.* 2020). In this study, a crude oil distillation unit simulation will be done with a pro//.

3.4 Simulation Design

The simulation process is based on several stages, with some points affecting the outcome of the simulation data. As for the number of attempts, it depends on the experience and practice of the designer. Where it will be in the first stage to define the compounds entering the crude oil to the distillation unit and their concentrations, temperatures, and pressure in the standard conditions of the oil refinery. Then the installation of the main and stripper column and heat exchanger units, the design of the streams, and the determination of their entry and exit locations (the tray number in the column). Then extracting data and results and comparing it with real data and knowing the size and shape of the difference, followed by the process of analysis and explanation about the reasons for the difference and the effect of changing temperature, concentrations, and pressures on the amount of oil products such as kerosene, naphtha, light gas oil and heavy gas oil presenting by Figure 3.2.

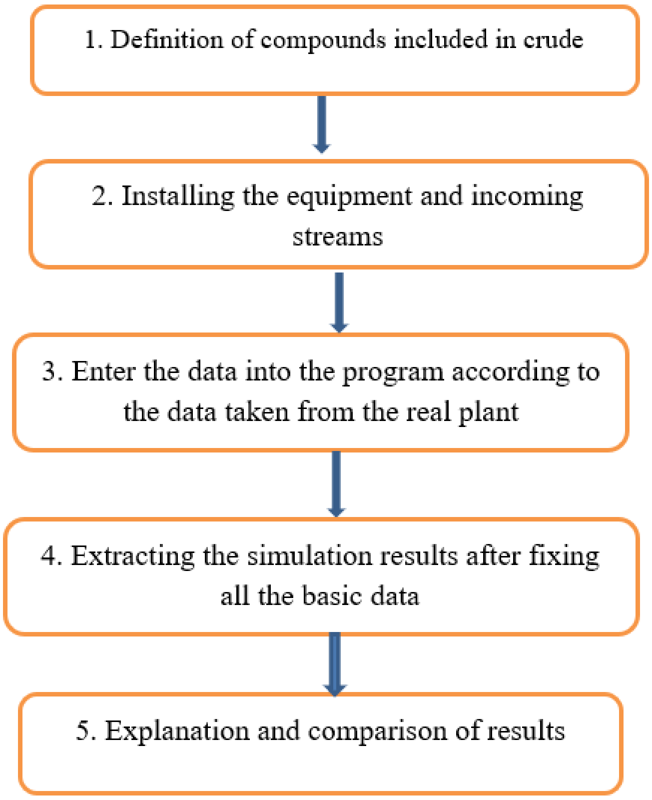

Figure 3.2 Design simulation

3.5 Software Package

The SimSci Pro/II version 9.4 program was used to Determination of Optimum Operating Parameters of Crude Oil Distillation Unit in AL-Dora Refinery by simulation method.

3.6 Program Summary and Procedures in This Study

Firstable the process data were taken from operational manual (PFD) in the refinery plant we extract information and by selection of necessary process data the volatile compounds c1-c2-c3-ic4-nc4-ic5-nc5 were selected from Basra Heavy Oil stream which it has sp.gr range (0.875-0.888) and the thermodynamically model is GREAY- STREED equation which are suitable for petroleum distillation units. unit Set were selected types of British Unit Metric value because this makes easier comparison with design and to the fact that system of units is used to control distillation unit. Material streams are formed starting from the entry feeding, intermediate streams, and outgoing streams in terms of temperature, pressure, molar concentrations, or weight, according to the data from the refinery data. Each stage of separation simulates the total tower which has a preheater. oil characterization has light ends and Assay can have by TBP curve data. The flow specifications are calculated from the general specifications of the design, which are very important in the simulation, which determine the validity of the work and its conformity with the real ones. The parameters are determined from the productivity of petroleum products and the density and gravity. Runout of Side Strippers used temperature and flow and Runout of pumps around used feed flows and duty and effective heat transfers between trays. Runout of Atmospheric Tower all the information data that gives to program is 46 trays and rate of condensers, operation conditions, and cutoff distribution. Side strippers are installed from kerosene, light gas oil and heavy gas oil products, with the addition of amount of production, pressure, and temperature, which work smoothly with the main tower to ensure flow rate. In the end, to get the best results, the currents are changed and modified, and the pressures, duties, and temperature, noting that they do not affect each other.

3.7 Modeling and Simulation of AL-Dora Crude Oil

In this branch the dynamic and thermal properties are predicted and made. The detailed procedure was done using Aveva pro// program version 9.4 by these steps:

1. Choice of Thermodynamic Mode
2. Setting units (distillation column and stripper)
3. Components in streams
4. Set current streams
5. Run Simulation.

First to open in PRO// to create a new flow sheet and window shown (Figure 3.3):

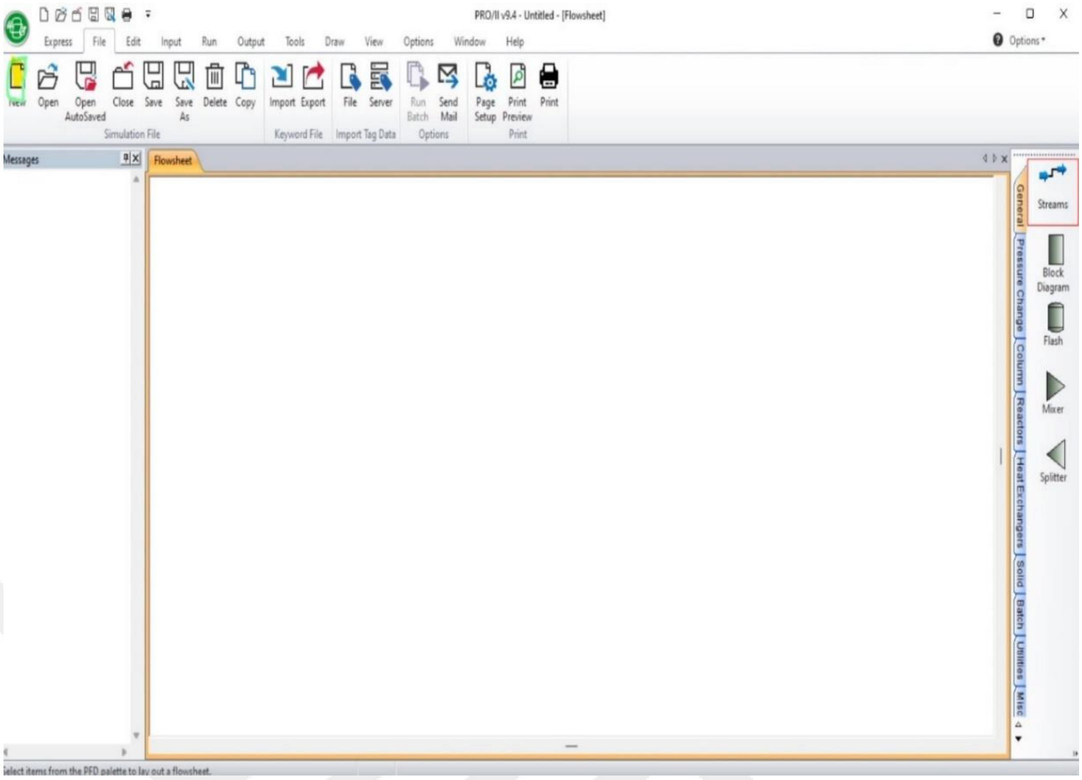

Figure 3.3 Simulation basis window

3.7.1 Data and oil characterization

After opening a new flow sheet, a page will appear with several tabs, each of which refers to a specific process. The required data is placed in the places indicated in the figure. Each choice has inside another window, and the data is set according to its temperature, concentration, or pressure. It is noted that the concentrations depend on one of the two options, either concentrations that depend on mass or concentrations that depend on volume. In the simulation process must be provided Information on the chemical, physical and thermal properties of pure components and mixtures.

units of measurement will show with several choices, the data units are identified, if they are identical to the original data, as any data entry after the installation process of the units is defined and converted to the main unit at the beginning of activation (Figure 3.4, Figure 3.5).

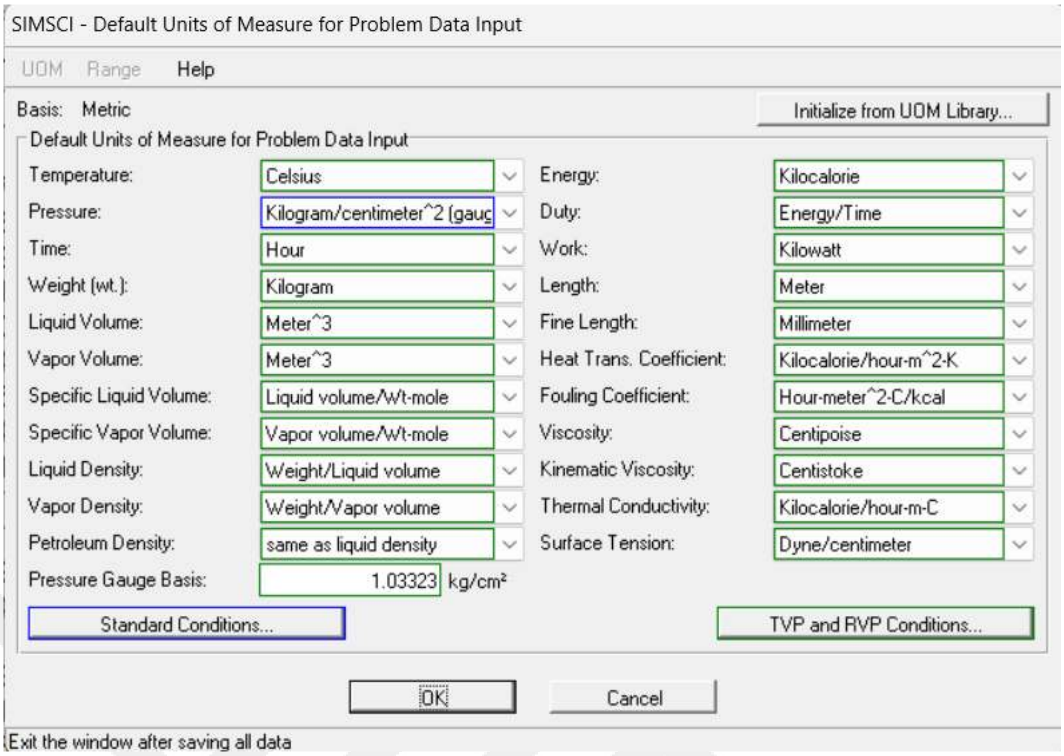

Figure 3.4 Default units of measure for petroleum data

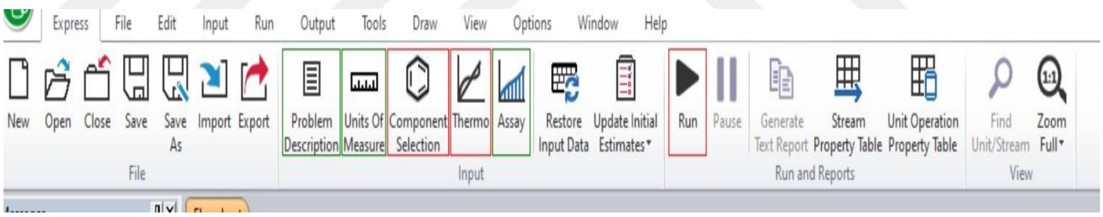

Figure 3.5 Main tools of the aveva program

Generate the pseudo-components it then the next step from the "Compound Selection" options, another window can be show as figure and from the data list then the "select from data" other window will be shown to choose the compound from data bank (Figure 3.6).

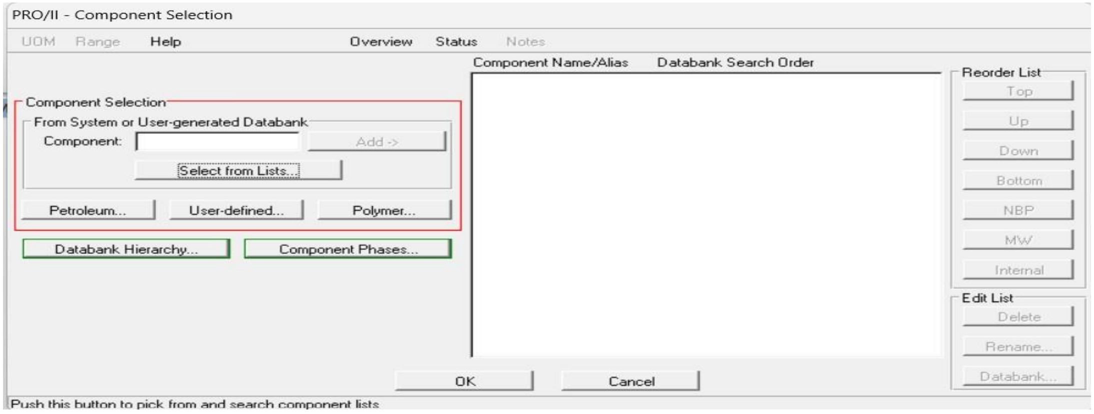

Figure 3.6 Compound selection and data bank

is used, which most of the compound consists of propane, butane, pentane isobutane, n-butane, and light and Hydrocarbons compounds associated with crude oil, “Table 2.5 “which are selected according to the symbols defined in the program or the name of the compound (Figure 3.7).

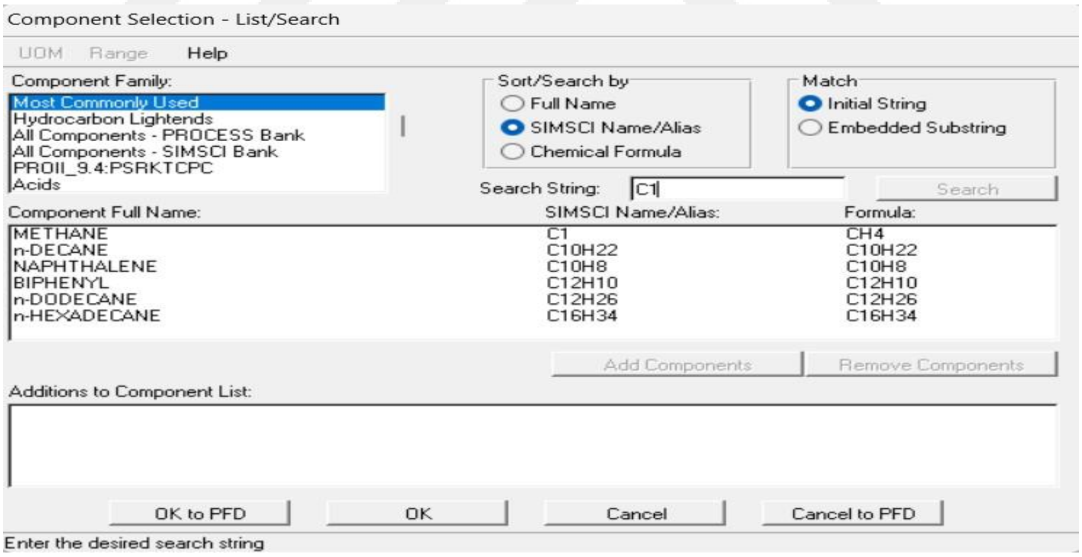

Figure 3.7 Choosing compound from pro // data bank window

When completing the formation of light and pseudo compounds in the simulation program, the introduction and definition of crude oil is done by entering the quantities of crude oil entering the refinery. Most of the chemical compounds entering are similar and difficult to separate, so the boiling point is relied upon to sort the chemical compounds from each other by determining their properties through characterization procedures. The simulation depends on the accuracy of the TBP curve used. Table 2.5 After entering the chemical compounds, Thermodynamic Data is chosen, which is the mathematical method for data extraction and is a main part of the definition of crude oil (Figure 3.8).

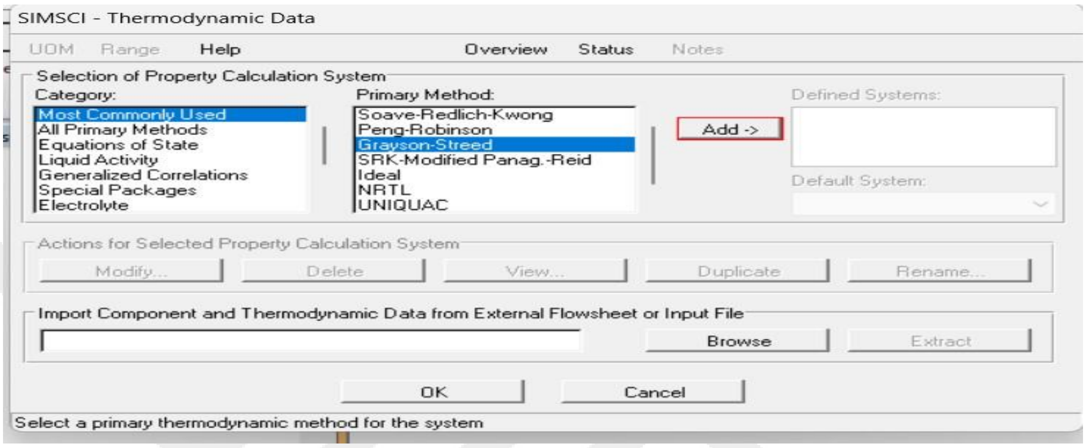

Figure 3.8 Selection equation method to the process (Grayson streed)

To the definition of oil flowers, the chemical composition cannot be accurately determined to determine the flows of oil and petroleum products, it should definition the assay by gravity data (API, specific gravity or Watson K) and TBP Basis and instill percent distillation with temperature (Figure 3.9).

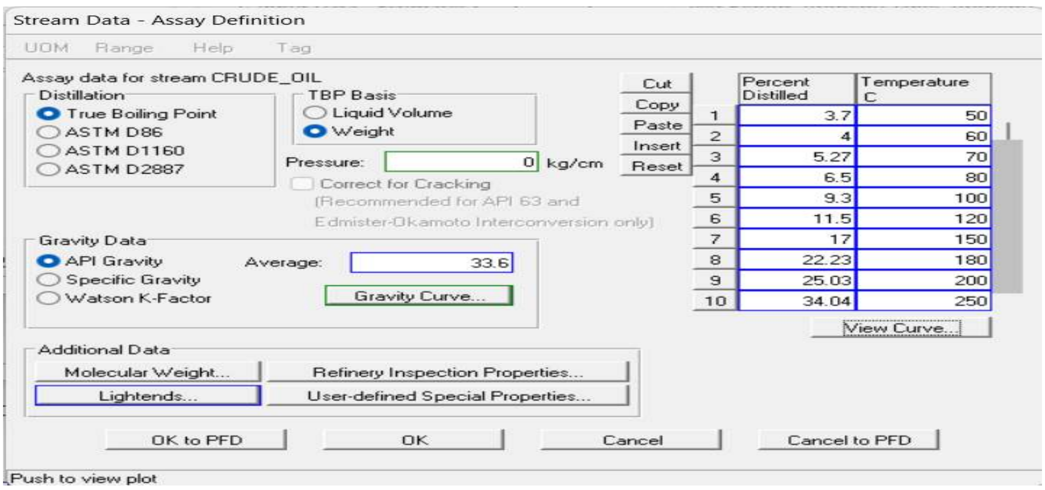

Figure 3.9 Assay definition and set it in the program

The Figure 3.10 below shows the relation between the temperature and the percent distillation from choosing the view curve by the pro// simulation.

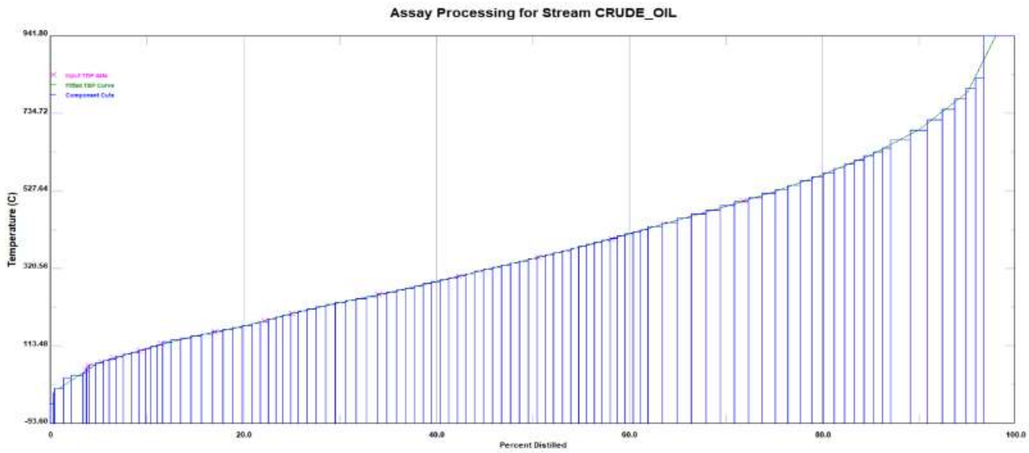

Figure 3.10 Assay processing for stream crude oil

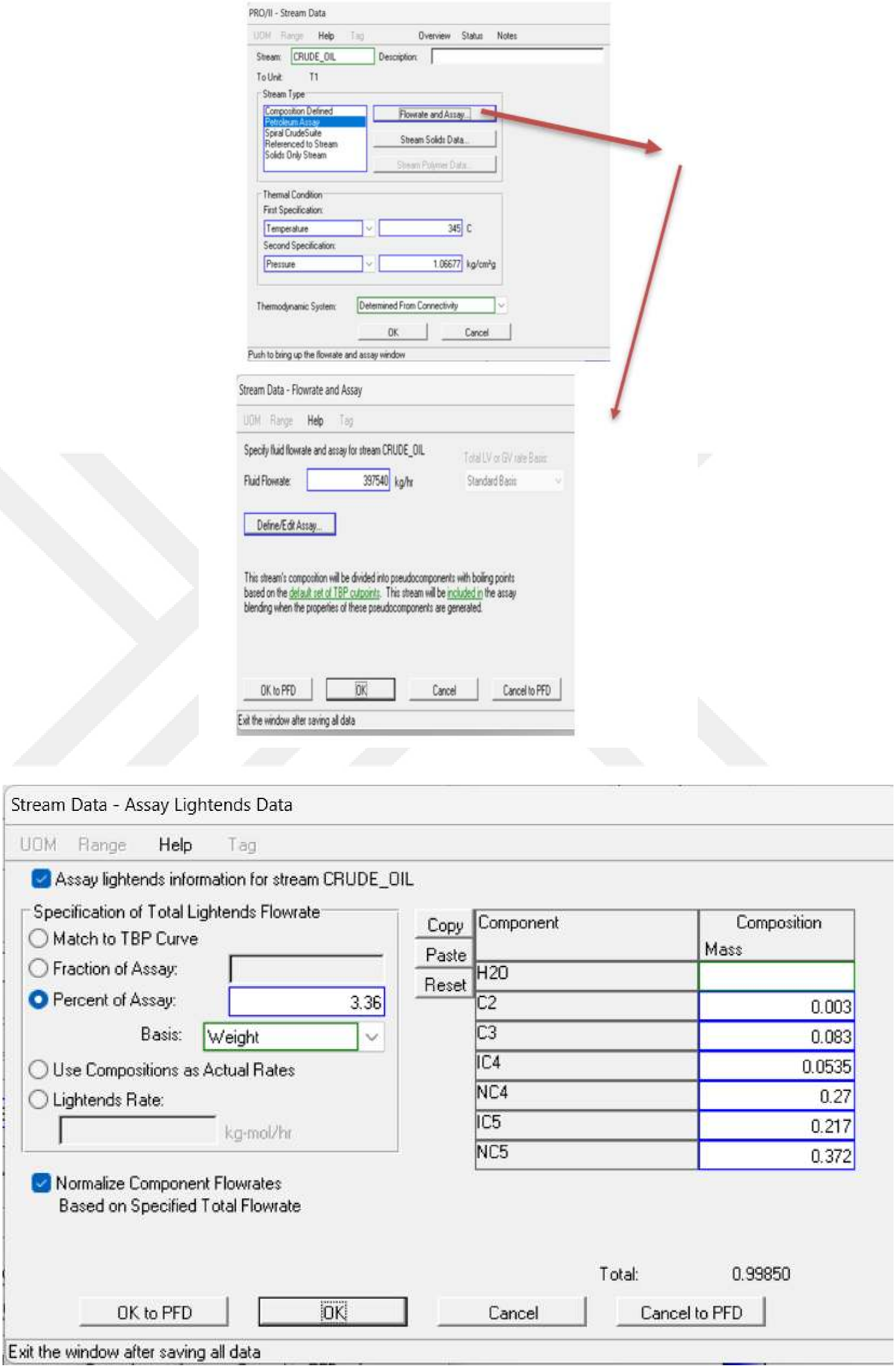

Figure 3.11 Assay light end data

Feed – Crude Oil By clicking on each option in the window, it is a definition of light end assay and entering data taken from Manual operations (Figure 3.11).

3.7.2 Fractional column

After entering the data on the chemical compounds dissolved in the crude oil and determining the mathematical units by the standard conditions and determining the thermodynamics, the distillation tower and the stripper are installed, in addition to the incoming and outgoing stream that are interconnected between the towers. Where the flow diagram (Figure 3.12) consists of a distillation column that includes heat exchangers that have heat and pressure measurements according to the original data, and from the top is a partial condenser. Crude oil is feed to the tower by pipes to tray 41 installed in the distillation column T1 at a balanced temperature of 345°C and in amount of 397,540 $\frac{Kg}{hr}$ to tray41 accompanied by a power stream from the bottom of the tower at a temperature of 365 and pressure 3.5 Kg/c.m^2 to separate liquids from vapors and according to the boiling point of each pseudo-chemical compound extracted Materials required to side stripper through the streams.

The distillation tower contain:

1. 46 trays
2. Side pumps (Upper Reflux and Lower Reflux).
3. Partial Condenser contain Naphtha and wastewater.
4. Steam entering through bottom of the column.
5. Side stream contain initial product and reflux of (kerosene, LGO, HGO) goes to the side stripper and return as

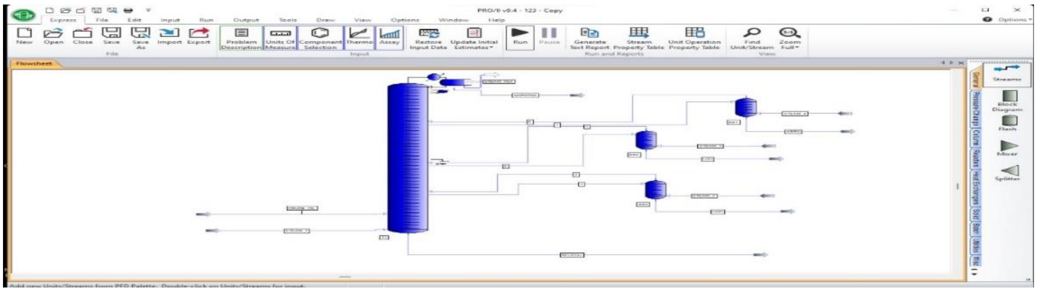

Figure 3.12 Process flow diagram of simulation by PRO// program

3.7.3 Flow diagram of side strippers

The side strippers are installed and the number of trays available for each side stripper is determined according to the operational manual for each product and the current that inlet to the stripper and reflux to the fractional column, as the number of trays different from one stripper to another in addition to the quantity of the product with the steam that inlet to the stripper from bottom (Figure 3.13). All the steam inlet the strippers are the same with main steam to the fractional column. as information is obtained from the AL-Dora oil refinery's PDF.

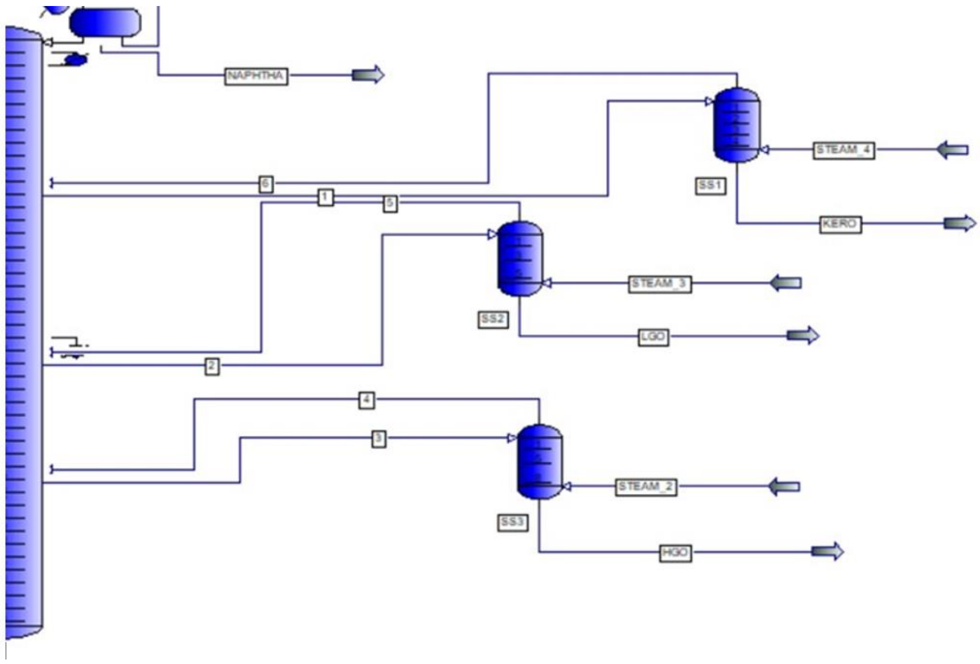

Figure 3.13 Instillation of side strippers of kerosene and HGO and LGO

3.7.4 flow diagram of pump around sections

Materials are extracted from the fractional column through two side pumps installed in the column from Tray No. 3 to Tray No. 1 and from Tray No. 26 to Tray No. 24 and the reflux temperature is lower than that of the outlet to maintain the thermal gradient of the tower and thus reducing economic costs in design (Figure 3.14).

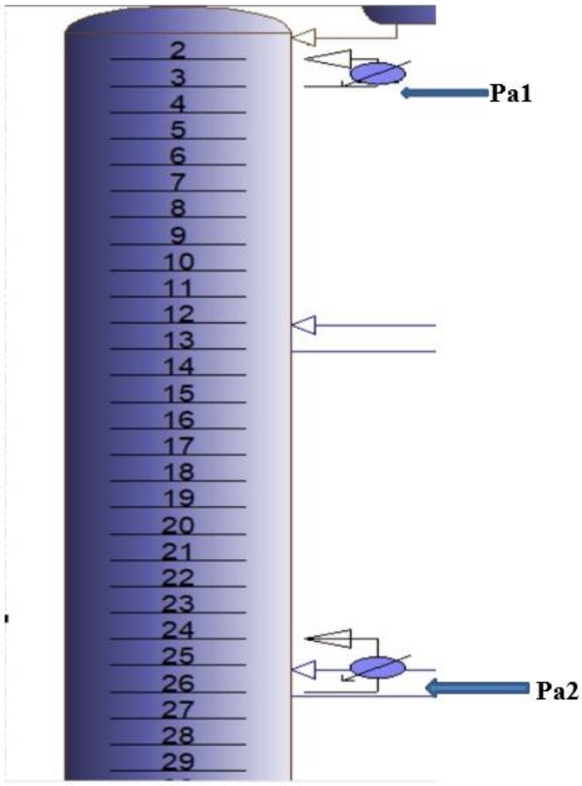

Figure 3.14 Installation of pump around main column

3.7.5 Heat exchanger

Heat exchangers (Figure 3.15) are found before the product is extracted and within the currents emerging from the columns, its function is to heat the current to increase the product by obtaining the highest concentration and ensuring wider vaporization and control of the temperature returning to the tower (Figure 3.16).

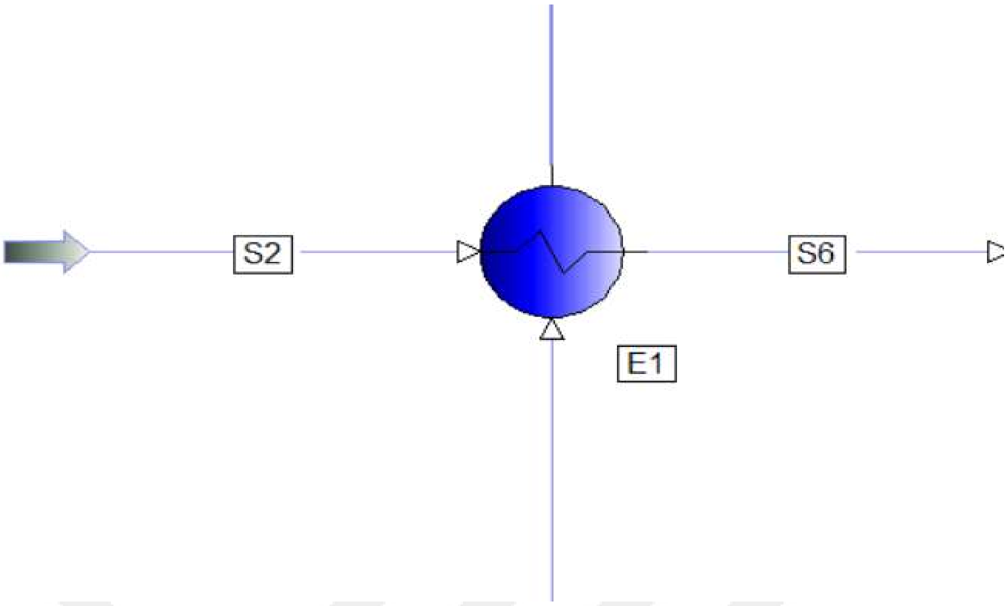

Figure 3.15 Heat exchanger flow chart

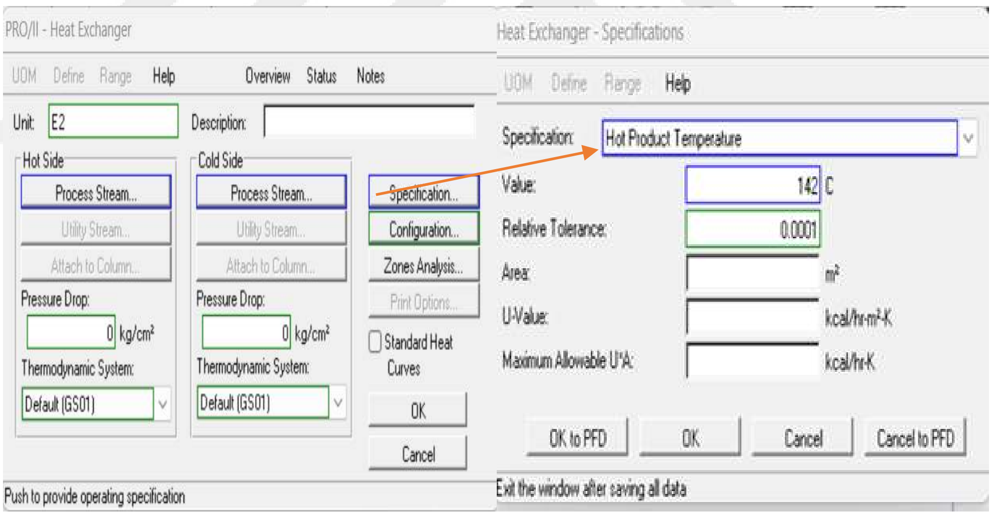

Figure 3.16 Heat exchanger specification

3.7.6 Run the simulation and show the results table

After installing the equipment and entering the data of pressure, temperature, and quantities, and according to the data, we start reading the results. After pressing the Run key, the Figure 3.17 in blue will be exclusively an indication of the correct entry and installation of the program. If it appears in red, this indicates an error in the installation.

After that, we verify the results by comparing them with the real readings. To validate the results, the materials to be studied must be defined and how they affect the system.

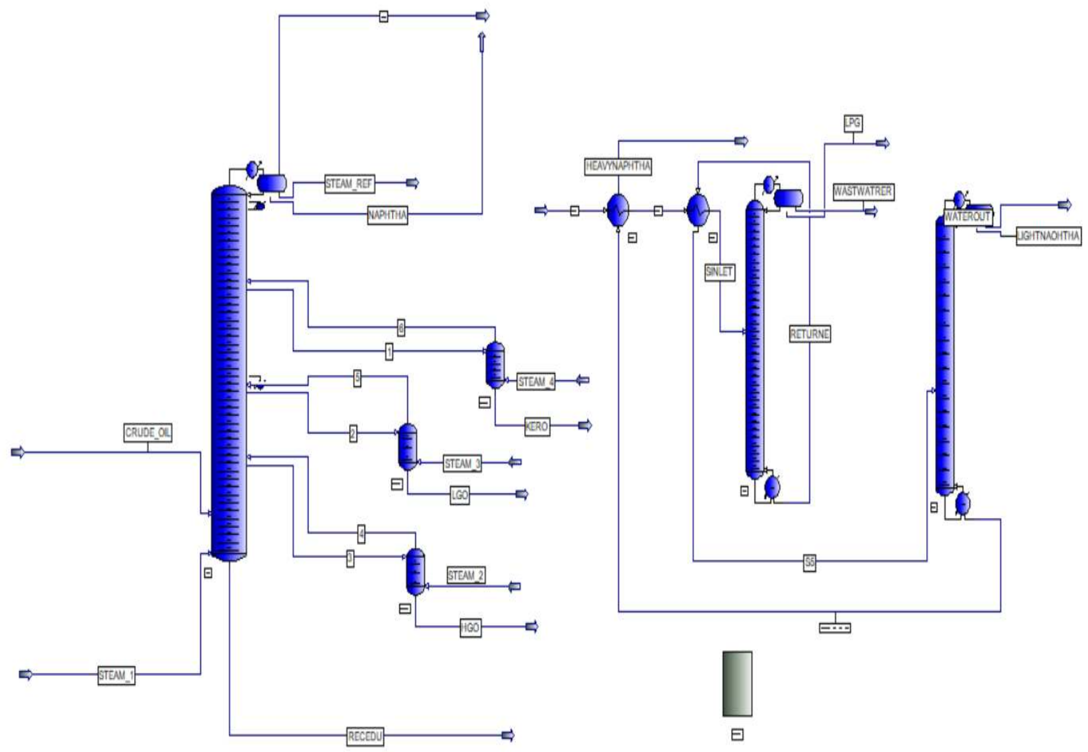

Figure 3.17 Crude oil distillation unit simulation model process flow diagram obtained by PRO//

And by clicking on stream property button and add the compounds (Figure 3.18).

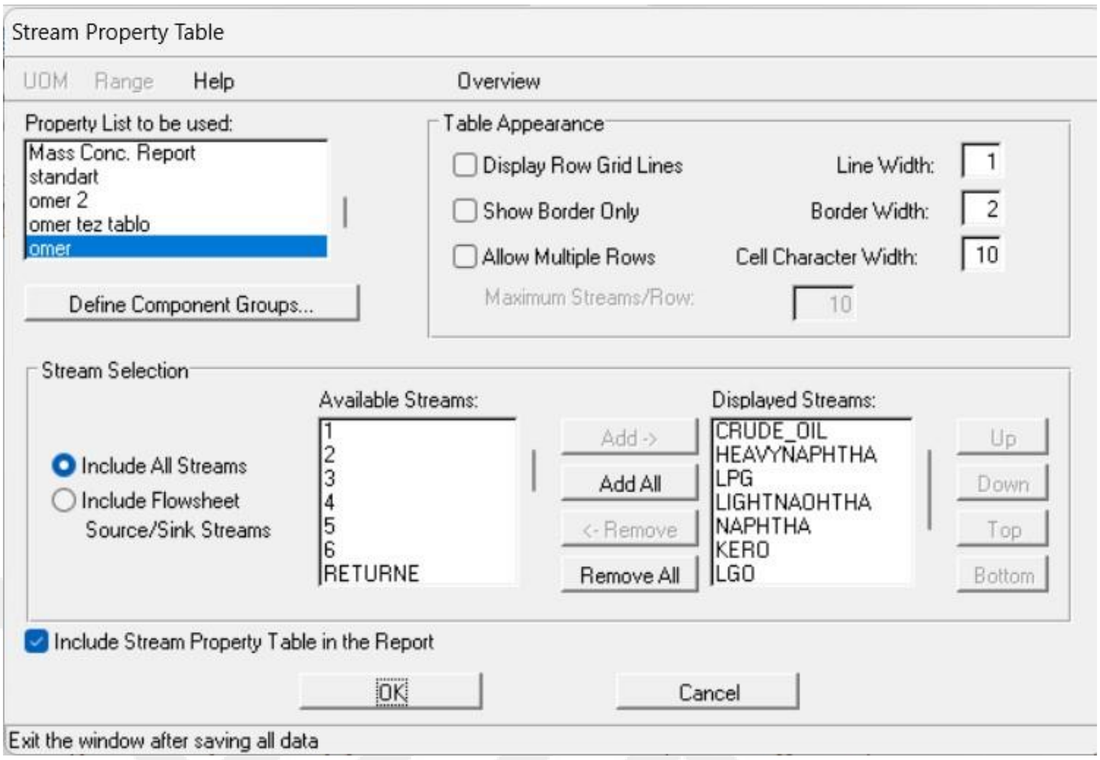

Figure 3.18 Block diagram table

After finishing press on ok key another table will show report of the results. The variables in the Table 3.11 depend on each other as they are affected by the increase or decrease of a variable. As it increases or decreases in terms of the quantity of the product. Simulation work begins by changing the value of a variable and studying the extent to which other variables are affected by recording events in tables and then comparing them to a graph.

Table 3.1 Compound results after run simulation

Stream Name		CRUDE_OIL	HEAVYNAPHTHA	LPG	LIGHTNAOHTHA	NAPHTHA	KERO	LGO	HGO	RECEDU
Phase		Mixed	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Stream Description										
	KG/HR	397540.00	45269.95	5040.00	39029.99	81443.55	39843.77	70670.25	12741.45	193005.55
Std. Liq. Rate	m3/day	11143.23	1426.15	215.92	1342.76	2725.01	1200.01	2019.81	348.29	4851.80
Temperature	C	345.000	85.000	45.347	78.000	66.045	209.442	264.096	304.824	339.707
Pressure	KG/CM2G	1.067	1.000	6.800	1.000	1.300	2.467	1.967	1.967	1.300
Molecular Weight		218.753	122.659	54.018	84.615	96.020	159.371	224.107	304.336	512.795
Enthalpy	x 10^6 W	102.477	2.183	0.166	1.830	3.179	5.130	11.618	2.435	41.153
	kJ/kg	928.00	173.64	118.72	168.79	140.50	463.48	591.85	687.91	767.59
Total Sp. Entropy	kJ/K-kg	7.332	4.158	7.175	4.575	4.509	5.277	6.070	6.691	7.921
UOP K factor		11.950	11.901	13.840	12.165	12.134	11.897	11.897	11.898	11.900
Total Std. Liq. Sp. Gravity		0.8571	0.7626	0.5608	0.6983	0.7180	0.7977	0.8406	0.8789	0.9557
Dry Total Std. Liquid Sp. Gravity		0.8571	0.7626	0.5607	0.6983	0.7179	0.7974	0.8404	0.8787	0.9556
Std. Liquid Density	KG/M3	856.211	761.825	560.210	697.610	717.297	796.870	839.724	877.997	954.725
API Gravity		33.600	54.055	120.835	71.136	65.574	45.895	36.842	29.503	16.564
ASTM D86 at 760 MM HG (LV)	C									
IBP		-16.321	124.199	-51.891	33.802	-15.466	151.143	212.964	302.017	306.837
5%		43.334	127.810	-43.360	46.451	24.404	177.124	242.947	325.007	357.596
10%		98.524	129.905	-32.697	50.562	51.939	185.000	251.000	337.180	388.630
30%		201.501	135.330	-9.803	60.487	81.676	192.410	260.635	348.182	440.547
50%		306.429	141.161	-5.627	72.853	103.153	200.732	274.470	353.727	501.043
70%		456.006	148.096	-2.133	82.217	128.290	209.406	292.861	359.872	594.108
90%		778.316	156.759	11.128	91.412	146.754	218.587	316.836	369.456	833.192
95%		802.773	161.525	16.253	96.211	153.065	223.351	324.149	374.913	865.803
EBP		845.936	166.301	19.328	100.930	158.421	227.852	330.635	381.331	885.626
ASTM D1160 at 760 MM HG (LV)	C									
IBP		7.109	115.403	-64.391	23.115	-8.001	152.333	216.856	309.756	312.395
5%		50.273	120.085	-56.341	34.783	17.828	172.599	240.226	328.146	357.923
10%		90.289	122.806	-46.251	38.584	35.741	178.762	246.523	337.914	385.775
30%		204.153	133.856	-12.899	55.995	77.016	192.748	263.627	356.918	452.718
50%		315.345	142.555	-6.307	72.333	103.357	204.467	281.704	365.287	521.817
70%		453.479	153.687	0.038	86.572	135.357	217.840	306.470	375.368	615.425
90%		659.669	167.131	18.577	100.634	159.160	231.886	335.462	389.876	779.987
95%		761.709	172.229	23.212	105.747	166.706	236.846	345.287	396.760	880.625
EBP		941.797	177.339	25.993	110.774	173.110	241.534	354.003	404.856	941.797

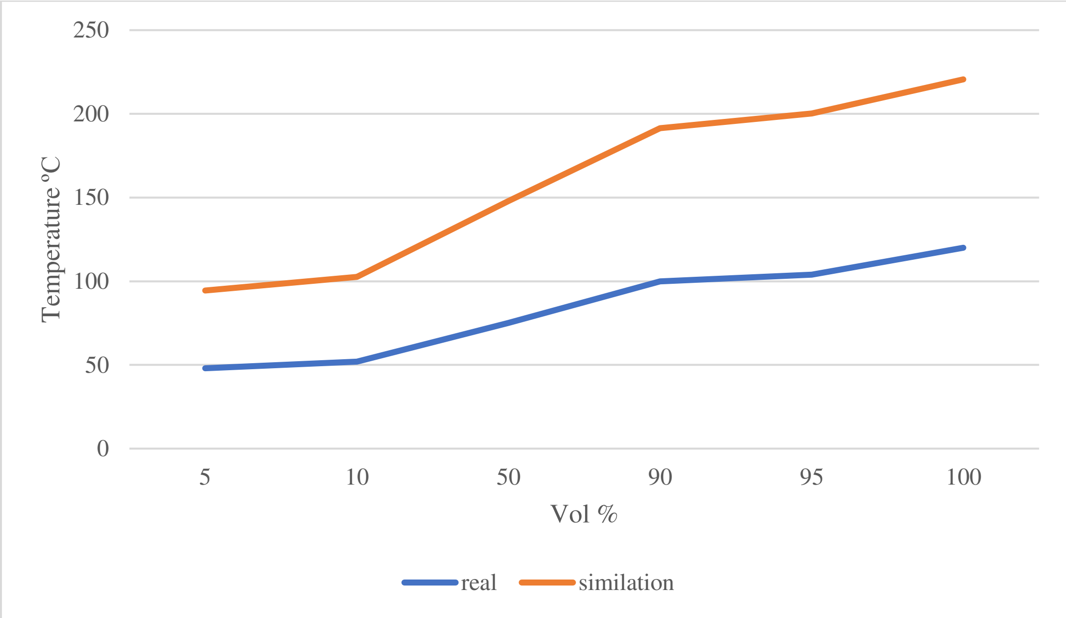

Figure 3.19 Simulated and plant data ASTM D86 curves of Light Naphtha

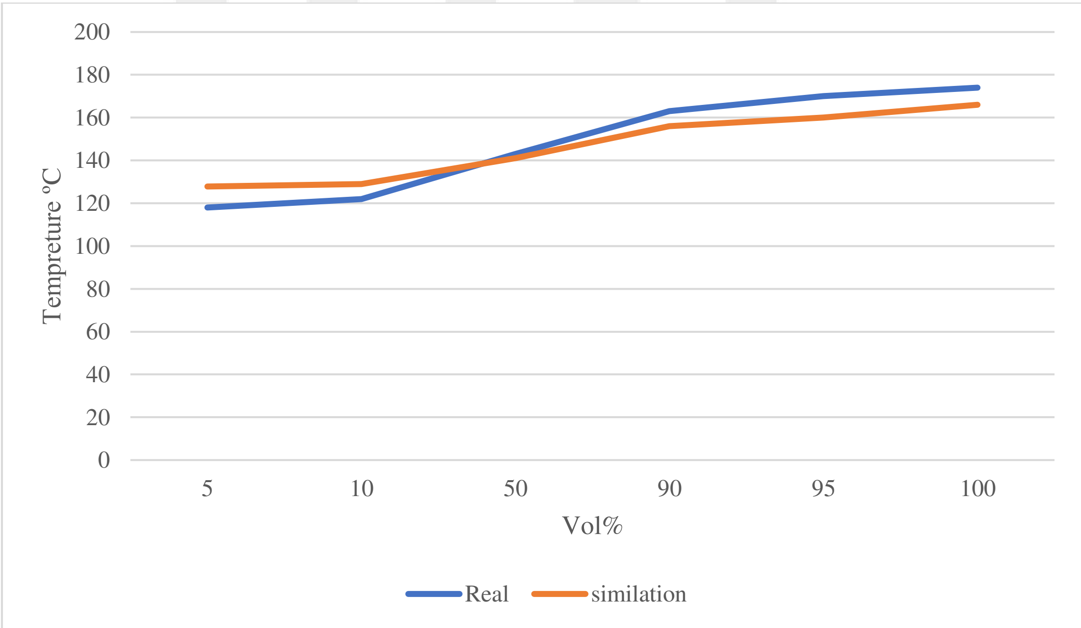

Figure 3.20 Simulated and plant data ASTM D86 curves of Heavy Naphtha

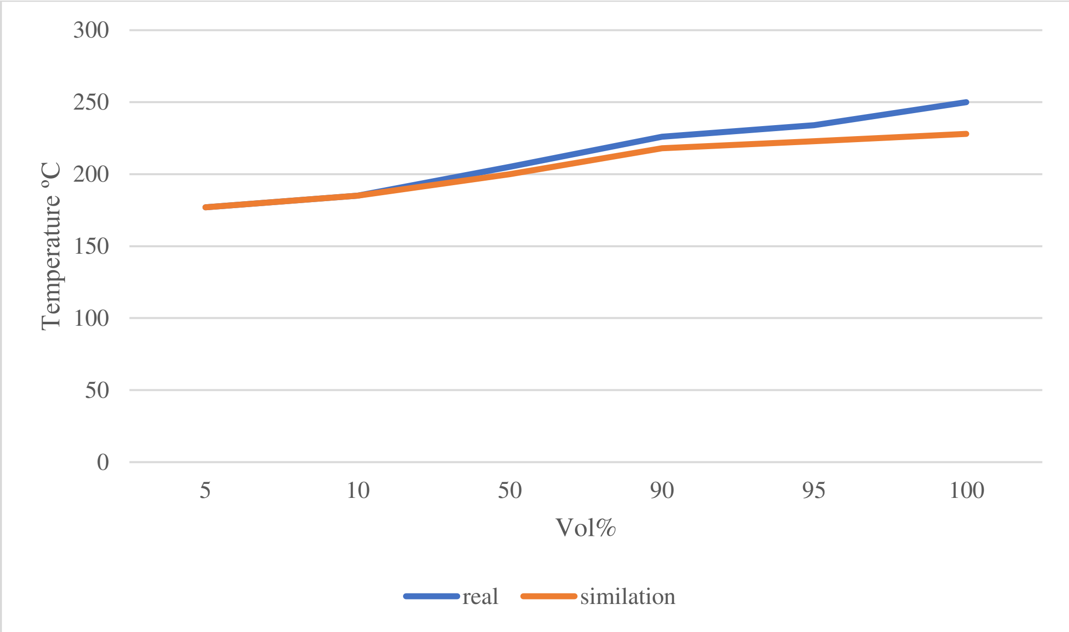

Figure 3.21 Simulated and plant data ASTM D86 curves of Kerosene

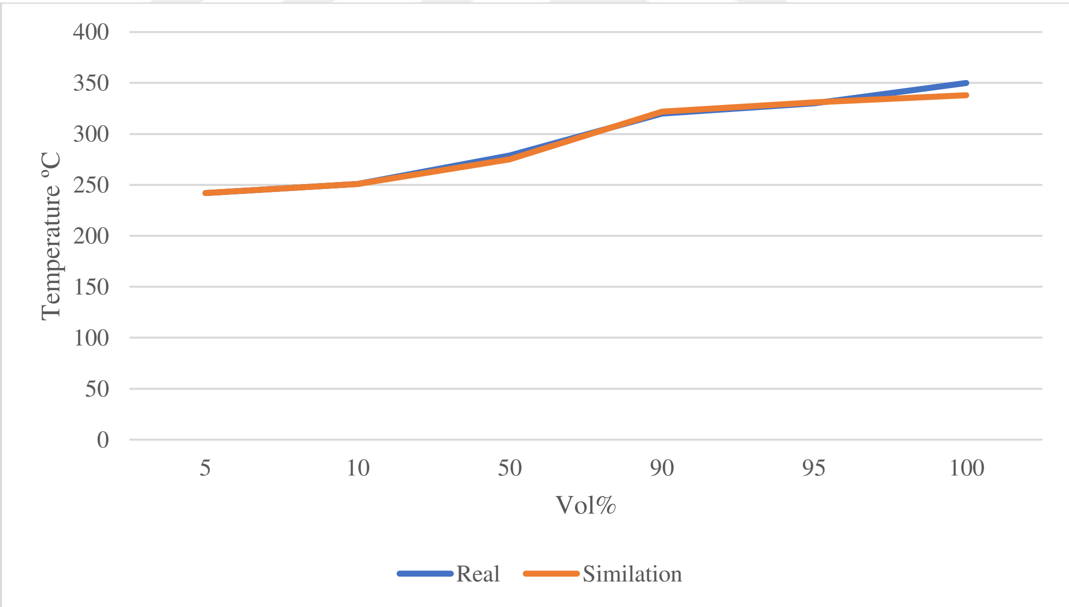

Figure 3.22 Simulated and plant data ASTM D86 curves of LGO

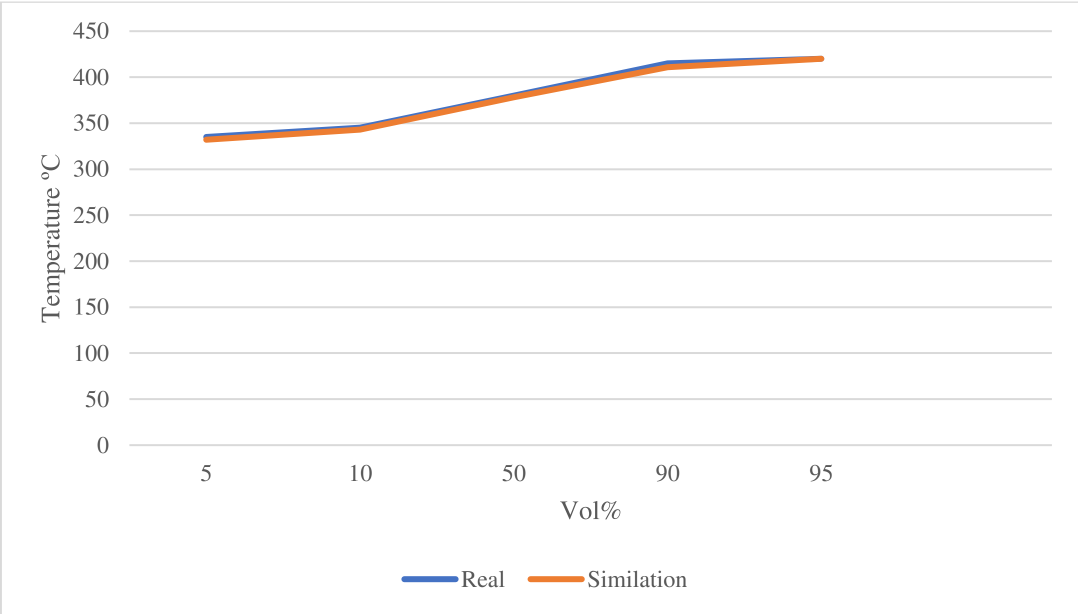

Figure 3.23 Simulated and plant data ASTM D86 curves of HGO

The above Figure 3.19-Figure 3.23 show the difference between the ASTM simulation and the real distillation unit data, where the difference can be noticed between the ASTM simulated temperatures, where it is generally assumed that the simulation matches the real data. These differences are usually simple due to the method of sampling in laboratory measurements, the method of operating the oil refinery, and the design of the ASTM is more or less by simple degrees, however, there are matching curves for the light components.

3.8 Comparison Between Simi Pro// Simulation and AL-Dora Refinery Results

Table 3.2 Comparison between mass flow rates of plant data and simulation

Product	unit	AL-Dora refinery	PRO/II simi.
Light Naphtha	Kg/hr.	31030	39030
Heavy Naphtha	Kg/hr.	45270	45270
Kerosene	Kg/hr.	39710	39843
HGO	Kg/hr.	12740	12741
LGO	Kg/hr.	70290	70670
LPG	Kg/hr.	5040	5040
Residue atm	Kg/hr.	193010	193005

From the above Table 3.2, it can be noted that there are no differences between the use of the program and the real data of the oil refinery, with the observation of small normal differences due to the difference in process parameters such as temperature and pressure. Except for light gas oil, the higher compounds may have a difference in terms of the unit of measure. Increasing the temperature, the vapor flow of the light compounds increases to the top of the distillation tower. It is possible that the big differences are according to the characteristics of the crude oil and the nature of the productive oil fields, including the stages of extraction, transportation, or the storage tank or in some distillation equipment there are some dirt and sediments that generate deviations in measurements and production efficiency In the simulation, the case is relatively stable, as the simulation indicated the ideal standard result, which is affected by the characteristics of crude oil and the process variables.

4. ANALYSIS AND RESULTS

As mentioned before, the purpose of the simulation is to provide the best practical results by controlling the effects to obtain the desired result with the least amount of energy, the least cost, and the most productivity. Therefore, in this chapter, the results are discussed and compared with the real ones, but primarily the results are matched with the real ones, considering the simple differences that are normal because the laboratory results are usually affected by some surrounding factors or some additions or reductions in the design of the oil refinery plant. The improvement process is carried out by other factors such as pressure, temperature, flow rat feed be constant, and a gradual little change in the cut's temperature, and notice the effect on the quantity of the product. The method of changing the operating temperature of kerosene cut and its effect on the rest of the cuts.

4.1 Effect of increasing Cut Temperature of Kerosene Production

After the distillation of crude oil and the rise of steam through the trays, the point of contact between the vapor and the liquid of the kerosene, according to the measurements of the operating conditions, is 203°C, and the exit of the kerosene flow from the concerned tray was measured. From this point, the effect of changing the amounts is measured by changing the temperature of kerosene withdrawal from the distillation tower (Table 4.1).

Atmospheric Tower T1

Table 4.1 Products withdraw cut temperature

Products	°C	Temperature Value
Kerosene withdrawal	°C	203
LGO withdrawal	°C	267
HGO withdrawal	°C	323

Consideration was taken of the kerosene withdrawal temperature from the distillation tower due to its economic importance (Table 4.2).

Table 4.2 The effect of increasing Kerosene withdraw temperature

Kerosene cut. Temperature °C	Kerosene volume Flow m^3/day	LGO volume Flow m^3/day
203	1175	2047
203.5	1196	2026
204	1217	2005
204.5	1239	1983
205	1260	1962
205.5	1282	1940
206	1305	1917
206.5	1327	1895
207	1350	1872
207.5	1373	1849
208	1420	1803
208.5	1467	1755
209	1491	1731
209.5	1516	1707
210	1540	1682

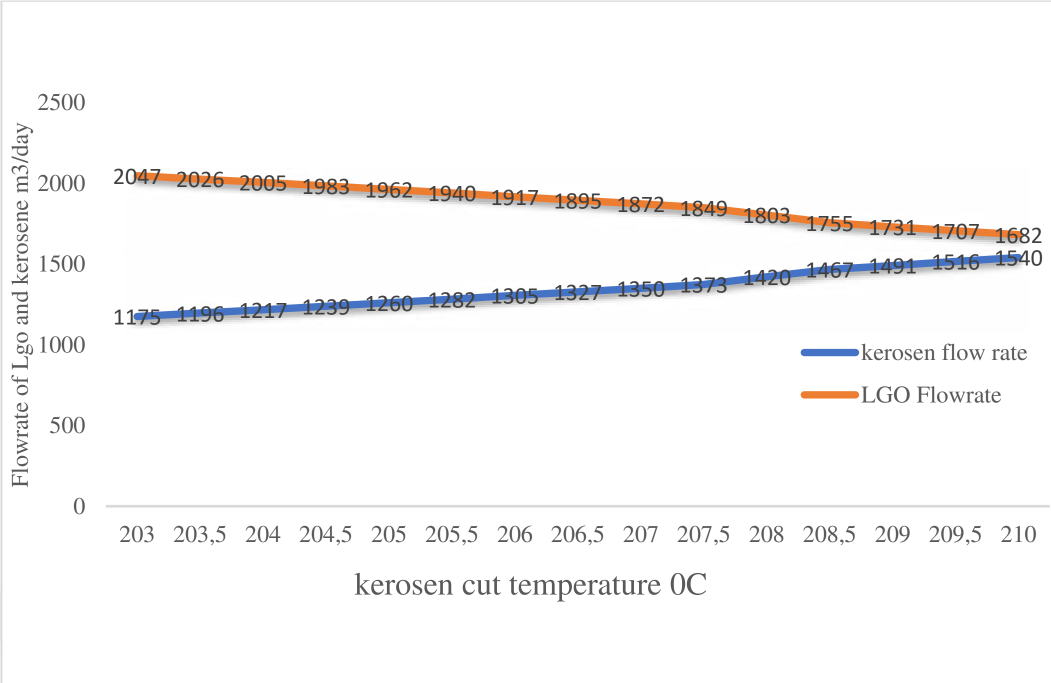

Figure 4.1 The effect of increasing Kerosene withdraw temperature on Kerosene and LGO

From the above Figure 4.1 with an increase in the temperature of the clouds, the amount of kerosene increases, in addition to that the flow of oil and light gas decreases inversely with the increase the cuts of kerosene because part of it is drawn into the upper tray, which is due to the evaporation of heavy components, which increases the flow of larger amounts of kerosene.

4.2 Effecting of Increasing Crude oil Feed Temperature

An increase in the temperature of the oil entering the distillation unit leads to an increase in the separation of components with a high boiling point, the rise of heavy products to the top of the tower, and an increase in the pressure of the tower, and of course it will affect the quality of the products (Table 4.3).

Table 4.3 Effecting of increasing crude oil feed temperature

Feed temperature ˚C	Kerosene volumetric Flow rates m^3/day	Final Boiling Point of Kerosene ^{0}C	Naphtha volumetric Flow rates m^3/day	Final Boiling Point of Naphtha ^{0}C	HGO volumetric Flow rates m^3/day	Final Boiling Point of HGO ^{0}C	LGO volumetric Flow rates m^3/day	Final Boiling Point of LGO ^{0}C
335	1192.75	229.68	2723.96	158.721	345.59	399.72	2021.02	337.93
340	1193.96	228.128	2724.1	158.675	346.67	394.747	2021.6	335.569
345	1194.87	227.832	2724.26	158.533	347.51	387.039	2022.04	332.885
350	1195.23	227.527	2724.49	158.403	348.17	381.683	2022.71	330.683

The high temperature of the feed entering the tower does not affect too much on the number of products as much as the middle components. It depends on the density of the crude oil. so, the evaporation of light materials increases, but it does not have an effect as much as the steam entering from the bottom of the tower.

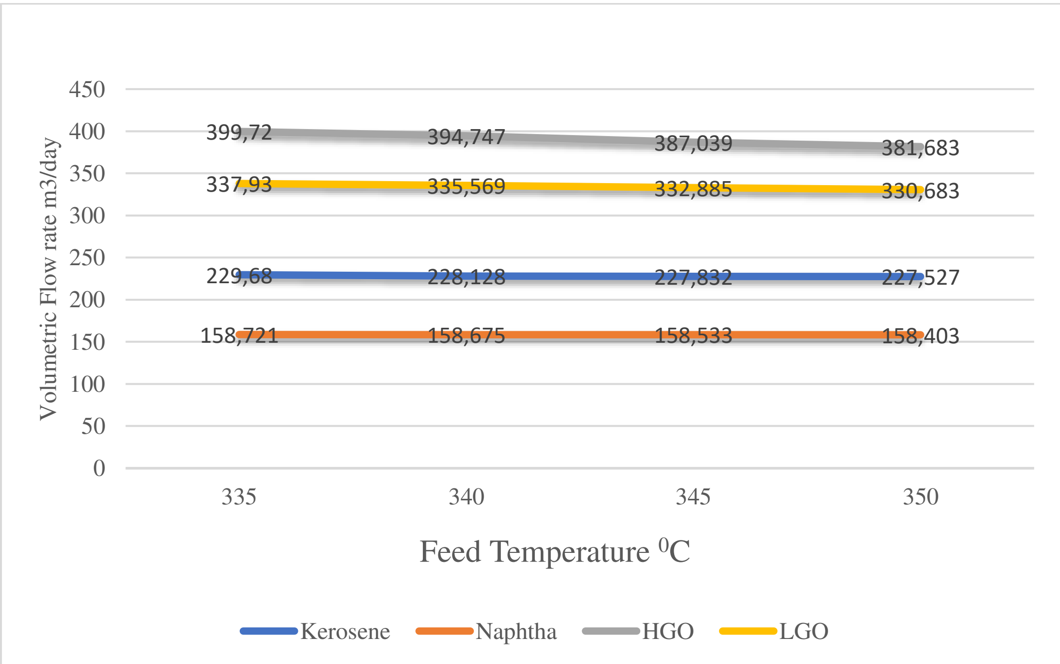

Figure 4.2 Effecting of increasing crude oil feed temperature on products

Raising the temperature of the feed increases the flow of compounds with high molecular weights to the mixing area (Figure 4.2). Increasing the boiling point of light compounds such as kerosene and naphtha leads to an increase in the flow of elements with a higher molecular weight, as the elements with a higher specific gravity respond with the elements with a higher molecular weight, as the heavy compounds rise to the upper trays and change the properties of the light products. Where compounds or elements with lower molecular weights mix, thus increasing the final boiling point.

4.3 Effecting of Increasing Steam Flow Rate

An increase in the mass flow rate of the steam entering the distillation tower leads to a decrease in the pressure of the products and an increase in the amounts of heavy products. With the continuation of the flow of steam, the final boiling point increases, and when the heavy products rise, they are drawn to the upper trays, with the decrease in the surface tension of the mixture of compounds (Table 4.4).

Table 4.4 The effect of increasing steam flow rate

Steam kg/hr.	Kerosene kg/hr.	Naphtha kg/hr.
3400	39709.22	81503.39
3410	39710.12	81504.05
3420	39710.94	81505
3430	39711.66	81505.74
3440	39712	81506.1
3450	39712.41	81506.52
3460	39712.98	81506.90
3470	39713.40	81507.44
3480	39713.9	81508
3490	39714.5	81509.33
3500	39714.88	81509.87

Each increase in the flow of steam leads to an increase in the movement of steam upstream, and thus the kerosene cuts increase, and the vapors of light compounds are carried to the upper trays, which condense each one according to the partial pressure and according to the temperature of the tray. An increase in kerosene and naphtha products can be seen due to the mixed light components in the residue.

4.4 Effecting of Increasing Top Tray Pressure

An increase in the partial pressures of products with increasing pressure at the top of the tower decreases flow rates of light cut products (Table 4.5)

Table 4.5 Effecting of increasing top tray pressure

Top Tray Pressure $kg/cm^2.g$	Kerosene volume Flow m^3/day	Final boiling point of Kero. ^0C	Heavy naphtha Volume Flow m^3/day	Final boiling point of H.N ^0C	Light naphtha Volume Flow m^3/day	Final boiling point of L.N ^0C	LGO volume Flow m^3/day	Final boiling point of LGO ^0C	HGO volume Flow m^3/day	Final boiling point of HGO ^0C
1.10	1203.9	227.765	1426.3	166.127	1343.38	100.728	2019.2	328.992	348.78	377.627
1.2	1202.03	227.815	1426.23	166.216	1343.06	100.831	2019.43	329.812	348.53	379.411
1.3	1199.99	227.852	1426.15	166.301	1342.77	100.928	2019.83	330.535	348.14	381.33
1.4	1198.8	227.877	1426.09	166.411	1328.26	101.01	2020.32	333.897	347.48	387.251
1.5	1195.77	227.896	1426.04	166.446	1327.87	101.114	2020.96	332.306	347.74	385.489

With the increase in pressure, the separation process of oil products improves and change the Api of the compounds that will be due to change the properties of elements and change the final boiling point therefore will go to effect on the number of products. Light cuts such as Kerosene, Naphtha, and LGO tend to decrease their production. When the pressure is raised in the upper trays of the tower, the upper products increase due to the formation of an increase in carbon chains in the upper plates, and the temperatures of withdrawing products from the trays decrease and the boiling point of heavy products increases. Because the specific gravity depends on the components of the cuts and increases because the higher molecular weight increases the specific gravity in the mixture.

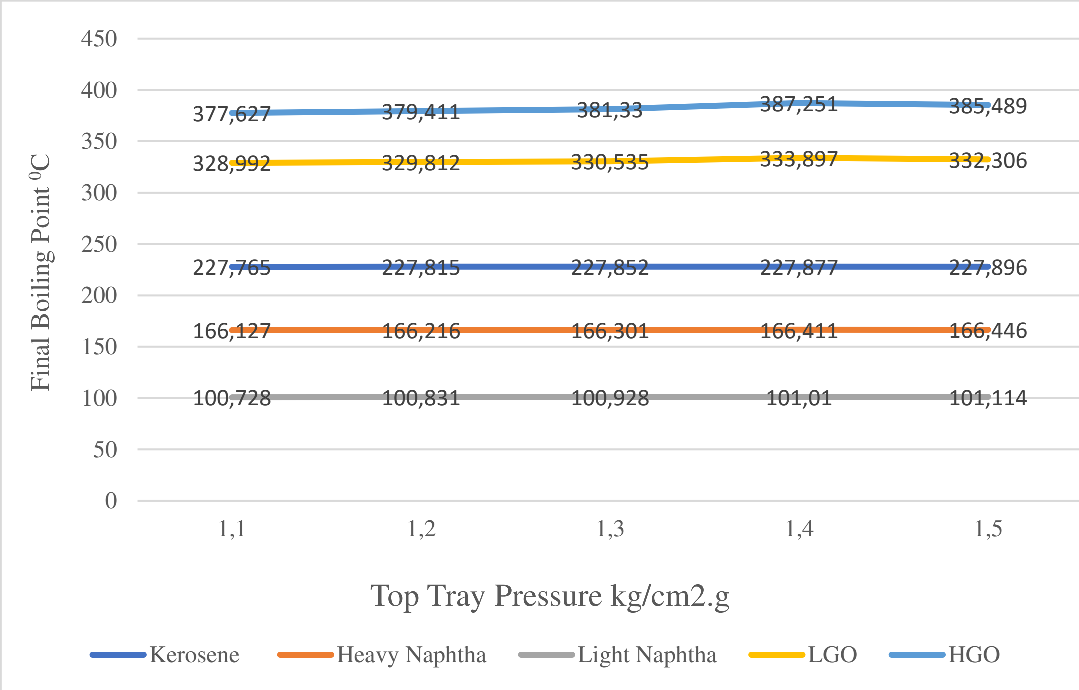

Figure 4.3 Effecting of increasing crude oil feed temperature

decreasing the pressure is recommended to increase the amount of oil products, and the concentration of sulfur must be monitored, because in decreasing it, it leads to a increase in light products, and causes damage to pipes and steam boilers, and a higher operating cost in the use of fuel, so it must not exceed the specifications required for consumption (Figure 4.3).

4.5 Statistical Analysis

Table 4.6 Comparison between mass flow rates and of plant data simulation

Product	unit	AL-Dora refinery	PRO/II simi.	P-value
Light Naphtha	Kg/hr.	31030	39030	
Heavy Naphtha	Kg/hr.	45270	45270	
Kerosene	Kg/hr.	39710	39843	
HGO	Kg/hr.	12740	12741	
LGO	Kg/hr.	70290	70670	0.532[a]
LPG	Kg/hr.	5040	5040	
Residue atm	Kg/hr.	193010	193005	

NOT: [a]There is not statistically differences between simulation model and Al-Dora Refinery.

The Table 4.6 allows to see the difference between the simulation and the real values taken from the refinery plant, and that the increase in the yield of cutting products leads to an increase in their prices, especially if their yield is small in residue The simulation procedures were focused on increasing the rates of kerosene and naphtha due to their economic importance And raising the kerosene withdrawal temperatures will lead to having the largest amount of lighter cuts than of fuel, which in turn will automatically go to the top of the distillation column. The differences between simulation behavior and real values such as temperature and pressure can be summarized according to the characteristics of crude oil due to the different oil production processes, in addition to the effect of storage in oil tanks or storages that lead to fouling and loss in heat exchangers, a decrease in the efficiency of oil pipelines and deviations in measurement units such as pressure and temperature. As for the simulation, there are no deviations from the standard values and no malfunctions in the tools. The decrease of the waste flow depends on the characteristics of the crude oil and the methods of operating the distillation unit.

4.6 Effecting on Properties of Naphtha and Kerosene

The results of the resulting compounds were compared with the basic operation of the refinery, where we notice in some temperature variables or pressures after doing the simulation the different properties of the products cuts (Table 4.7).

Table 4.7 Effecting on properties of NAphtha and Kerosene

Properties	Kerosene at basic operation at 335 °C	Kerosene after simulation at 348 °C	Naphtha at basic operation at 335 °C	Naphtha after simulation at 348 °C
Sp.gr	0.7975	0.7979	0.7238	0.7184
Enthalpy $*10^6$ W	5.126	5.24	4.491	3.2
Api	45.254	45.877	63.995	64.427
Final boiling point ^{0}C	239.54	228.415	165.471	158.833

Kerosene increases with the increase in temperature because it has a higher molecular weight that allows the strength of cohesion and the increase in viscosity due to the increase in the molecular weight of it. the viscosity does not allow the transverse deformations resulting from the flow of diesel cuts into the kerosene particles the heavier hydrocarbon compounds are flowing the kerosene. It is also noted that lowering the temperature leads to obtaining a difference in the enthalpy quantities of the oil entering the unit, where energy is utilized, and the amount of fuel used for operation is shortened. Also, lowering the boiling point temperature of chemical compounds saves energy and time and has financial returns for the beneficiary.

5. CONCLUSION

The simulation process was used using the PRO // program to study the effect of changing some operating conditions on the products in the oil distillation unit. Due to the importance of naphtha and kerosene in the necessary industries, the changes were focused on the temperature of kerosene withdrawal and the study of the effect of changing conditions on their quantities to obtain the maximum amount of these materials. Where the results showed the different products according to the change of operating parameters. The results were compared to the results of the AL-Dora refinery / crude oil distillation unit. It can be noted in the program that several adjustments can be made in the quantities of the required products by controlling the operating variables. It is worth noting that the variables were set according to the ideal operating system to obtain the required quantities, but due to Depreciation of the equipment's and too long uses in the refinery plant, the operating capacity does not exceed 60%. Therefore, the idea of improving distillation processing will show the way to other simple and practical solutions to obtain products in controlled quantities. Performance design was conducted based on the physical properties of chemical compounds, as the Pro program is an ideal simulation environment to serve the manufacturing and production industries and has many options to expand industrial capabilities. Monitoring, error detection and repair, operational improvement and business planning can also be performed using the Pro //program. the interface of pro //it can be completely interactive, process variables and unit manual operation can easily be treated (pro///8.4).

It is necessary to operate all distillation columns on a regular basis to reach the required rates and high quality. distillation column management the objectives should be clarified as follows:

- Set and establish stable operating conditions for the column.
- Regulate the main conditions within the column until the product achieves the specified specifications.
- Specifications to obtain the required high efficiency, which is by increasing production and reducing energy losses.

The operating conditions have effects on the products coming out of the distillation process, such as temperature, pressure, and flow rates. It is necessary to monitor the mentioned variable where any change in any variable affects the process so all sections must be monitored and not one specific unit. Each column has a management system consisting of several loops that regulate the process variables during operation due to the occurrence of disturbances during operation. The loops usually consist of a control device, a transmitter, and a safety valve controlling the process variable, where adjustments are made by opening its control valve, and thus the variable and the amount of current flow are controlled.

- Column pressure is always controlled as a constant value.
- The feed rate entering the column is determined by the value leaving the previous column, unless the flow rate is coming from the tank, where it can be controlled individually.
- The temperature is controlled by heating the current flowing through the pre-heat exchangers and can also be heated from the bottom product.
- Higher temperatures can be controlled by varied reflux.
- The distillation column undergoes material and energy balancing processes.

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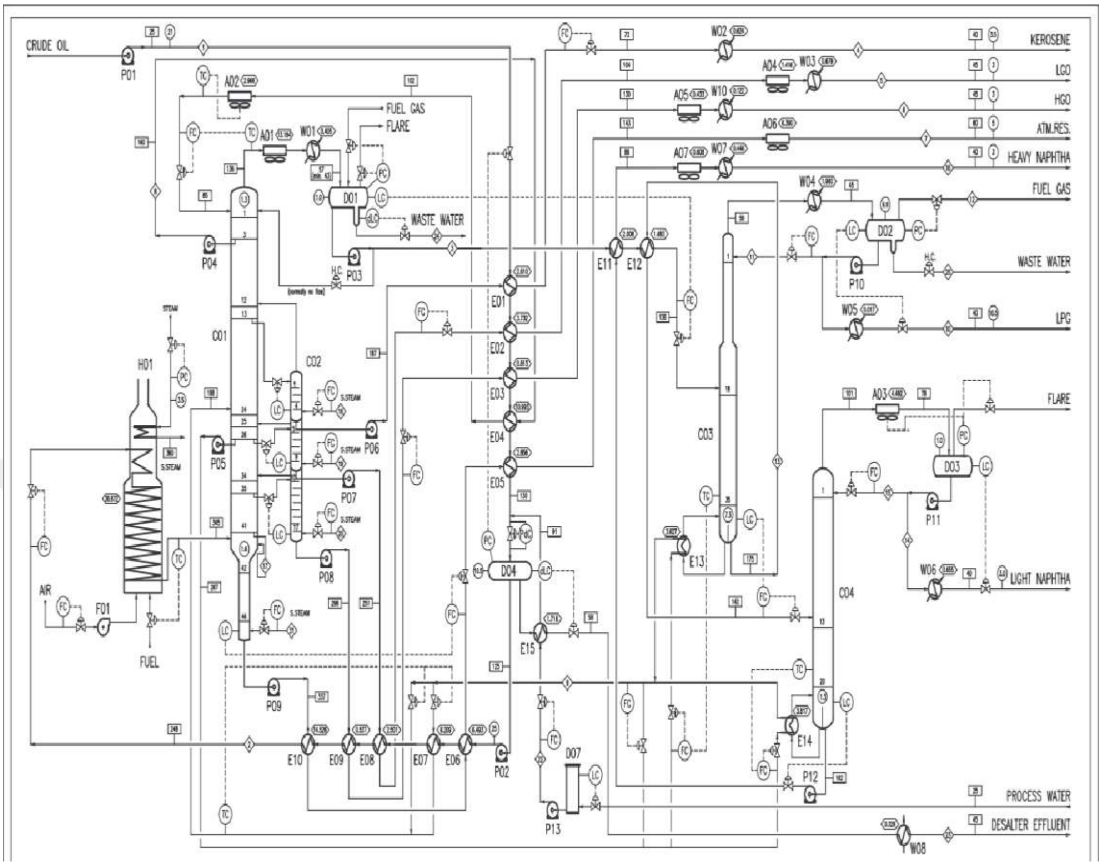
APPENDICES

APPENDIX 1. Process flow diagram of AL-Doura refinery plant (distillation unit)

APPENDIX 1. Process flow diagram of AL-Doura refinery plant (distillation unit)



LEGEND

- ◇ –STREAM NO.
- ○ –PRESSURE [kg/cm2 g]
- ▭ –TEMPERATURE [°C]
- ⬭ –HEAT DUTY [MMkcal/hr]

STREAM NO. ◇	1	2	3	4	5	6	7	8	9	10	11	12
MEDIUM	crude oil	desalt. crude oil	naphtha	kerosene	LGO	HGO	atm. residue	naphtha	LGO	LPG	LPG	fuel gas
FLOW kg/h	397540	398140	81390	39710	70290	12740	193010	320830	300000	5040	19060	50
STATE	L	L	L	L	L	L	L	L	L	L	L	V
DENSITY AT 15°C kg/m3	856	857	707	800	838	879	960	764	829	562	562	
MOL.WEIGHT kg/kg mol										54	54	49

STREAM NO. ◇	13	14	15	16	17	18	19	20	21	22	23	24
MEDIUM	stabilized naphtha	light naphtha	light naphtha	heavy naphtha	overflash	s. steam	s. steam	s. steam	s. steam	process water	desalted effluent	waste water
FLOW kg/h	76300	31030	18720	45270	24970	500	1100	800	3400	26000	25000	6750
STATE	L	L	L	L	L	V	V	V	V	L	L	L
DENSITY AT 15°C kg/m3	720	678	678	750						999	999	999
MOL.WEIGHT kg/kg mol						18	18	18	18			

CURRICULUM VITAE

Personal Information

Name and Surname : Salwan Kanaan Alwaan AL-AJEELE

Education

MSc	Çankırı Karatekin University Graduate School of Natural and Applied Sciences Department of Chemical Engineering	2020-2023
Undergraduate	Baghdad University College of Engineering Department of Chemical Engineering	2002-2006

Work Experience

Year	Institution	Position
2006-2011	Sites Engineering of Building and Constructions	Site Engineer
2011-2012	Beji Refinery Plant (instilling desalination plants)	Site Engineer
2012-2014	Modern Village in AL-Najaf City	Site Manager
2014-2019	Department of Chemical Security Ministry of Industry and Minerals	Engineer