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Exploitation of Condensates to Produce Gasoline

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Abstract

Gas condensate or natural gasoline is a valuable liquid hydrocarbon mixture which could be utilized as fuel or converted to different petroleum products like gasoline, light oil, jet fuel etc. In Libya, the total production of gas condensate is up to 70,000 BBLD. These enormous quantities of condensates produced do not find now any industrial application. This proves however, that the condensate is of superior quality for the production of fuels than the oil itself. The purpose of this work is to present the suggestions for utilization of Libyan condensate instead of export especially for production of useful light products such as Naphtha and Kerosene. Naphtha is a key product for gasoline production.

In this study, three suggestions for utilization of Libyan condensate were presented. The first one is using condensate to produce varieties of useful products by using condensate fractionation column. For this suggestion, the distillation column was used to produce three products, Naphtha, Kerosene and Diesel. Where Naphtha is the top product while kerosene as side product and Diesel as the bottom product. The design of condensate fractionation column and the effect of some design parameters such as reflux ratio and the number of stages on the quality of three products (Naphtha, Kerosene and Diesel) have been studied and investigated in order to obtain prior data before implantation of the plant. Also, the quality of three products of a fractionation column considering different design conditions of the column have been studied and investigated. The first design was on a single traditional distillation column whereas the consecutive studies were done on modifying the distillation column to yield the same quality of products keeping the material balance constant. This is done by using simulation which is a standard and reliable tool. The whole simulation study and analysis was done on HYSYS software.

The second suggestion is blending condensate with crude oil and then used as feed stock to Libyan refineries. The third suggestion is using paraffinic condensate as feed stock to reforming unit for gasoline production.

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1 Introduction

1.1 Nature of condensate

Condensate is a low-density mixture of hydrocarbon liquids that are present as gaseous components in the raw natural gas produced from many natural gas and oil fields. It condenses out of the raw gas if the temperature is reduced to below the hydrocarbon dew point temperature of the raw gas [1]. Condensate is also referred to as gas condensate, or sometimes natural gasoline because it contains hydrocarbons within the gasoline boiling range.

Condensate is of superior quality for the production of fuels than the oil itself. Indeed, the condensate is a slightly colored liquid having general characteristics similar to those of an oil fraction. It is practically free of hydrogen sulfide and has a characteristic bitter odor. Condensate may come from any one of three types of gas wells

- Crude oil wells, condensate that comes from crude oil wells is called associated gas. This gas can exist separate from the crude oil in the underground formation, or dissolved in the crude oil. Condensate produced from oil wells is often referred to as lease condensate.
- Dry gas wells, these wells typically produce only raw natural gas that does not contain any hydrocarbon liquids. Such gas is called non-associated gas. Condensate from dry gas is extracted at gas processing plants and, hence, is often referred to as plant condensate.
- Condensate wells, these wells produce raw natural gas along with natural gas liquid. Such gas is also called associated gas and often referred to as wet gas.

Condensates usually boil in a range of approximately (100 - 650F) [1] with this range of boiling condensates containing a variety of hydrocarbons (paraffinic, Naphthenic and aromatic); these materials contain compounds that form petroleum cuts referred to as naphtha, kerosene, and diesel. Naphtha is a lighter cut with boiling point range between (100 - 400F) [1], the estimated number of carbon atoms of the compounds found between 5 to 10, the other cuts, kerosene and diesel, have boiling points range between (350 - 650F), The number of carbon atoms are between 10 to 20. When the percentage of paraffin compounds more than 67% it will be considered as paraffinic type which is used

for the production of olefins such as ethylene and Propylene in addition of production of motor gasoline. Condensates vary in quality and quantity when extracted, and each gathering system and processing facility needs to be tailored accordingly based on commercial and operational factors. Amongst their various uses, condensates can be added to other crude to be refined, as they lower the sulfur content of the crude and reduce the volatility of the condensate.

Aromatics, monomers, and olefins obtained from condensates are used to produce polymers, fibers, and resins. Products from refined condensates are almost identical to those produced from crude, but these products are limited to a select basket of lighter hydrocarbons. Condensate volumes vary by region and the field from which they are extracted. The Middle East, North America (the United States, Canada, and Mexico), and Russia are the leading producers for crude and lease condensates [1]. Condensate prices follow crude oil prices and can be sold as a liquid blended with crude oil, lowering the price of crude oil as well.

Countries that produce large amounts of condensate, such as some countries in the Arabian Gulf (Qatar, Saudi Arabia and the UAE) are the most exploited of condensate producing light products, mainly naphtha, which is then used for motor gasoline or as feedstock for the petrochemical industry. In the beginning of 2010 the total of the units splitting condensates in the Asia Pacific region and the Middle East about 2.2 million barrels per day, more than half of them in different parts of the Middle East, the production of condensates is expected to increase to 4.0 million barrels per day [13] due to the increased demand of gasoline and increasing economic returns in 2016. Table 1-1 shows world production of condensate. Figure1-1 Shows total US condensate production by source

Table 1-1 Production capacities to split condensate in Asia pacific and the Middle East.

Country	2010	2014	2016
Middle east	1,135	1,312	2,143
Qatar	201	201	345
Iran	244	382	804
Saudi Arabia	196	196	294
Emirates	496	496	661
Pacific region	956	1,207	1646
India	15	15	15
Australia	45	45	45
China	146	261	461
Indonesia	98	98	98
Japan	119	119	119
Malaysia	74	74	119
New Zealand	30	30	30
Singapore	69	69	69
South Korea	134	262	262
Taiwan	69	69	69
Thailand	138	138	138

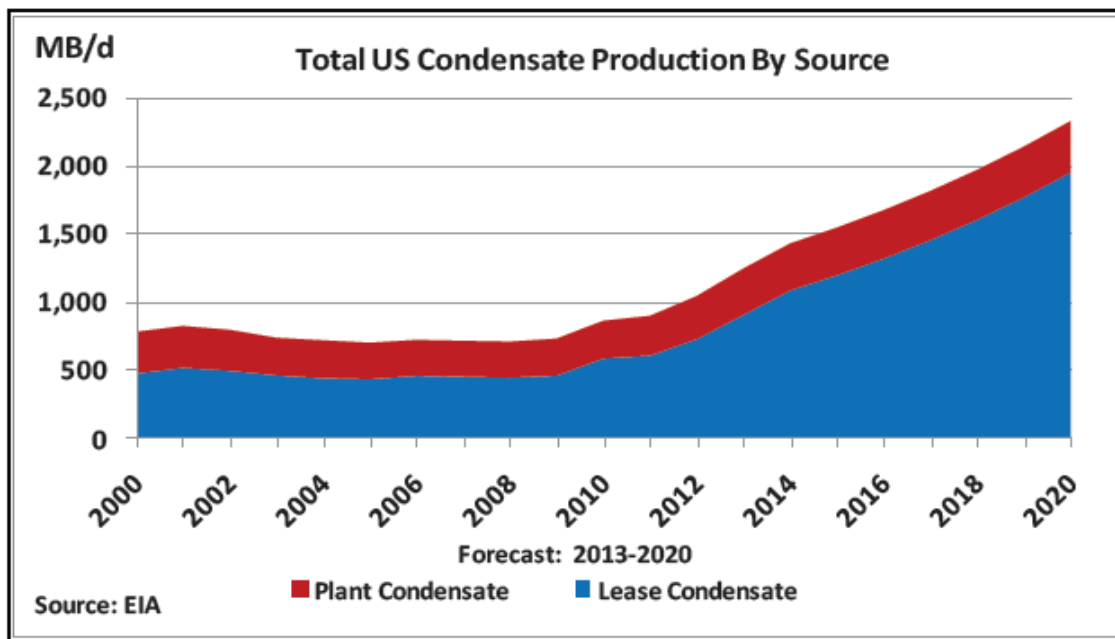


Figure 1-1total US condensate production by source

1.2 Condensate production in Libya

Libya production is about 70,000 bbl/day of condensate in different gas fields. At the moment there are three national companies operator most of the fields that produce condensates, Sirte oil company, Mellitah oil & gas company and Zueitina oil company [1]. Condensates productions by these companies are different in their properties and specification.

1.2.1 Condensates produced by Mellitah Oil and Gas Company

Mellitah gas is the operator of western Libya gas project (WLGP), which entails the development of two fields; Wafa and Bahr Essalam field [2]

Wafa fields located about 540 km southwest of Tripoli and about 160 km south of the city of Ghadames in the NC160A concession, along the Libyan – Algerian border. The southern part was discovered in 1964 by shell – Libya with well D1, and the northern culmination, was discovered in 1991 with well A1. The field is a gas-condensate reservoir with a thin oil leg. Wafa development plan called for drilling of 37 oil and gas wells, which were put on production in September. 2004. The average daily production from wafa field is 37,290 bbl/d of crude oil and condensate, 22,503 bbl/d of NGL [2].

Bahr Essalam field is located about 110 km from Tripoli coast. The exploration activities in the field started in 1977 and 1979 by drilling of two wells C1 and C2 followed by another five exploratory wells. The development plan calls for two phases, phase I consists of drilling 26 wells which were put on production in Sep. 2005 whereas phase II will be developed in the near future and consists of drilling 10 wells.

The gas and condensate are produced from 15 platform wells and 11 subsea wells divided in 2 clusters located 20 and 25 km away from Sabratha platform. The total production capacity is 600 MMSDFD of sales gas and about 35,000 bbl/day of crude oil and condensate. [2] The production from the subsea and platform wells is treated on Sabratha platform for separation and dehydration. The condensate is pumped through a 10" pipeline to Mellitah for further treatment and export. Table 1-2 shows Milletah condensate specifications

Table 1-2 The specification of condensate (Mellitah Company).

API gravity @60F	60
Specific gravity @60/60F	0.735
Reid vapor pressure @100F	10.5 psia
Corrosion, Copper Strip @122F	1b
Molecular Wight	110
Density @15C	0.735Kg/L
Hydrogen sulfide	<50 ppm
Sulfur, weigh %	<0.1
Mercaptan Sulfur	<50 ppm
SayboltColour	12.4
ASTM D-86 Distillation	Temperature °C
IBP	92
5%	124
10%	141
20%	166
30%	193
40%	222
50%	253
60%	291
70%	334
80%	390
90%	479
95%	554
FBP	584
Parafins	57 vol%
Naphtenes	28 vol%
Aromatics	15 vol%

1.2.2 Condensates produced by Sirte Oil Company (SOC)

Sirte Oil Company manages several fields for the production of natural gas and crude oil. (Figure 1-2) shows the flow diagram for condensate and gas treatment in Brega. It can be seen that the associated gas is pumped through 36" pipeline to slug catcher unit, where condensate separate from gas. Condensate stream goes to the gas liquid extraction unit (GLRU) for further treatment while gas goes to gas plant for the production of natural gas, and liquefied petroleum [1].

Non-associated gas is pumped through 16" pipeline to GLRU where condensate separate from gas. The first stage in GLRU is heat up condensate by heat exchanger unit and then it (stream: condensate) fed to splitter column (a distillation column) to separate light products ($C_1 + C_2$) where ($C_1 + C_2$) go out from the top of the splitter column while C_{3+} go out from the bottom of the splitter column. Then the bottom product C_{3+} is sent to a debutanizer column to extract ($C_3 + C_4$) where these products go out from the top of the debutanizer column while the heavier products (condensate C_{5+}) go out from the bottom of the debutanizer column and then is pumped to storage tank.

A condensate production in GLRU is about 28,000 barrels per day. It is mixed with 2000 bbl/day of surplus naphtha from refinery. Table (1-3) shows the most important specifications of condensate produced by Sirte Oil Company [1].

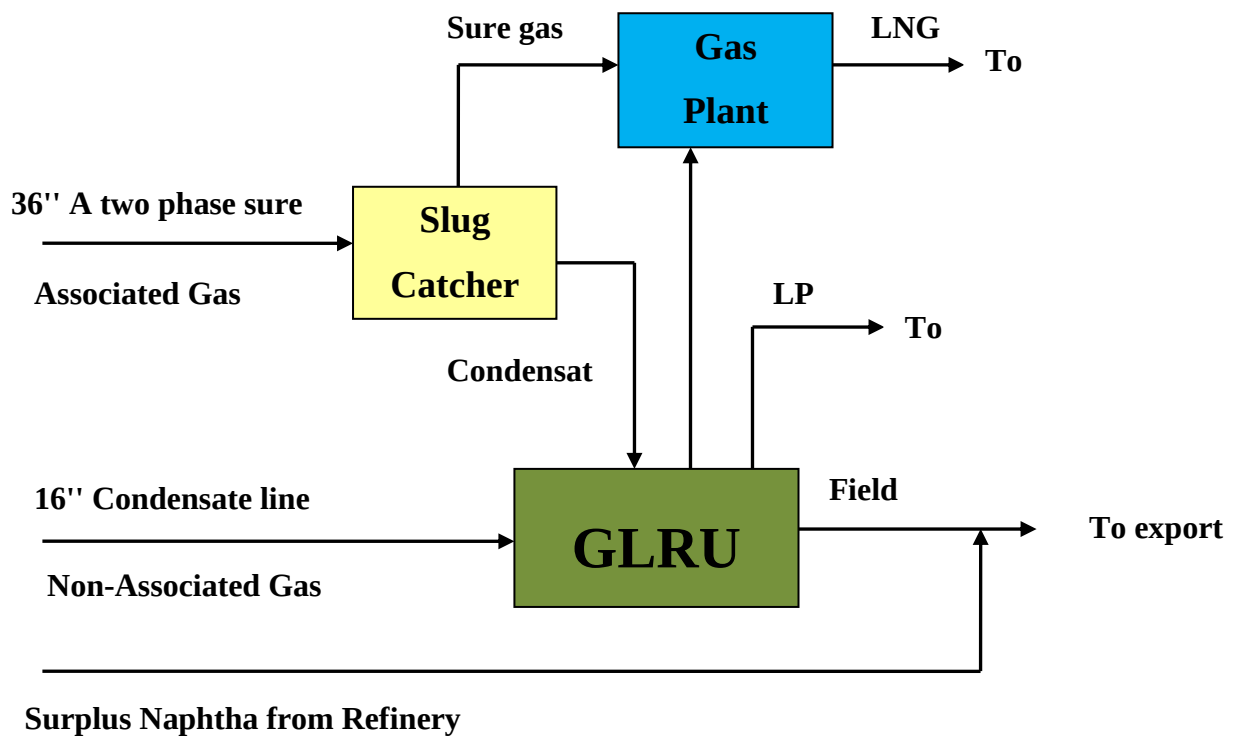


Figure 1-2 Process diagram for condensate separation in Brega.

Table 1-3 Specifications of condensate (Sirte Oil Company).

API gravity @60F	60.3
Reid vapor pressure @100F	10.7
Corrosion, Copper Strip @122F	2a
Doctor test	4.4
Hydrogen sulfide, wt%	0.0004
Sulfur, weigh %	0.0305
Mercaptan Sulfur	36 ppm
SayboltColour	12.05
ASTM D-86 Distillation: Vol%	Temperature F
IBP	86
5%	116
10%	127
20%	159
30%	194
40%	236
50%	288
60%	351
70%	438
80%	545
90%	661
95%	-
FBP	677
Paraffin's	67 vol%
Naphtenes	8 vol%
Aromatics	25 vol%

1.2.3 Condensates produced from Zueitina Oil Company

Condensates are received from several onshore fields, Intisar (103 A), (103D) and condensate from Wintershall company. The production is about 9,000 barrels per day. [2]. All condensate production is export out of the country. Table 1-4 shows the most important specifications of condensate produced by Zueitina Company, which is Paraffinic type.

Table 1-4 The specification of condensate (Zueitina Company).

API gravity @60F	77.5
Specific gravity @60/60F	0.677
Reid vapor pressure @100F	10.6 psia
Corrosion, Copper Strip @122F	1B
24,000Kinematic Viscosity @ 60F	0.51 cSt
Freezing point, Dec C	-73
Flash point	Less than 0 Deg. F
Sulfur, weigh %	0.0080
Mercaptan Sulfur	38ppm
ASTM D-86 Distillation	
IBP	98
5%	114
10%	120
20%	125
30%	130
40%	139
50%	150
60%	164
70%	184
80%	212
90%	249
95%	307
FBP	339

These enormous quantities of condensates produced do not find now any industrial application. However, until the current hour Libyan industry was not interested in utilization of this raw material; there is just one study from National Oil Corporation, which investigated some options for utilization of Libyan condensates instead of export [1] but this study does not go in more details for design aspects .only oil and the gas received a particular and privileged attention of the Libyan industrial policy. From now Libya must seeks to develop and explore its condensate.

1.3 Research Objectives

Due to the high consumption of gasoline and shortage of production it is importance to direct the research to find thoughts to develop the productivity. The purpose of this work is to present the suggestions for utilization of Libyan condensate instead of exporting especially in the production of light products such as Naphtha and Kerosene. Naphtha is the key product for gasoline production. The main strategic points for this study are:

1. Three design options will be presented
 - Design of condensate splitter unit with capacity of 35,000 bbl/day. Mellitah condensate is used as feed for this splitter (case-1).
 - Design of gas condensate splitter with capacity of 35,000 bbl/day. The condensate production from Sirte and Zuitina are used as feed for this splitter (case-2).
 - Design of gas condensates splitter with capacity of 70,000 barrels per day for all condensate production in Libya (Sirte, Mellitah and Zuitina condensate) (case-3).
2. Find optimum design parameters that much the target for three cases.
3. Studying the effect of some parameters such as the reflex ratio, reboiler heat duty, and the number of stages on the quality of three products (Naphtha, Kerosene, and Diesel) of a fractionation column.

2 Concepts and Literature Review

2.1 Distillation process

Distillation is a process that separates two or more components into an overhead distillate and a bottoms product. It is probably the most widely used separation process in the chemical and allied industries; its applications ranging from the rectification of alcohol, which has been practiced since antiquity, to the fractionation of crude oil [15]. The separation of liquid mixtures by distillation depends on differences in volatility between the components. The greater the relative volatilities, the easier the separation. The basic equipment required for continuous distillation is shown in Figure 2-1. Vapour flows up the column and liquid counter-currently down the column. The vapour and liquid are brought into contact on plates, or packing. Part of the condensate from the condenser is returned to the top of the column to provide liquid flow above the feed point (reflux), and part of the liquid from the base of the column is vaporized in the reboiler and returned to provide the vapors flow.

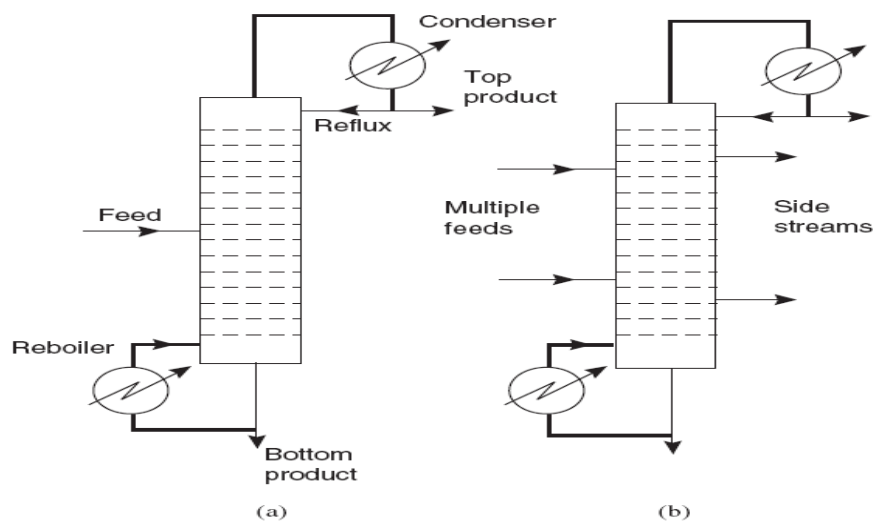


Figure 2-1 Distillation column (a) basic column (b) Multiple feeds and side streams.

In the section below the feed, the more volatile components are stripped from the liquid and this is known as the stripping section. Above the feed, the concentration of the more volatile components is increased and this is called the enrichment, or more commonly, the rectifying section. Figure 2-1a shows a column producing two product streams,

referred to as tops and bottoms, from a single feed. Columns are occasionally used with more than one feed, and with side streams withdrawn at points up the column [15], Figure 2-1b. This does not alter the basic operation, but complicates the analysis of the process, to some extent.

If the process requirement is to strip a volatile component from a relatively non-volatile solvent, the rectifying section may be omitted, and the column would then be called a stripping column.

In some operations, where the top product is required as a vapour, only sufficient liquid is condensed to provide the reflux flow to the column, and the condenser is referred to as a partial condenser. When the liquid is totally condensed, the liquid returned to the column will have the same composition as the top product. In a partial condenser the reflux will be in equilibrium with the vapour leaving the condenser. Virtually pure top and bottom products can be obtained in a single column from a binary feed, but where the feed contains more than two components; only a single “pure” product can be produced, either from the top or bottom of the column. Several columns will be needed to separate a multi component feed into its constituent parts.

2.2 Distillation column design

The design of a distillation column can be divided into the following steps [15]:

1. Specify the degree of separation required: set product specifications.
2. Select the operating conditions: batch or continuous; operating pressure.
3. Select the type of contacting device: plates or packing.
4. Determine the stage and reflux requirements: the number of equilibrium stages.
5. Size the column: diameter, number of real stages.
6. Design the column internals: plates, distributors, packing supports.
7. Mechanical design: vessel and internal fittings.

The principal step will be to determine the stage and reflux requirements. This is a relatively simple procedure when the feed is a binary mixture, but a complex and difficult task when the feed contains more than two components (multicomponent systems).

2.3 Separation of condensate

There are literally hundreds of different equipment configurations for the processing required to separate natural gas condensate from a raw natural gas. Fig 2-2 shows the schematic flow diagram of one of the possible configurations.

The raw natural gas feedstock from a gas well or a group of wells is cooled to lower the gas temperature to below its hydrocarbon dew point at the feedstock pressure and that condenses a good part of the gas condensate hydrocarbons. The feedstock mixture of gas, liquid condensate and water is then routed to a high pressure separator vessel where the water and the raw natural gas are separated and removed. The raw natural gas from the high pressure separator is sent to the main gas compressor.

The gas condensate from the high pressure separator flows through a throttling control valve to a low pressure separator. The reduction in pressure across the control valve causes the condensate to undergo a partial vaporization referred to as a flash vaporization. The raw natural gas from the low pressure separator is sent to a "booster" compressor which raises the gas pressure and sends it through a cooler and on to the main gas compressor. The main gas compressor raises the pressure of the gases from the high and low pressure separators to whatever pressure is required for the pipeline transportation of the gas to the raw natural gas processing plant. The main gas compressor discharge pressure will depend upon the distance to the raw natural gas processing plant and it may require that a multi-stage compressor be used.

At the raw natural gas processing plant, the gas will be dehydrated and acid gases and other impurities will be removed from the gas. Then, the ethane (C₂), propane (C₃), butanes (C₄), and pentanes (C₅) plus higher molecular weight hydrocarbons referred to as C₅+ will also be removed and recovered as byproducts.

The water removed from both the high and low pressure separators may need to be processed to remove hydrogen sulfide (H₂S) before the water can be disposed of underground or reused in some fashion.

Some of the raw natural gas may be re-injected into the producing formation to help maintain the reservoir pressure, or for storage pending later installation of a pipeline.

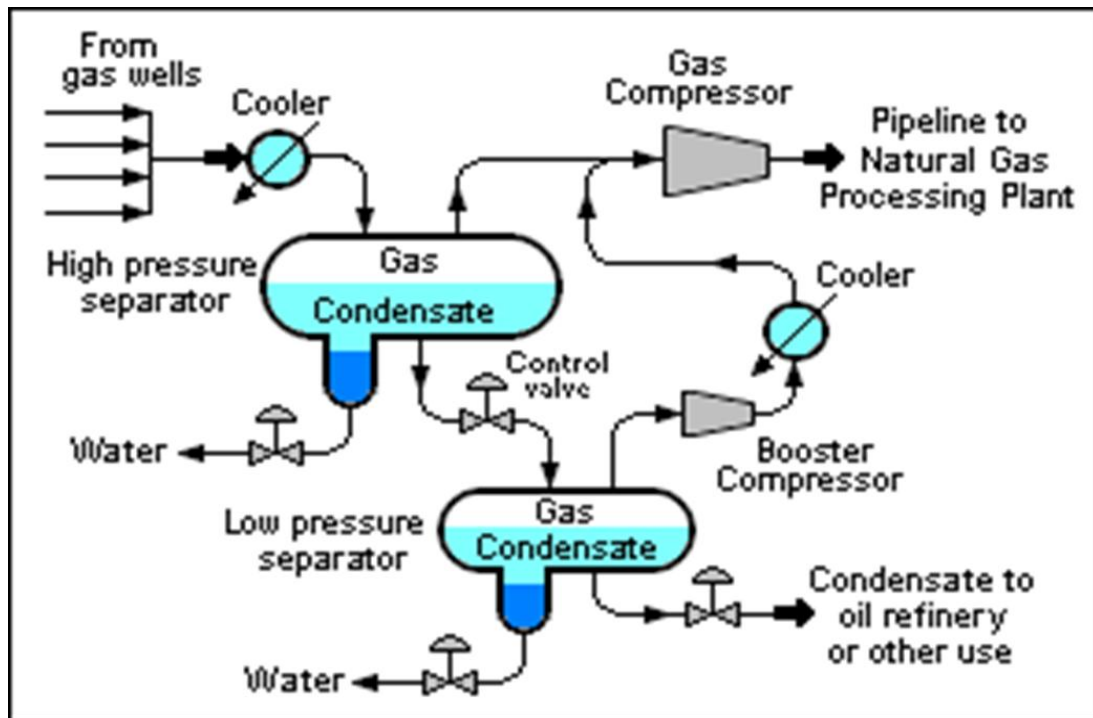


Figure 2-2 schematic flow diagram for natural gas processing

2.4 Condensate splitter

Condensates Splitters is a simple distillation columns which can be used to obtained fractions Represented in light naphtha, kerosene and diesel. Considered Condensates Splitters much simpler than traditional refiners because of:

- High conversion, for example production of naphtha and gasoline is higher than the production of the traditional refineries where 60 - 65 %, 40 - 45% respectively. Certainly naphtha is a basic compound for motor gasoline or used for petrochemical, BTX, or possible use as feedstock for the production of olefins such as ethylene or possible use for other purposes, such as fertilizer and power plants as well as the production of certain chemicals.
- Do not need additional operations.
- Technical problems are less if compared to traditional refineries
- cost less than traditional refineries, for example, the cost of creating complex Condensates Splitter in the Middle East, with a capacity of 200,000 barrels per day will cost about 1.5 billion dollars while costing

almost create sophisticated conventional refinery of the same capacity will cost about 4 to 5 billion Dollar Almost .

Condensate splitters are used to produce naphtha, gasoil, and other individual components. These can then be used in the production of various types of fuels (such as boiler, diesel, jet fuel, and high-octane gasoline) and as petrochemical intermediates (see Figure 2-3).

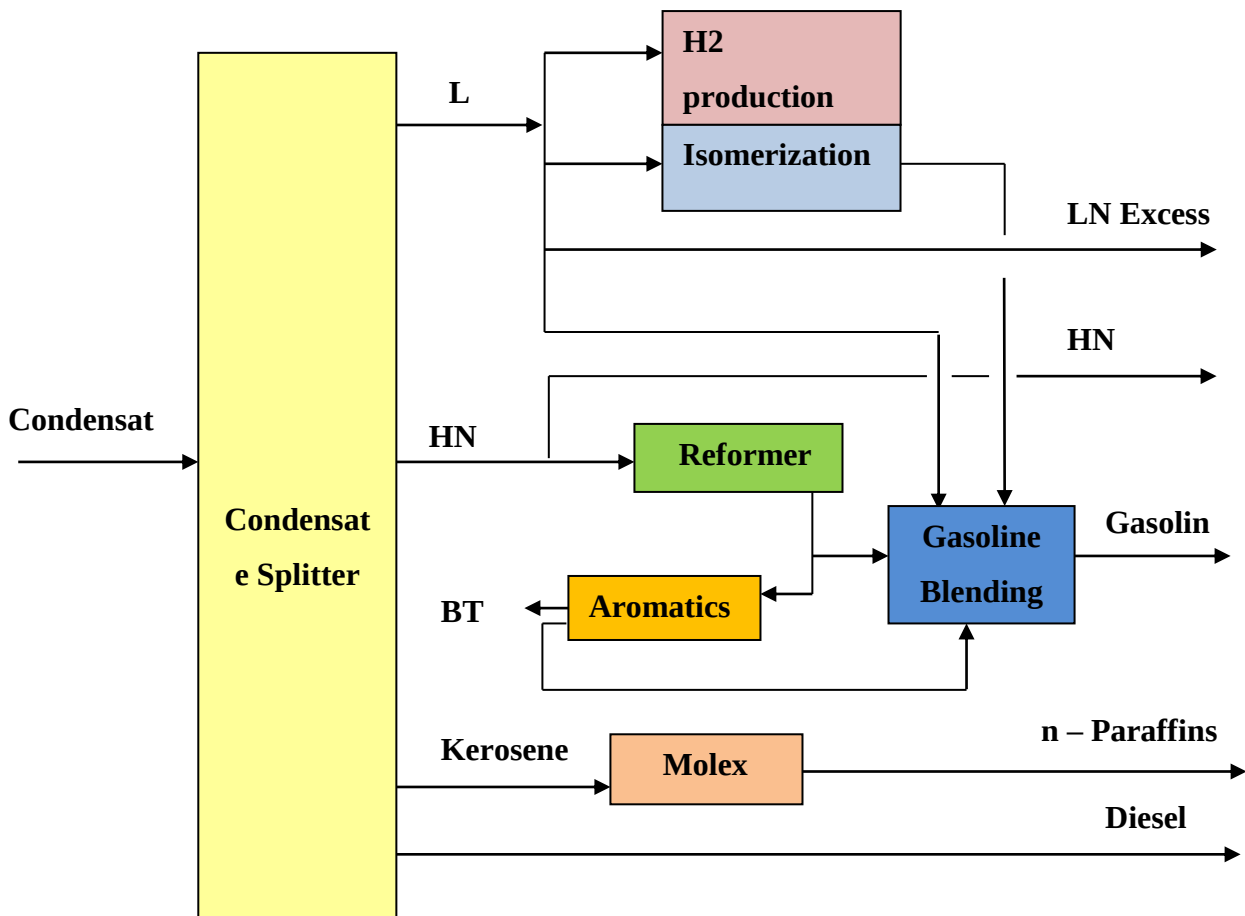


Figure 2-3 Simplified process diagram for condensate splitter.

2.5 Stabilization of condensate

Field stabilization of condensate is performed to remove lighter and more volatile gases prior to its transport and storage. Such gases, often methane, ethane and propane, are either burned off in a flare as a waste product, re-circulated in the stabilization unit to

use as a fuel to heat the oil or, if collection facilities are available, recovered and marketed separately as liquid petroleum gas (LPG).

Because transporting and storing “pressured” crude and condensate can be dangerous, the need to remove LPGs and natural gas from crude and condensate has been longstanding. A quick search indicates that patents were filed on field stabilization as far back 50 years ago; these methods, therefore have been used to treat crude oil and condensate since before relevant export controls were put in place in the 1970s.

While there have been technological changes in stabilization units since 1979s, they have been largely in electronics and instrumentation. The primary purpose of the changes has been to increase the volume of valuable liquid yield. Despite these technological advances, the fundamentals of the process remain the same as they have always been, relying on universal laws of physics and chemistry [16].

Importantly, and in contrast to processing through a traditional petroleum refinery or condensate splitters, in field stabilization only the lightest gases in the crude or condensate stream are vaporized, often at temperature below 200 degrees Fahrenheit, with many boiling below 100 degrees. In other words, the condensate stream is marginally heated to remove light gases to allow safe transport of the condensate, which is cooled before shipping [16].

2.6 Literature Review

From the very beginning of simulation, refinery was of great interest. In 1962, a sugar refinery was simulated to analyze the process manners and limitations of the refinery process [1, Brook, 1962]. The vast simulation scopes for refineries were studied by Koenig [3]. Long-term planning and day-to-day planning of crude oil refinery was analyzed by linear programming technique and modern operations research was used to discuss the optimization methods. Simulation on petroleum refinery waste treatment process was studied in Hoffman [4]. The corrosive environment of oil refinery was simulated and several problems disturbing safety operations in the units were studied by Hitoshi et al. [5]. For optimizing the crude oil operations, different solution approach was discussed by Reddy [6].

The properties of gas condensate are described by Dzou et al. [7] and Thompson [8]. Detailed study on distillation column simulation is done by Wagialla et al. [9] and Drozdowicz et al. [10].

Bentahar et. al. [11] have developed the possibility of developing Algerian condensates by the catalytic isomerization process of its light fractions in vapor phase, in order to obtain gasoline bases with a raised octane number, by exploring bentonite as an Algerian local available catalyst. However, it was noted that the best output of the isomerizes products is obtained by using catalyst containing chromium and at temperature of 250 °C, and 275 °C at which the octane number is also highest.

Navid Moghadam & Masoud Samadi [12] have investigated condensate stabilization using two methods of multistage flash vaporization and distillation (fractionation) within two case studies. The results show that depending on the properties of feed to be stabilized, one or both of the two methods could be practical and/or economic.

Sukanta et. al. [13] Have presented the simulation of a condensate fractionation plant. In their study a Process Flow Diagram (PFD) was presented with heat and mass balances. The simulated results were compared with the real plant's data. They showed that the column needed to be optimized in order to convert more of the atmospheric residue into other premium products like diesel, kerosene and petrol. Their presented results have been obtained using the steady state version of the software, but all the simulations done in steady state can have an evolution to a dynamic simulation (for example to build process simulators for operator training or to study the behavior of the process units in transient conditions), or to a real time optimization system where, together with the advanced process control tools, can be very profitable in the optimization of the operation in real time.

D. A. Begum, A. Rahman [14] and K. Kirtania present an interactive study of major design changes from the traditional fractionation column to increase gasoline production using gas condensate. The aims was to study the quality of three products of a fractionation column considering different design conditions of the column using natural gas condensate as column feed. The first design was on a single traditional distillation column whereas the consecutive studies were done by modifying the distillation column to yield the same quality of products. The whole simulation study and analysis was done on ASPENTM HYSYS 7.1. In the end, it can be concluded that

this work mainly contributes by providing different results from the simulation non various design modification of a gas condensate fractionation column. A more rigorous study can be done by dividing one column into two which can provide a different set of data and some new possibilities.

J. B. Rashed and E. E. Zorgani [1]. showed that using Pyrolysis Gasoline (PyGas) can be a suitable solution to improves the productivity and economical margins of Azzawia refinery as well as the positive environment impacts .They used Py-Gas which produced by Raslanuf Company as a byproduct during naphtha cracking process. Benzene content in gasoline will be sternly restricted by prospective specifications. So it is required to lower the benzene in the pyrolysis gasoline when it is used as a blending fuel in the gasoline pool of Azzawia refinery. Three options of benzene removal have been studied using HYSYS software. The first option was set up a new fractionator column for reducing the concentration of benzene. The second option was redesign of deoctanizer tower and investigates the effect of operation parameters. The third option was using a new splitter. The results showed that the volume of the gasoline will be increased by 40%, 25% and 15 % for the three options respectively while the benzene contents 0.35 .56%and4.7%.

3 Process Simulation

In this chapter, the first section presents definition of the process simulation. The second section presents the scope of process simulation through two examples of problems typically encountered by a process engineer. The third section presents specification (design) problem which is one of the most important problems in process engineering. The fourth section presents the process simulator, the main features of a process simulator, the organization of a typical process simulator and most well-known commercial process simulators.

3.1 What is process simulation?

Process simulation is the act of representing some aspects of the real world by numbers or symbols that may be easily manipulated to facilitate the study. The important steps of process simulation are therefore, description of the part of the “real world” that needs to be simulated, representation of this part of the “real world” in terms of a model (mathematical or symbolic), and finally, solution of the mathematical model to obtain numbers or symbols. With respect to chemical engineering, the real world is a chemical process described by a process flowsheet. Typically, process simulation is needed to solve problems related to process design, process analysis, process control and many more. Depending on the type of the problem, different types of process simulation problems are formulated. For example, verification of design or for inventory control (mass and energy balance) requires the solution of steady state simulation problems while verification of the control system or analysis of the effect of disturbances requires the solution of dynamic simulation problems [17].

Obviously, each simulation problem is associated to a corresponding mathematical model. In steady state simulation, the mathematical model is usually represented by a set of algebraic equations while in dynamic simulation; the mathematical model is usually represented by a mixed set of algebraic equations and ordinary differential equations. For complex or rigorous simulation problems, the mathematical model may even be represented by a mixed set of algebraic equations, ordinary differential equations and partial differential equations. Each mathematical model, therefore, is associated to a corresponding method of solution.

Since there can be many ways to solve a set of equations representing a mathematical model, it is necessary to have a simulation strategy which ensures that the simulation problem is solved efficiently and that the simulation results are reliable. Reliability also depends on the model accuracy.

As described above, process simulation requires a number of important steps that are linked to each other. Each step, however, can be large enough to justify the use of a computer to solve the problem. A computer program that combines the important steps into a single program package is called a process simulator. The process simulator is designed to help the user in performing the important steps without the need to develop new computer programs for solving new problems.

In the solution of problems related to process synthesis/design, control/operation, analysis, etc., the user needs to provide sufficient information to properly specify the simulation problem. Typically, a simple steady state simulation of a process flowsheet requires a description of the process flowsheet (including an identification of the compounds present in the system and the unit operations present in the flowsheet), choice of a method of solution, specification of equipment parameters and input streams and many more. Solution of a process design problem may require many solutions of the process simulation problem (for each trial, a different simulation problem may need to be solved). Similarly, solution of process optimization may require many solutions of the process simulation problem [17].

3.2 Scope of process simulation

The purpose of this section is to give an overview of the scope of process simulation through examples of problems typically encountered by a process engineer. The use of process simulation and optimization is described through two examples.

The flowsheet shown in figure 3-1 is a typical intermediate result from a preliminary design project. A flowsheet (showing one alternative process to obtain the specified products) first need to be generated before any computations for the process can be made. Having the flowsheet, the next step would be to try to simulate the process and obtain all the stream information. From the stream information, it is possible to verify if the flowsheet shown in figure 3-1 can actually give all the specified products. Note that

in this case, it is assumed that all the necessary equipment design variables (such as number of stages, reflux ratio, etc., for distillation columns) have also been estimated. If the product specifications cannot be matched, either the equipment design parameters can be changed, or, the flowsheet configuration can be changed. In either case, a simulation of the process flowsheet is necessary for verification of any new alternative. Since there can be many ways of obtaining the products (in this case, the five pure compounds), it is also necessary to make sure that the proposed alternative is not only feasible, but is also better than other alternatives with respect to cost of operation and/or equipment cost. For such an evaluation, process optimization needs to be performed.

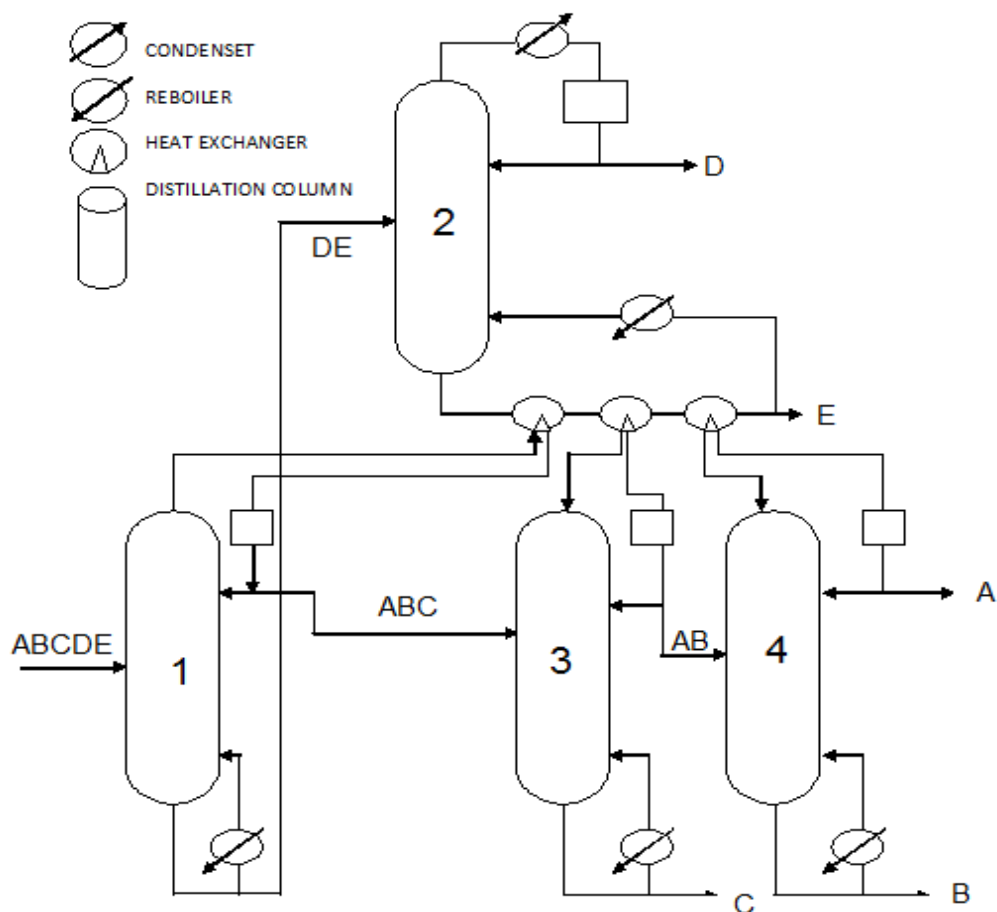


Figure 3-1 A generated flowsheet for separation of a multi-component mixture into pure products.

The above three examples are just an illustration of when and why problems related to process simulation and optimization need to be solved. The next chapter deals with the formulation (definition) of the various types of process simulation problems.

3.3 Specification Problem

In the specification problem, instead of some variables that must be specified in a flow sheeting problem, some output or intermediate stream variables are specified (as shown in the figure below). In the figure below, some output variables have been specified instead of some variables belonging to the set of operating conditions and equipment parameters [18].

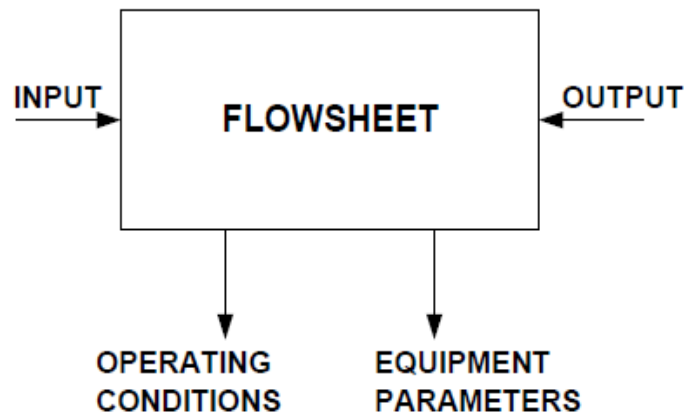


Figure 3-3 Specification (design) problem.

Because of the nature of the problem, solving the flow sheeting problem in an inner-loop (as shown in the figure below) can solve specification problems in an iterative manner. That is, we assume values of the unknown variables belonging to the set of operating conditions and/or equipment parameters, and then we have the correct problem formulation for the flow sheeting problem. We now solve the flow sheeting problem, and, from the calculated output stream variables, we check if the calculated values are close to the known values. If yes, we have found the solution to the specification problem. If no, we have to make new assumptions for the unknown variables and solve the flow sheeting problem again. We continue until the solution has been found.

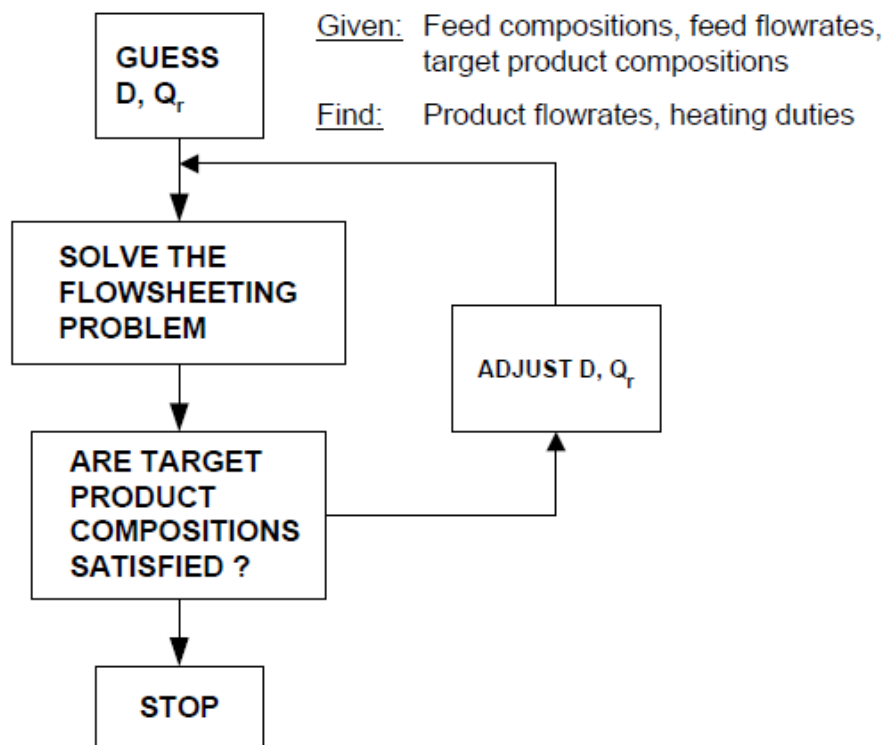


Figure 3-4 Calculation procedure for specification problem.

3.4 Process Simulator

In its simplest form, a process simulator is an engineering tool providing automated calculations of material and energy balances. In order to be able to do this, the simplest process simulator must contain an input section (where the flowsheet description and the individual unit descriptions are given), an output section (where the calculated values are presented in a useful form – such as a spreadsheet matching the flowsheet), a library of unit operation models (so that the user does not need to write new mathematical models), a database for physical properties (so that compound and mixture data can be extracted, when needed), a solver library (so that the simulation problems can be solved) and an administrative section (which sets up the simulation problem and determines what is needed for solving a specified problem). Often, a process simulator is mistaken for a process engineer [19]. A process simulator does (perform) calculations based on the instructions (decisions) that the process engineer has given. The process simulator does not make decisions. It helps the process engineer to make decisions by providing the necessary information.

The organizations of a typical process simulator in terms of the main functions are shown in the figure below Figure 3-5. In this figure, the main functions are related to what a simulator must have in order to perform these functions. For example, in order to define the problem, the simulator needs property data, unit module data and cost data. The boxes on the left hand side of the figure indicate the functions the simulator performs and the boxes on the right hand side of the figure indicate what they need in order to perform the functions.

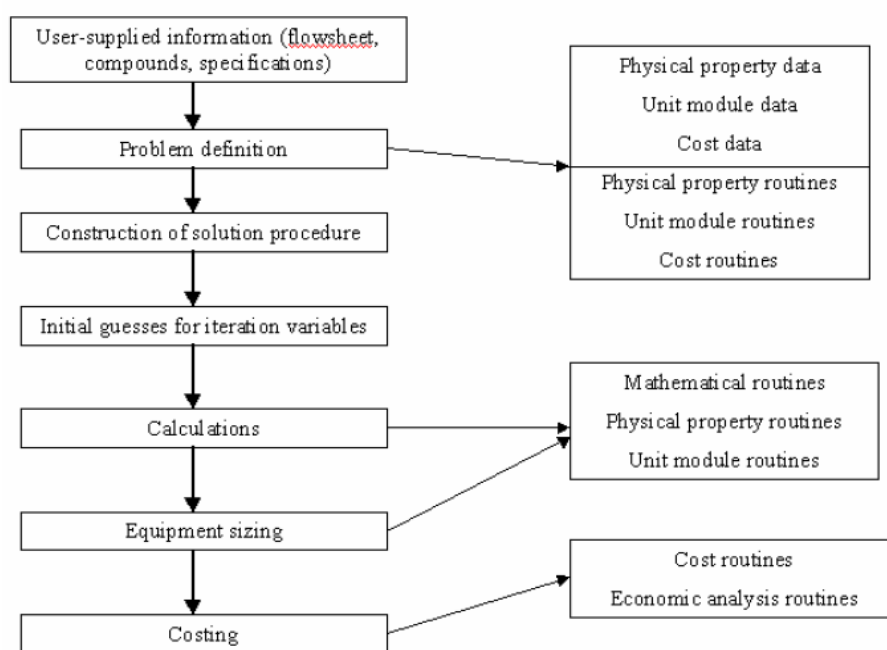


Figure 3-5 Organization of a simulation package.

The main feature of a process simulator is shown in figure 3-5. Here, the content of a modern simulator is shown in terms of the boxes on the left hand sides of figure 3.6. The simulator executive is a knowledge-based system extracting the information necessary of any specified simulation problem from a collection of objects available to it. In object oriented programming, all the objects can communicate with each other with or without the simulator executive. The simulator executive is needed for solving a simulation problem. In this way, the simulator performs other functions in addition to process simulation.

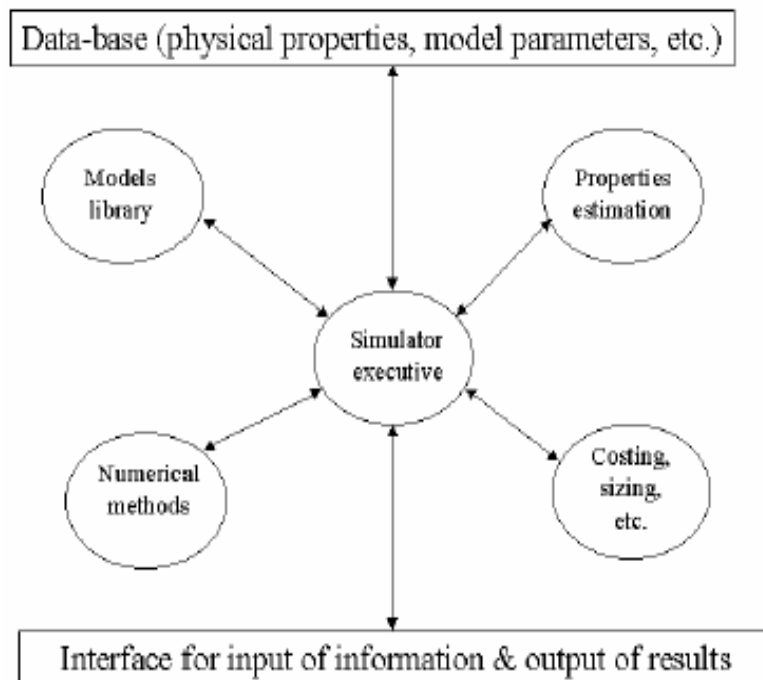


Figure 3-6 Main features of a process simulator.

3.5 Commercial Process Simulators

The most well-known commercial process simulators are,

- ASPEN Plus – Aspen Technology, USA
- Pro-II/Provision – Simulation Sciences, USA (Seibe, UK)
- HYSYS– HyproTech, Canada (AEA Technologies, UK)
- OLGA (SPT group)

ASPEN and Pro-II are steady state process simulators with process optimization features. Both of them employ a sequential modular approach. HYSYS provides both steady state and dynamic simulation features. It employs a mixed simulation strategy. ASPEN has the largest number of users followed by Pro-II and then HYSYS. All the three simulators have Windows-based PC-versions. All have extensive database of compounds for physical properties, have a large collection of unit operation models and thermodynamic models. HYSYS will be used to achieve all steps and configurations goals for the study.

Varieties of products are obtained from fractionation of natural gas condensate. Heavy parts of it are used as diesel whereas the lighter parts are divided into different fractions for different uses. Distillation column is used for the separation of different fraction of condensate. One distillation column is sufficient for producing three products – two solvents and diesel. If any design change for the column is to be suggested, a new column cannot be built because it will require a lot of money. To evaluate different designs, simulators have become very handy. Several soft-wares have been developed for the petroleum industries. ASPENTM HYSYS is one of the software which is widely accepted and used for refinery simulation. ASPENTM HYSYS performs the oil distillation calculation through detail plate by plate calculation. This calculation includes generating pseudo-components from the ASTM D86 data and generating properties from them. ASPEN HYSYS contains an oil manager which organizes the data for the pseudo-components separately.

The purpose of this paper is to present the work developed at a typical condensate fractionation plant in Libya. The work was done by HYSYS as a simulation tool. The challenge here was to model a complete process unit in order to allow the optimization of the operation.

The steady state simulation of condensate fractionation plant was carried out using Hysys 3.2 Process Simulator. The condensate is the by product, produced by processing of natural gas which contains mostly C 2 to C16. Varieties of products are obtained from fractionation of natural gas condensate. Heavy parts of it are used as diesel whereas the lighter parts are divided into different fractions for different uses. Distillation column is used for the separation of different fraction of condensate. One distillation column is sufficient for producing three products – two solvents and diesel. If any design change for the column is to be suggested, a new column cannot be built because it will require a lot of money. To evaluate different designs, simulators have become very handy.

This calculation includes generating pseudo-complex carbon chain. In this simulation, using atmospheric distillation (fractionation) has the volumetric flow rates of three products like Petrol (Motor Sprit or MS), Kerosene and Diesel are 75%, 15% and 10% respectively on basis of the condensate feed to the plant. This unit models a condensate processing facility consisting of a pre-heating train used to heat up the liquid condensates, an atmospheric distillation column to fractionate the condensates into its

straight run products, stripper, heat exchangers, buffer tanks and oil transferring systems. Preheated condensate (from a preheat train) is feed to the fractionators, where vapour-liquid separation done and specialized products are produced from different zone. A furnace was used to heat the oils at desired level. A comprehensive study has done between the simulated data and the plant's operating data.

Simulation software is a very good tool for the process industry, not only at the level of conceptual design but also during the entire lifecycle of the equipment, where it can be very useful for performance, debottlenecking and process studies. The study presents the simulation of a condensate fractionation plant. A Process Flow Diagram (PFD) was presented with heat and mass balances. The simulated results were compared with the real plant's data. Almost all the parameters matched with each other. This showed that the Column needed to be optimized in order to convert more of the atmospheric residue into other premium products like diesel, kerosene and petrol. The presented results have been obtained using the steady state version of the software, but all the simulations done in steady state can have an evolution to a dynamic simulation (for example to build process simulators for operator training or to study the behaviour of the process units in transient conditions), or to a real time optimization system where, together with the advanced process control tools, can be very profitable in the optimization of the operation in real time.

4 Results and discussion

4.1 Condensate exploitation options

The proposed methodology for utilization of Libyan condensate is presented. Three scenarios for exploitation of Libyan condensate are applicable for oil and gas sector based on the existing condensate production.

- The first one is using condensate to produce varieties of useful products by using condensate fractionation column. For this suggestion, the distillation column was used to produce three products, Naphtha, Kerosene and Diesel. Where Naphtha is the top product while kerosene as side product and diesel as the bottom product.
- The second suggestion is blending condensate with crude oil and then used as feed stock to Libyan refineries.
- The third suggestion is using paraffinic condensate as feed stock to reforming unit for gasoline production.

4.1.1 Option-1 description

Importance is given in this work to the first suggestion for design condensate fractionation column. Since in many cases the required information for designing a process is not readily available, therefore the design of condensate fractionation column and the effect of some design parameters on the quality of three products (Naphtha, Kerosene and Diesel) of fractionation column have been studied and investigated in order to obtain prior data before implantation of the plant. Fig 4-1 shows the procedure and steps to implement the study.

Suggestions for utilization of Libyan condensate

1. Using condensate to produce varieties of useful products by condensate fractionation column.

2. Blending condensate with crude oil and using as feedstock to refineries.

3. Using paraffinic condensate (Zueitina condensate) as feedstock directly to reforming unit for produce gasoline.

Case 1: Create Gas condensate splitter with capacity of 35,000 bbl/day. Mellitah condensate is used as feed for this splitter.

- Find design parameters that much the target.
- Study and investigate the effect of design parameters on the quality of three products of condensate fractionation column.

Case 2: Create Gas condensate splitter with capacity of 35,000 bbl/day. The condensate production from Sirte and Zuitina are used as feed for this splitter.

- Find design parameters that much the target.
- Study and investigate the effect of design parameters on the quality of three products (Naphtha, Kerosene, and Diesel) of fractionation column.

Case 3: Create Condensates splitter with capacity of 70,000 barrels per day for all condensate production in Libya (Sirte, Mellitah and Zuitina condensate).

- Find design parameters that much the target.
- Study and investigate the effect of design parameters on the quality of three products (Naphtha, Kerosene, and Diesel) of fractionation column.

Figure 4-1 Suggestions for utilization of Libyan condensate

In this work, HYSYS software was used to run the three cases. It's widely accepted and used for refinery simulation. HYSYS performs the oil distillation calculation through detail plate by plate calculation. This calculation includes generating pseudo-components from the ASTM D86 data and generating properties from it. HYSYS contains an oil manager which organizes the data for the pseudo-components separately.

4.1.2 Design basis and variation

True Boiling Point (TBP) analysis was done for the three types of Libyan condensate, which is one of the base inputs for this simulation study. The condensate feed rate was 35,000 Barrel/day (BPD) for case-1, 35,000BPD for case-2 and 70,000 BPD for case-3 as a basis. A fractionation column was used to produce three products. The package and method used for this study is listed in table4-1.

Table 4-1 Design basis for simulation by HYSYS

Fluid Package	Peng-Robinson
Method of simulation	Pseudo-component generation and plate by plate calculation
Solver	HYSIM Inside-Out
Properties generation	HYSYS properties

Fluid package was selected to be Peng-Robinson. The main reason behind this; it is widely used for refinery simulation as it can handle hypothetical pseudo-components. The method of simulation for HYSYS is pseudo-component generation and plate by plate calculation from the 'True Boiling Point' or 'ASTM D86' input data. For this simulation, ASTM D86 input data were available for three types of Libyan condensate. The HYSYS solver uses different numerical methods for simulation and the selected method for the simulation was HYSIM Inside-Out which is suitable for most cases. HYSYS properties were used for property generation of the streams.

The ASTM D86 data for three types of Libyan condensate were used as input for the oil manager in HYSYS is tabulated below. Lagrange method was selected for interpolation to generate pseudo-components from the curve. 24 components were generated from interpolation.

Table 4-2 The specification of condensate for all company's

Liquid volume evaporated %	Mellitah	Sirte	Zueitina
	T, °F	T, °F	T, °F
IBP	92	86	98
5%	124	116	114
10%	141	127	120
20%	166	159	125
30%	193	194	130
40%	222	236	139
50%	253	288	150
60%	291	351	164
70%	334	438	184
80%	390	545	212
90%	479	661	249
95%	554	-	307
FBP	584	677	339

4.2 Design of condensate fractionation column

A distillation column is the main equipment in condensate fractionation plant. The simulation model for condensate fractionation column can be seen in Figure 4-2. In fractionation column due to relative volatility of different components of condensate it's divided mainly in three portions. Heat transfer and mass transfer are played at different stages and try to get equilibrium conditions.

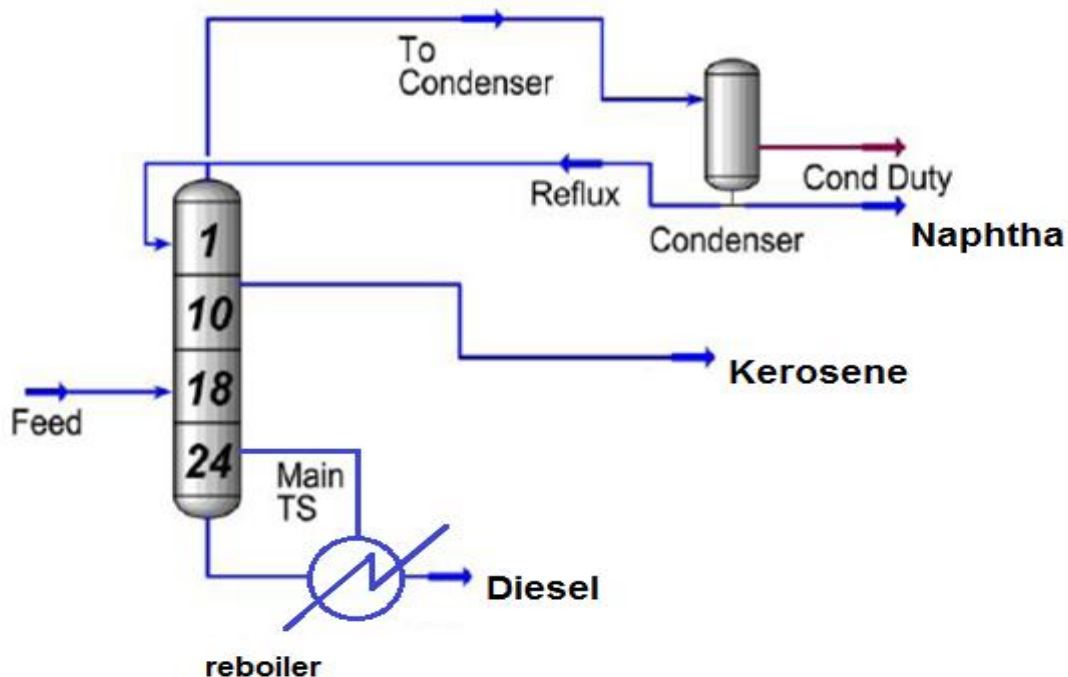


Figure 4-2 Process flow diagram (PFD) of the condensate fractionation column.

Among the three products, the top product was named as Naphtha and it was the lightest of all. It would be used for gasoline production. Kerosene was the side draw from the column. It was composed of mostly kerosinic components. Diesel was the bottom product of the column and heaviest of all.

From Table 4-3, it can be noted that Mellitah condensate contains about 75% Naphtha, 15% Kerosene, and 10% Diesel. Therefore, the Naphtha flow rate and Kerosene flow rates are primarily considered as 25,660 and 5132 bbl/day in case-1/or case-2 , and

50,180 or 8702 bbl/day in case-3 respectively. The operating pressure is 1 atm for all three cases.

Several design specifications for condensate fractionation column were proposed and validated through HYSYS simulation, in order to find the optimum for each case.

Table 4-3 shows the condensate fractionation column configuration and design specifications for three cases. The operating pressure is 1 atm for three cases, the number of stages is 24 for three cases. The Heat and material balance of the whole streams in the condensate fractionation column are shown in Table 4-4, 4-5, and 4-6 for three cases as a result of the simulation.

Table 4-7 shows the design composition targets for three cases. As you can see also the production of Light and heavy naphtha. Heavy naphtha is used as feed to reforming unit for gasoline production while Light naphtha is used as feed to isomerization unit. The expected gasoline production in case of install a new reforming unit is 13,463.8 bbl/day for case 1, 10,222.5 bbl/day for case 2 and 24,342 bbl/day for case 3.

In this study the effect of various design parameters such as reflux ratio and number of stages on the three products (Naphtha, kerosene and diesel) have been studied and investigated. It is useful to identify the factors that mainly contribute to output variability.

Table 4-3 Condensate fractionation column design specification for three cases.

Item	Value		
	Case 1	Case 2	Case 3
Number of stages	24	24	24
Condensate feed flow (bbl/day)	35,000	35,000	70,000
Reflux ratio	2.75	2.75	2.75
Column pressure	101.3Kpa	101.3Kpa	101.3Kpa
Feed plate location	15	15	18
Naphtha product rate (bbl/day)	25,660	24,270	50,180
Kerosene product rate (bbl/day)	5132	3570	8702

Table 4-4 Heat and material balances for condensate fractionation column streams
(case-1).

Streams				
	Condensate feed	Naphtha	Kerosene	Diesel
Temperature °C	25	52.23	190.5	278.1
Pressure Kpa	101.3	101.3	101.3	101.3
Molar flow (kgmole/h)	1572	1300	169.5	102.1
Std ideal Liq Vol flow	231.9	170	34.0	27.86
Heat flow (KJ/h)	-3.715*10 ⁸	-2.553*10 ⁸	-4.877*10 ⁷	-3.595*10 ⁷
Molar enthalpy (KJ/kgmol)	-2.363*10 ⁵	-1.193*10 ⁵	-2.877*10 ⁵	-3.522*10 ⁵

Table 4-5 Heat and material balances for condensate fractionation column streams
(case-2).

Streams				
	Condensate feed	Naphtha	Kerosene	Diesel
Temperature °C	25	50	179.6	295.4
Pressure (Kpa)	101.3	101.3	101.3	101.3
Molar flow(kgmole/h)	1557	1284	118.3	155
Std ideal Liq Vol flow	231.9	160.8	23.65	47.4
Heat flow (KJ/h)	-3.707*10 ⁸	-2.367*10 ⁸	-3.433*10 ⁷	-6.030*10 ⁷
Molar enthalpy(KJ/kgmol)	-2.380*10 ⁵	-1.844*10 ⁵	-2.908*10 ⁵	-3.891*10 ⁵

Table 4-6 Heat and material balances for condensate fractionation column streams
(case-3).

Streams				
	Condensate feed	Naphtha	Kerosene	Diesel
Temperature °C	25	56.76	181.9	256.8
Pressure Kpa	101.3	101.3	101.3	101.3
Molar flow (kgmole/h)	3157	2563	298.4	295.6
Std ideal LiqVol flow	463.8	332.4	57.65	73.75
Heat flow (KJ/h)	-7.418*10 ⁸	-4.946*10 ⁸	-8.323*10 ⁷	-9.792*10 ⁷
Molar enthalpy (KJ/kgmol)	-2.350*10 ⁵	-1.930*10 ⁵	-2.790*10 ⁵	-3.312*10 ⁵

Table 4-7 Design composition targets for three cases.

Item	Value		
	Case 1	Case 2	Case 3
Condensate feed flow (bbl/day)	35,000	35,000	70,000
Naphtha Product rate (bbl/day)	25,660	24,270	50,180
Kerosene product rate (bbl/day)	5132	3570	8702
Diesel product rate (bbl/day)	4205	7156	11,130
Light Naphtha (45 - 120 °C)	9904.76	12,912	20,725
Heavy Naphtha (120 - 180 °C)	14,960	11,359	27,047
Expected gasoline production (In case of install a reforming unit)	13,464	10,223	24,342
Expected gasoline production (In case install reforming unit, and isomerization unit)	22,378	21,843	43,000

4.3 Simulation Results

The lighter products mainly contain naphtha in higher amount so the quality of Naphtha is verified by analyzing the percentage of naphtha present in the top product. While the quality of kerosene is verified by analyzing the percentage of kerosene in the side stream (kerosene cut). The quality of diesel is verified by analyzing the percentage of diesel in the bottom product of fractionation column (diesel cut). The pressure of the fractionation column is primarily considered as 101 Kpa in two cases (case-1 and case-2). Figure 4-3 shows the effect of the reflux ratio on the quality of naphtha for different number of stages. It can be seen, from Figure 4-3 that the quality of naphtha increases as the reflux ratio increases. When the reflux ratio above 2.75 the effect is very small on naphtha quality. Hence, this number may be primarily considered as the optimized one. Figure 4-3 also shows the effect of the number of stages on naphtha quality. Also, It can be seen that the naphtha quality increases as the number of stages increase. The additional of stages further than 25 has small effect on the naphtha quality. Hence this number may be primarily considered as the optimized one.

Figure 4-4 also shows the effect of the number of stages on Naphtha quality. As mentioned above the naphtha quality increases as the number of stages increases.

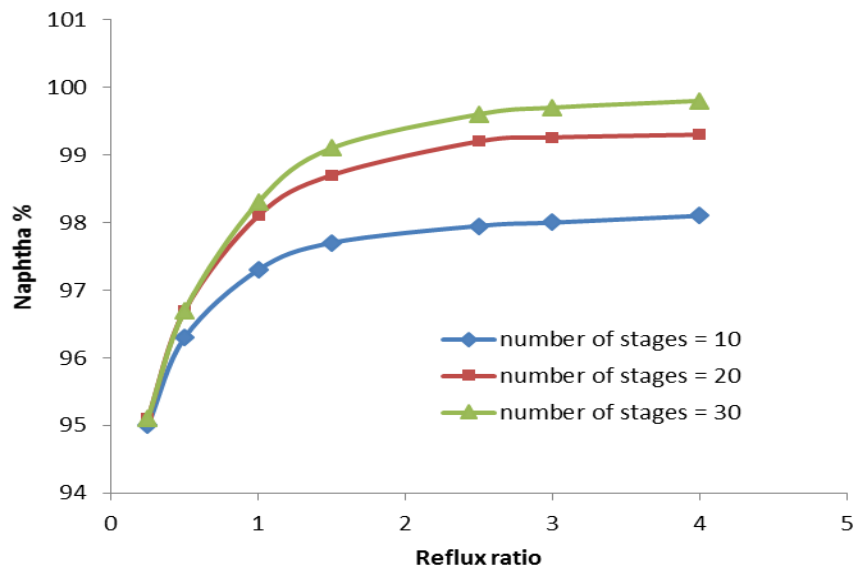


Figure 4-3 The effect of the reflux ratio on naphtha quality for different number of stages (case 1).

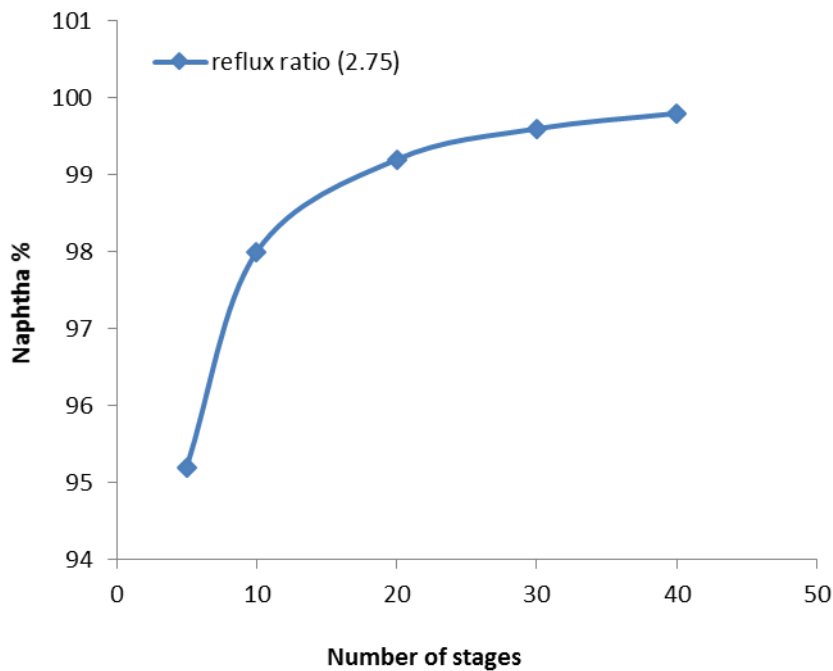


Figure 4-4 the effect of the number of stages on Naphtha quality at RR= 2.75 (case 1).

The effects of the reflux ratio and the number of stages on the kerosene quality are shown in Figure 4-5. It can be seen, from Figure 4-5 that, kerosene quality increases as the number of stages and the reflux ratio increase. Figure 4-5 also shows that the additional of stages further than 20 has no effect on kerosene quality see also Figure 4-6. Also, it can be observed that the reflux ratio above 2.75 has small effect on kerosene quality. So there is no need to increase the reflux ratio more than this number.

Figure 4-7 shows the effect of the reflux ratio and the number of stages on diesel quality. It can be seen, from Figure 4-7 that diesel quality increases as reflux ratio and the numbers of stages increase. The effect of the reflux ratio is very small when it is above 2.75 while the effect of the number of stages is small when the number of stage more than 20 see also Figure 4-8. Also, it can be observed that the quality of kerosene increases from 92.3% to 98.8% at the reflux ratio 2.75.

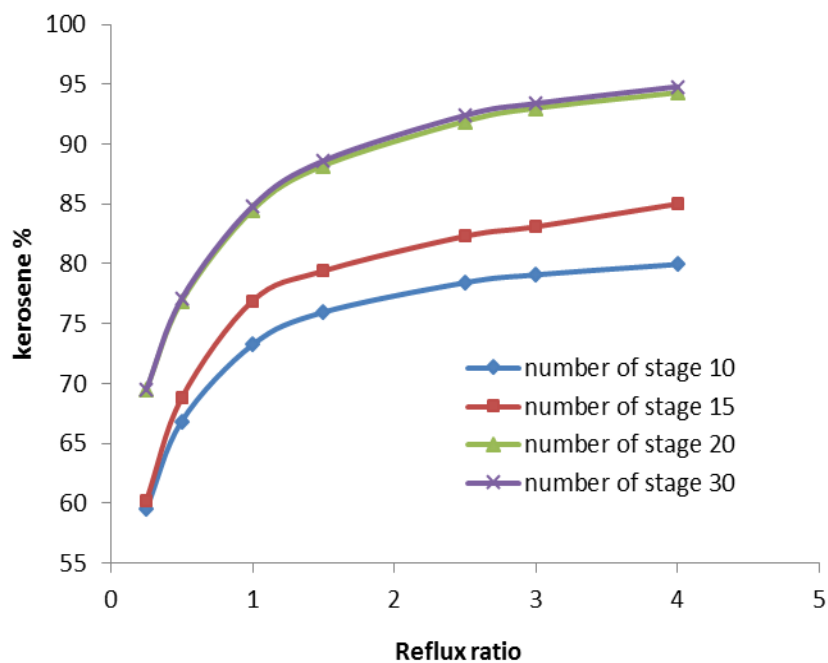


Figure 4-5 The effect of reflux ratio on kerosene quality for different number of stages (case1).

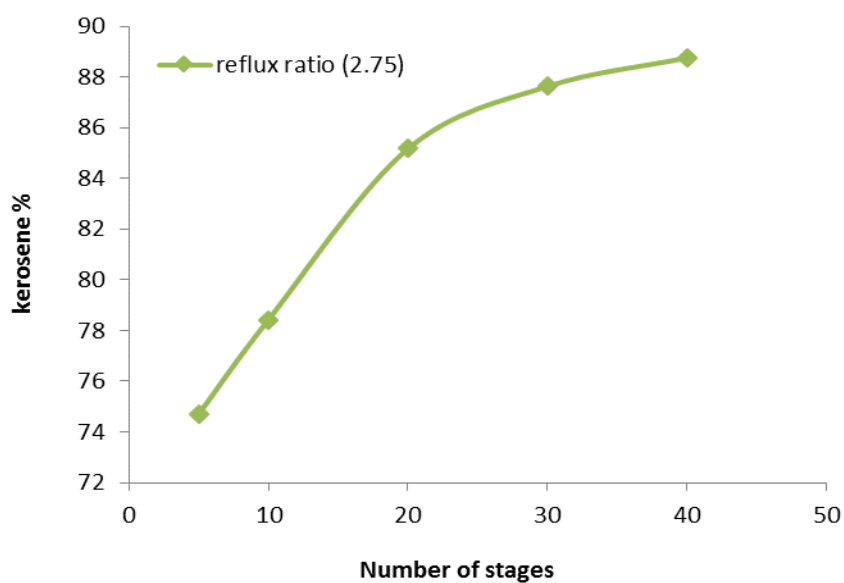


Figure 4-6 the effect of the number of stages on Kerosene quality at RR= 2.75 (case 1).

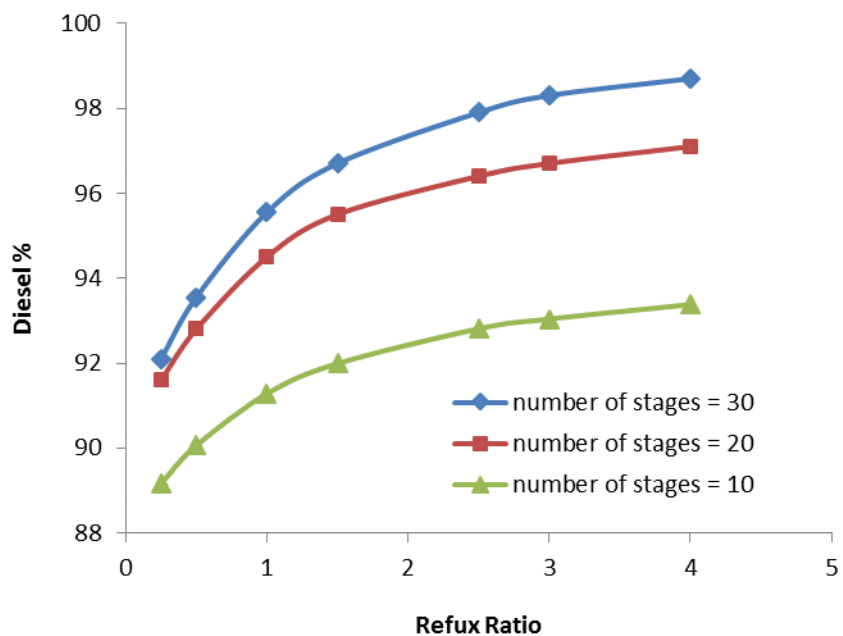


Figure 4-7 The effect of the reflux ratio on the quality of Diesel at different number of stages (Case -1).

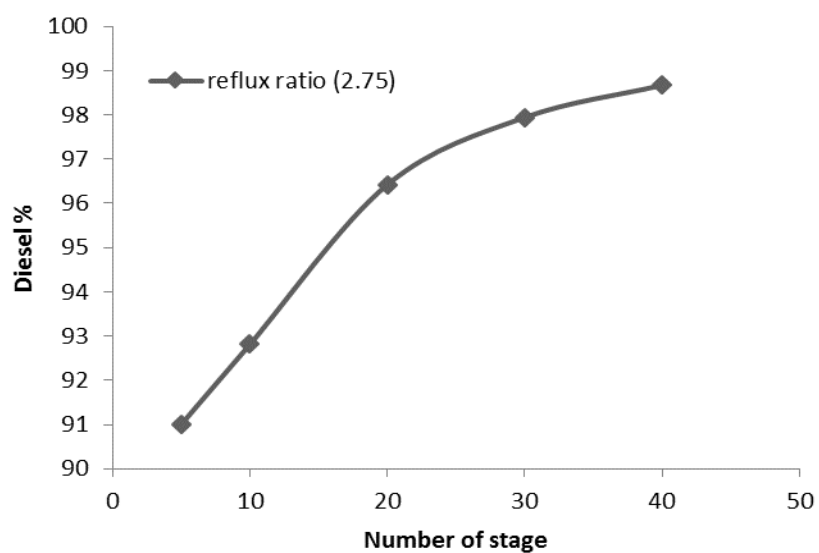


Figure 4-8 the effect of the number of stages on Kerosene quality at RR= 2.75 (case 1).

A high reflux ratio is not economically attractive because it requires large equipment, thus increasing the energy requirements. Figure 4-9 shows the reflux ratio versus the reboiler heat duty. It can be observed from Figure 4-9 that the reboiler heat duty increases as the reflux ratio increases.

For a definite separation, the reflux and boil-up ratios (consequently the total heat duty of condenser and reboiler) decrease as the number of stages increases. However, increase in the number of stages results in higher capital costs due to higher heights of column and trays price. Therefore, there's a trade-off between the number of stages and the total heat duty. The change in reboiler duty of condensate fractionation column is depicted in Figure 4-10. It can be seen that the addition of stages further than 26 has small effect on the reboiler heat duty and the condensate flow rate. Hence, this number may be primarily considered as the optimized one.

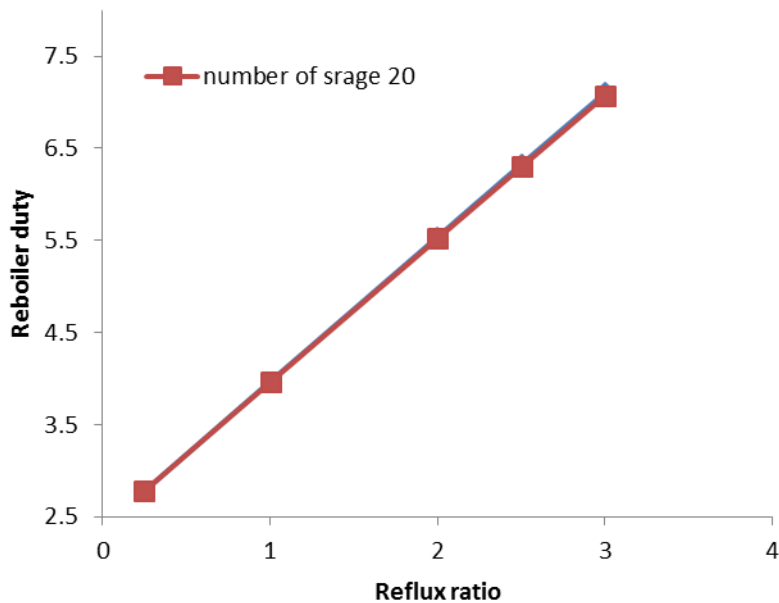


Figure 4-9 Reboiler heat duty versus the reflux ratio in case-1.

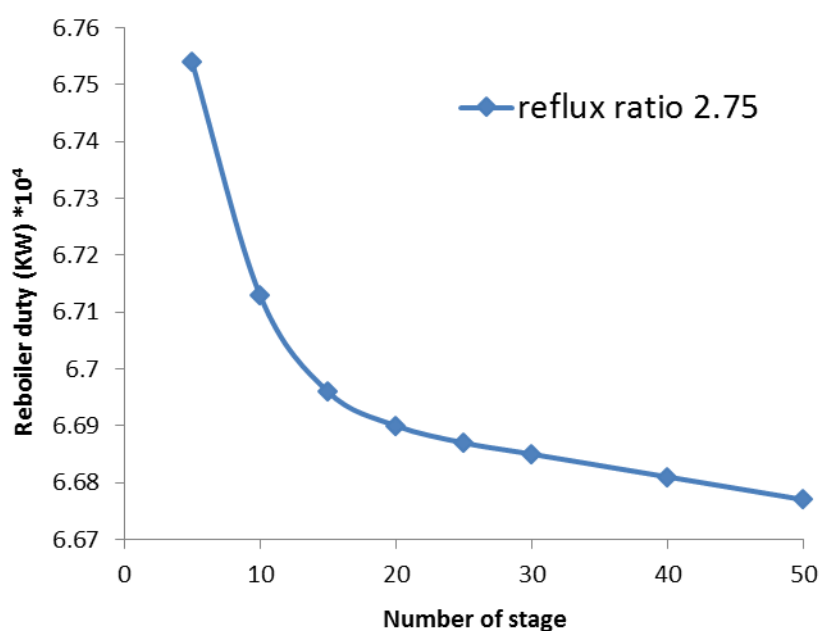


Figure 4-10 Reboiler heat duty versus number of stages of condensate fractionation column (case-1).

The ASTM D86 curves were shown for different products – Naphtha, Kerosene and Diesel at different values of reflux ratio. In Figure 4-11, the quality comparison for Naphtha is shown. From the figure, it can be easily understood that Naphtha has almost the same quality except a slight variation for the reflux ratio 0.25. That is because; lighter components increase as the reflux ratio decreases so at low reflux ratio it contains the lighter components than the high values of reflux ratio. When the reflux ratio above 1 the quality of Naphtha is almost the same and contains a little amount of heavier components excess to reflux ratio below 1.0. This means that for high Naphtha quality we must work on the reflux ratio above 1.0.

In Figure 4-12, the ASTM D86 data for the comparison of the kerosene is shown at different values of the reflux ratios. When the reflux ratio is 5, the quality of Kerosene has a lead over the other two values of the reflux ratios. It contains almost 30% of some components which gives the boiling point around 160 °C whereas at below reflux ratio Kerosene product has a lack of those components. At the deviation region, Kerosene product has some components of an average boiling point of 120. Then at 50% of composition, the boiling point data from ASTM D86 collide and they remain the same till the final boiling point. This deviation clearly indicates that the reflux ratio above 1.0

Kerosene product contains some extra lighter components whereas low reflux ratio does not. Those lighter components will make Kerosene cut to evaporate easily. If this is a product which is to be used for paint, then obviously this will not be a problem. But for other purposes, this fast evaporating tendency of the product must have to be taken under consideration.

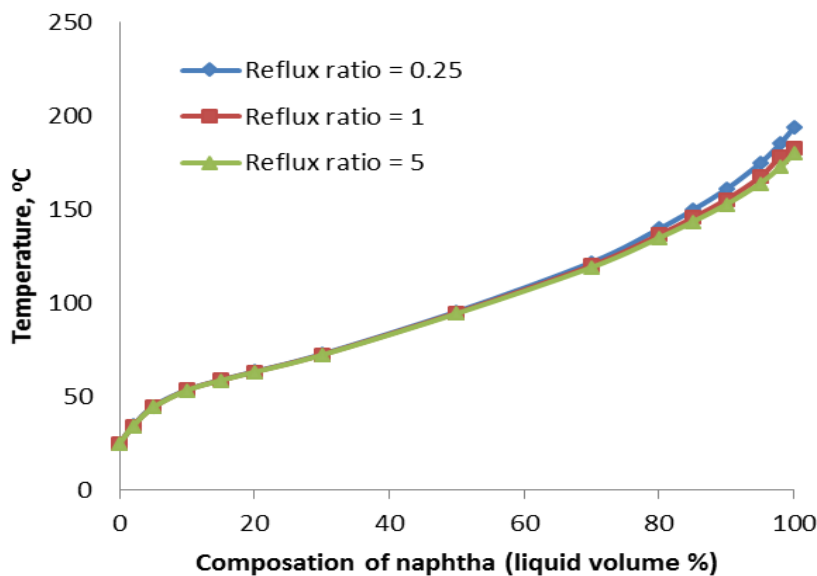


Figure 4-11 ASTM D86 data for Naphtha at different reflux ratio (case-1).

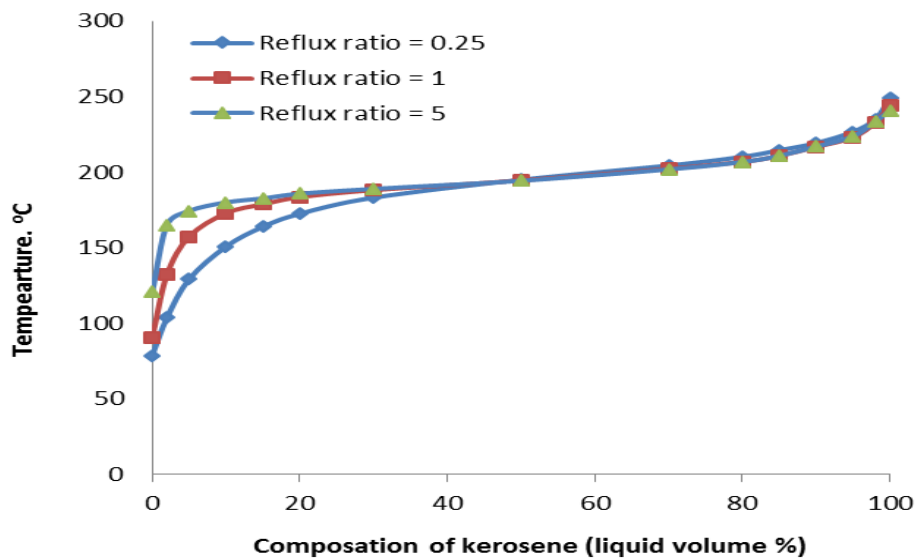


Figure 4-12 ASTM D86 data for Naphtha at different reflux ratio (case-1).

Figures 4-13, 4-14 and 4-15 show the effect of the reflux ratio and the number of stages on the quality of products (Naphtha, Kerosene, and Diesel) for Case-3. Figures are similar to case-1. From these figures, it can be seen that the quality of three products increase as the reflux ratio and the number of stage increase. From Figure 4-13, it can be seen that Naphtha product has very high quality when the reflux ratio above 1.0. The reboiler heat duty increases as the reflux ratio increases as shown in Figure 4-13 therefore the light components increase as the reboiler heat duty increases. Figure 4-13 also, shows that the effect of the reflux ratio on the quality of Naphtha is very small when it's above 1.0. Also, it can be observed that the additional stages further that 20 has small effect on the quality of Naphtha.

From Figure 4-14, it can be observed that the quality of Kerosene has almost the same for the number of stages more than 20. Also, shows that the reflux ratio has small effect when its value above 2.75. From Figure 4-15, it can be seen that the reflux ratio has very small effect on the quality of Diesel but the effect of the number of stages is very small when the number of stages more than 20.

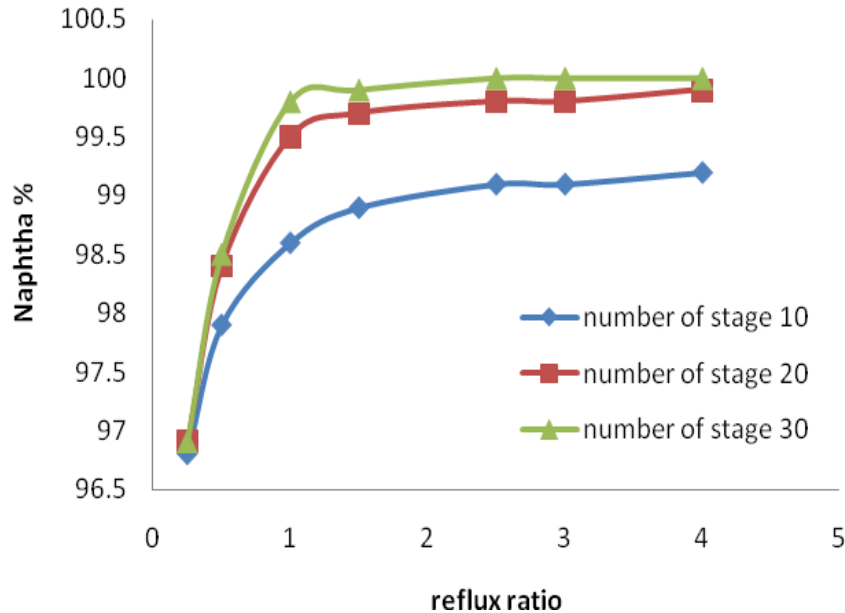


Figure 4-13 the effect of the reflux ratio on the Naphtha quality at different number of stages (Case -3).

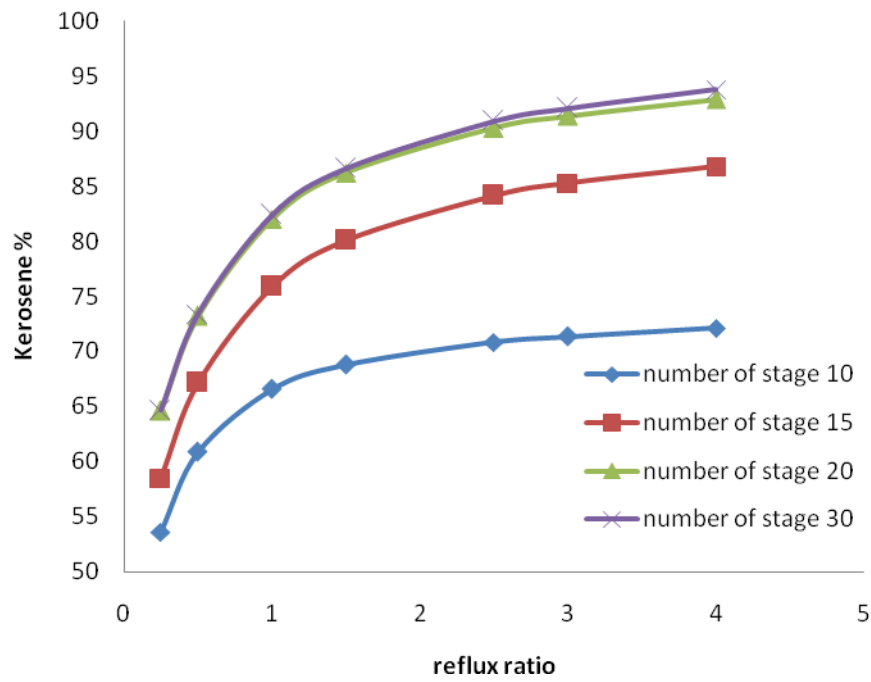


Figure 4-14 The effect of the reflux ratio on kerosene quality at different number of stages (Case -3).

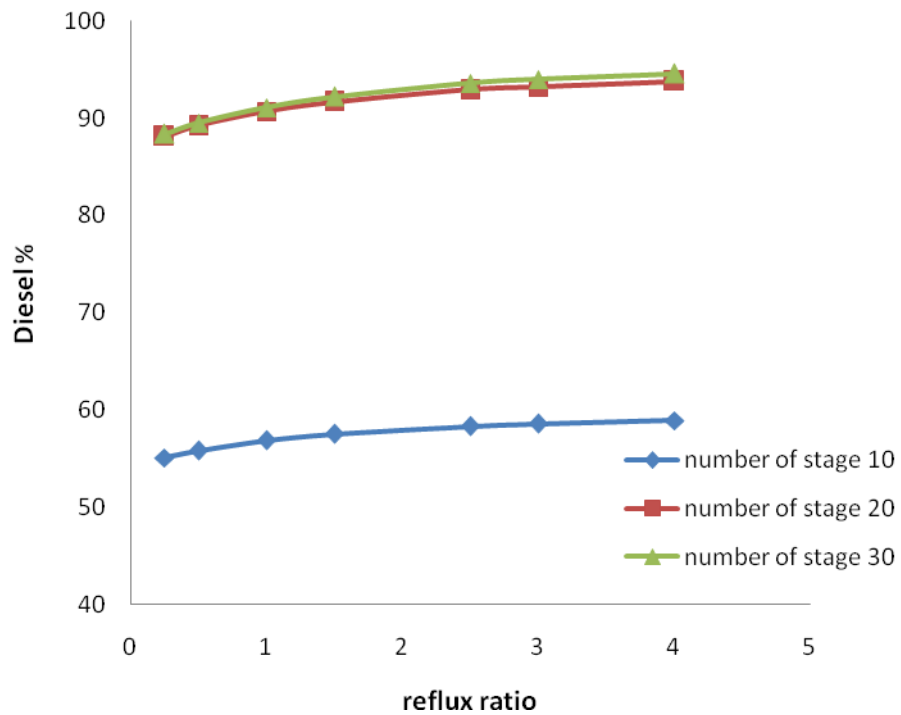


Figure 4-15 The effect of the reflux ratio on the quality of Diesel for different number of stages (Case -3).

4.4 Condensate fractionation column without reboiler

All previous design for condensate fractionation column were done for a traditional distillation column, which has a reboiler at the bottom and a condenser at the top. Another design modification has been proposed and checked for accordance with the basic design product of Case-1. For a design change, the reboiler was eliminated from the condensate fractionation column in case-1. Then extensive simulation was done to maintain the product quality to the basic Case-1 design. For this, the feed stage was changed to 24 and the side draw plate was changed to 10. So the column worked as a rectifying column. The schematic of the column is shown in Figure 4-16.

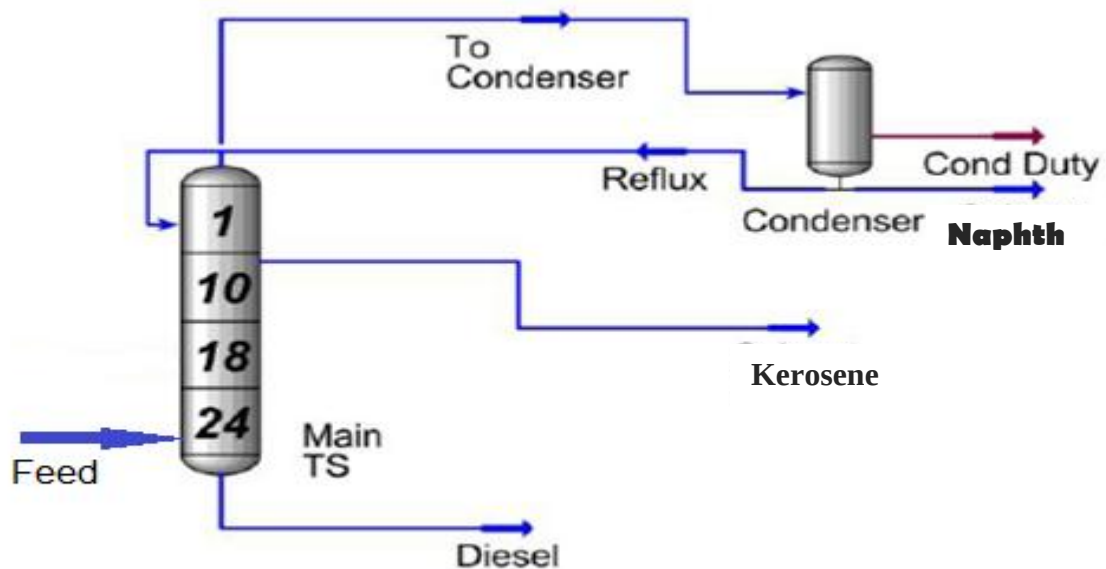


Figure 4-16 Process flow sheet for column-2 (rectifying column).

The distillation column for Case-1 is denoted as Column-1 and the modified column (without reboiler) is denoted as Column-2. The design of two different columns were simulated and compared for the analysis. Maintaining the same product quality (with a

slight variation). The feed position and side draw for the two columns are shown in the table below.

Table 4-8 Column data for the simulation.

	Column – 1	Column – 2
Total no. of stage	24	24
Feed Stage	18	24
Side Draw Stage	17	10

The idea is to verify if any major design change is made, would it be able to produce the products of same quality?

The convenience of the design was the reduction of cost due to the removal of reboiler from the column. But with the reduction of the cost, the product quality was changed. This is the trade-off between reduction of cost and quality.

The comparative results are shown in Figure 4-17. Here, the ASTM D86 curves were shown for different products – Naphtha, Kerosene and Diesel. In Figure 4-17, the quality comparison for Naphtha is shown. From the figure, it can be easily understood that two columns have almost the same product quality except a slight variation for Column-1. That is because, Column-1 had more degree of freedom than the Column-2 and it contains the lighter components than the Column-2 which contains a little amount of heavier components excess to Column-1.

In Figure 4-18, the ASTM D86 data for the comparison of the kerosene cut is shown. Column-1 has a lead over the column-2. It contains almost 30% of some components which gives the boiling point around 180 °C whereas the column-2 has a lack of those components. At the deviation region, they have some components of an average boiling point of 160. Then at 50% of composition, the boiling point data from ASTM D86 collide and they remain the same till the final boiling point. So here remains the trade-off between quality and cost minimization. Column-1 definitely suffices the need for the consumers but Column-2 has some deviations from the original. This deviation clearly indicates that Column-2 contains some extra lighter components whereas Column-1

does not. Those lighter components will make the kerosene cut to evaporate easily. If this is a product which is to be used for example as solvent for paint, then obviously this will not be a problem. But for other purposes, this fast evaporating tendency of the product must have to be taken under consideration. For this particular simulation, as material balance was kept constant, product quality cannot be upgraded from this.

Figure 4-19 shows the bottom product quality from the columns. From the figure, it can be noted that Column-2 contains some extra lighter parts. These lighter parts change the quality of diesel as this diesel would boil or evaporate faster. The explanation of this difference is pretty simple; Column-2 has no heating system at the bottom like reboiler. So it lacks behind the other column (Column-1) to strip the lighter parts of the condensate to the top section of the column. But it is noteworthy that after 50%, it coincides with the Column-1 till the final boiling point.

So if this quality difference can be tolerated, then this design is also acceptable. But these plots are not enough to understand the product quality of three products. The oil distributions of the products were studied. These studies are presented in the form of bar plots which would provide the necessary insight about the products in the next section.

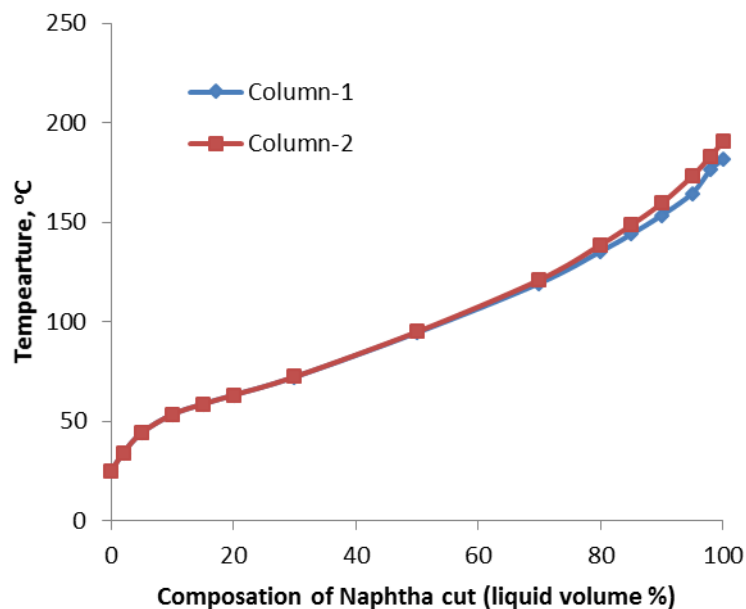


Figure 4-17 ASTM D86 data for Solvent-A obtained from the three different design consideration (case-1)

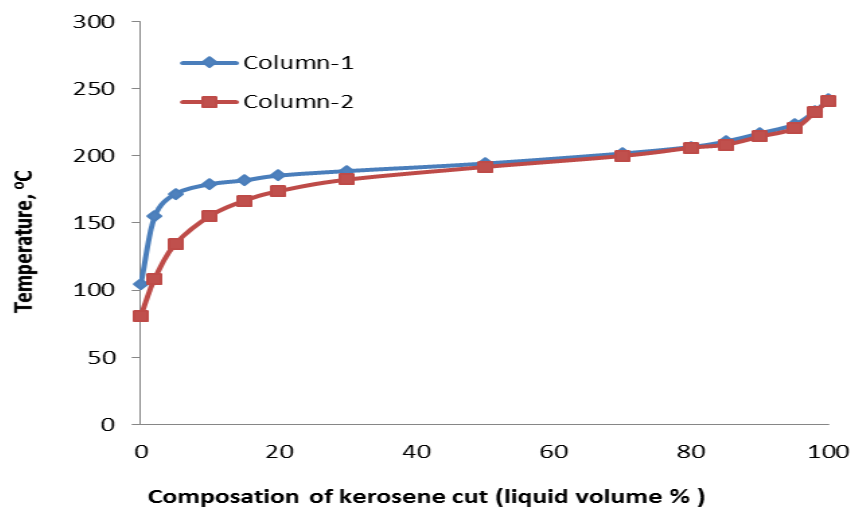


Figure 4-18 ASTM D86 data for kerosene cut obtained from the three different design consideration(case-1).

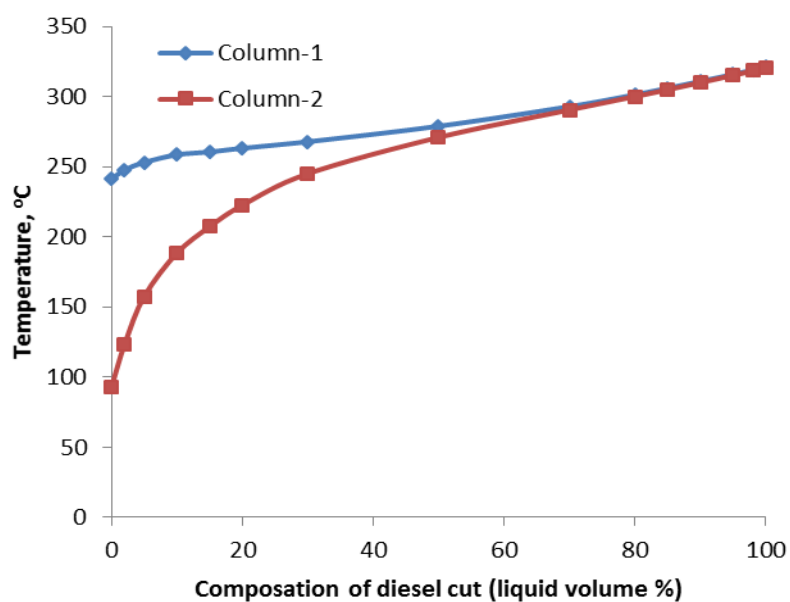


Figure 4-19 ASTM D86 data for diesel cut obtained from two different design consideration (case-1)

4.4.1 Comparison of product quality

4.4.1.1 Quality of Naphtha

the lighter product mainly contains naphtha in higher amount so the quality of Naphtha cut is verified by analyzing the percentage of naphtha present in the top product. The Figure 4-20 illustrate that after partial fractionation of natural gas condensate in a typical distillation column having a condenser at top and a reboiler in bottom will produce Naphtha cut with a quality of 99.7 % naphtha. In the second case, when the column contains only the condenser and no reboiler is used for heating the bottom liquids, the top product contains 95.6 % naphtha.

From Figure 4-20 it is clear that for Column-2 when there is no reboiler, the quality of Naphtha does not differ much from the product found in a typical distillation column. So, in these cases omission of a reboiler from the column will decrease the investment as well as operating cost of the plant keeping the product quality very nearly the same.

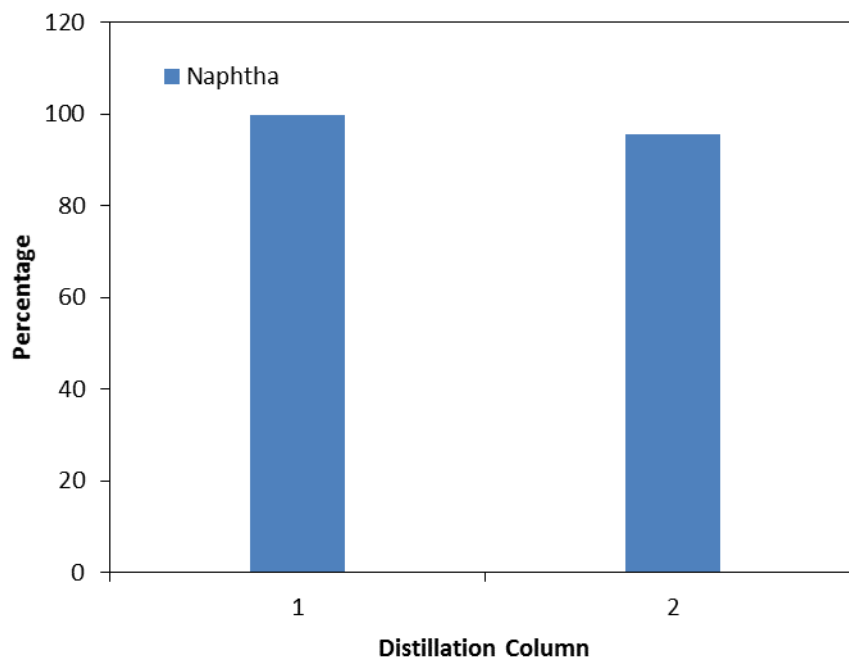


Figure 4-20 The percentage of Naphtha in Naphtha cut for two distillation columns.

4.4.1.2 Quality of Kerosene

Kerosene cut is a side stream of the distillation columns collected from stage-17 for Column-1, and stage-10 for Column-2. It contains mainly mixture of naphtha and kerosene. Figure 4-21 shows the quality of kerosene cut found from two separate distillation columns.

For the column-1 the percentage of naphtha and kerosene in kerosene cut is 93.3% and 6.7% respectively. For the column-2 these compositions are 85.3% and 14.7% respectively.

From the Figure 4-21, it can be said that the quality of kerosene has slight degradation for second case than the first case. Although column-2 has degraded quality of kerosene cut, still it is in the acceptable limit. In all the simulation work it was the primary objective to maintain the amount of product same in all the considered design modifications i.e., the quantity of Naphtha cut, kerosene cut and diesel must be same from the two distillation column using 375,400 lb/hr of natural gas condensate as feed. In all the two cases the amount of kerosene cut produced is 59,890 lb/hr. To maintain the amount of product same, a slight degradation in quality of the product has occurred.

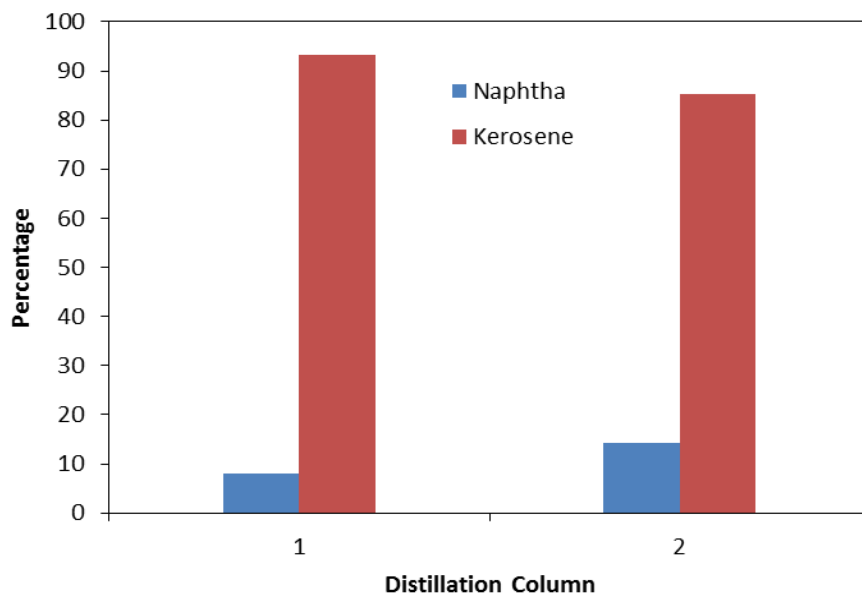


Figure 4-21 The percentage of Naphtha and kerosene in Kerosene cut for two distillation columns.

4.4.1.3 Quality of Diesel

The column bottom products are usually diesel and it mainly contains mixture of light diesel, heavy diesel and a considerable amount of kerosene. The Figure 4-22 describes the quality of diesel found from the two distillation columns. For a typical distillation column (column-1) the percentage of kerosene, and diesel in diesel cut is 1.70 and 98.3% respectively. For second column this compositions are 15.5 and 84.5% respectively.

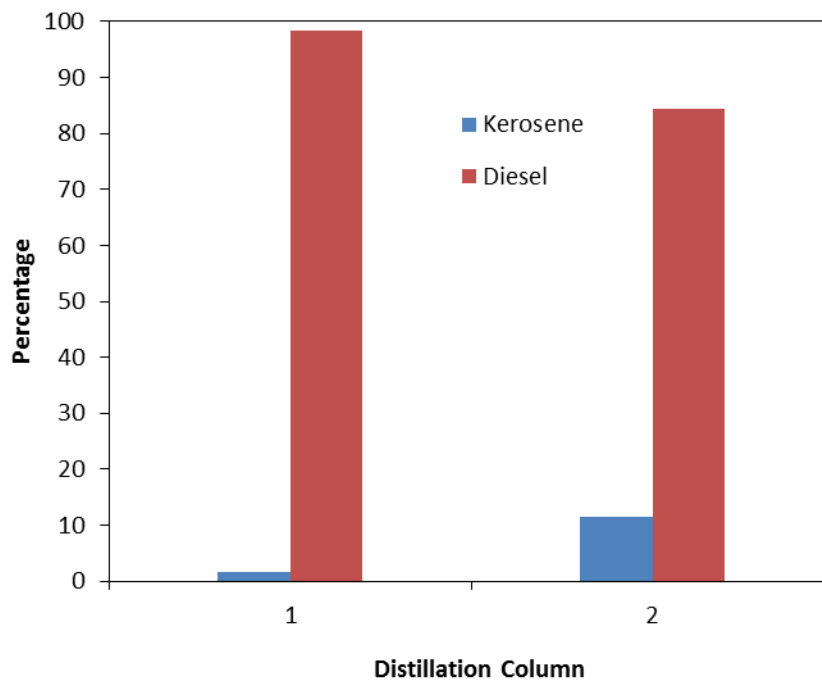


Figure 4-22 The percentage of kerosene and diesel in diesel cut for two distillation column. (case-1).

It has already been mentioned that, there is a tradeoff between material balance and quality of the products. To keep the amount of product same, quality of product must be sacrificed. That's why for the second column the percentage of kerosene is much than that for first column.

4.5 Blending of condensate with crude oil

The second suggestion for utilization of Libyan condensate is blending condensate with crude oil and then used as feed stock to the refineries in order to increase the production of light products such as Naphtha and Kerosene where Naphtha is the key product for gasoline production.

Libya has 5 refineries with a combined crude oil distillation capacity of 378,000 bbl/d. Ras Lanuf is the country's largest refinery with a capacity of 220,000 bbl/d. Azawiya refinery is the second-largest refinery with a capacity of 120,000 bbl/d. Capacities of other refineries are very small. The best candidate refinery for this suggestion is Azawiya refinery for many reasons. Ras Lanuf refinery will not be considered in this proposal because the current operator for this refinery (The Libyan Emirati Refining Company) has in the past expressed an intention to increase and upgrade the refinery's capacity. It's possible to apply this proposal for Azawiya refinery especially it is close to Mellitha and Sabrata. This proposal needs to find out how much of condensate can be added to the crude oil?. This also needs retrofit design for atmospheric distillation column. Blending condensate with crude oil and using as feed stock to Azawiya refinery will increase SRN production in the refinery then it's possible to produce more gasoline in the refinery by adding a new reforming units and isomerization unit or use other options like for example adding a new octane poster PT10515G, which is a new octane poster that can blends with SRN, LN, REFORMAT for gasoline blending. It is possible also to apply this proposal for Sirte refinery where we can use condensate produced by Sirte company. This can be also increase Naphtha production in the refinery.

4.6 Using of paraffinic condensate as feedstock to produce gasoline

The third suggestion is using paraffinic condensate as feed stock to reforming unit for gasoline production. Zueitina condensate is paraffinic condensate. 96% of Zueitina condensate in the range of Naphtha that can be used as feedstock directly to reforming unit to produce reformat. The production of Zueitina condensate is about 9,000 barrels

per day. In case, we use all of this production, this means that we will produce about 8000 bbl/day (336.87 ton/day) (if efficiency of reforming 90%). The gasoline production in Libya will increase with 10% by using this suggestion.

5 Conclusions and Recommendations

In the present study, three suggestions for utilization of Libyan condensate were investigated. The design of condensate fractionation column and the effect of some design parameters such as reflux ratio and the number of stages on the quality of three products (Naphtha, Kerosene and Diesel) of gas condensate fractionation column were studied and investigated. Results show that the quality of these three products for three cases increases as the reflux ratio and the number of stages increase. Also, the reboiler heat duty increases as the reflux ratio increases.

- Several design specification for condensate fractionation column were proposed and validated through HYSYS simulation. Calculation made to determine the optimum design specifications of condensate fractionation column for three cases as follows: 24 stages, column pressure is 1 atm, the reflux ratio is 2.75, and feed stage location is 15 in Case-1; and similar type of column with the same number of stages, operating pressure, reflux ratio, and feed stage location in Case-2; similar type of column with the same number of stages, reflux ratio and operating pressure but feed plate location is 18 in Case-3.
- This study also presents an interactive study of major design changes from the traditional fractionation column. The decision from the simulation is quite straight forward. The remarkable outcome from this study is, if the cost of reboiler is to be excluded, the quality of Kerosene and diesel will degrade. The degradation of the products was studied in this study in details. So if the product quality is acceptable, then this strategy should be adopted.
- In the end, it can be concluded that this work mainly contributes by providing different results from the simulation on various design modification of a gas condensate fractionation column. A more rigorous study can be done by varying the material balance or dividing one column into two which can provide a different set of data and some new possibilities.

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