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Department of Petrochemistry

END OF STUDIES DISSERTATION

Submitted in Partial Fulfillment of the Requirements for the Master's Degree

Sector: Petrochemical Industries

specialty: Petrochemical Engineering

Theme:

Simulation and optimization of atmospheric distillation column of Skikda's refinery RA1K for Linear Alkyl Benzene production project

Submitted by:

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Abstract

The Topping Unit (U10) at the Skikda Refinery (RA1K) processes crude oil using distillation. It fractionates the crude into different hydrocarbon cuts, characterized by their initial and final boiling points.

This study focuses on the kerosene cut (160-219°C), extracted from the 46th tray of the atmospheric distillation column 10-C-1. Conducted using Aspen HYSYS V11 simulation software on the Topping Unit, it forms part of a final year project aimed at enhancing the quality of the kerosene produced by RA1K. The goal is to meet the specifications required for the LAB project feed while adhering to the unit's operating parameters.

The key specifications for this feed include n-paraffins (C10-C13), the 5% and 95% points of ASTM D86 distillation, and molecular weight.

Keywords: atmospheric distillation column, Kerosene, specification, n-paraffins, simulation, optimization, LAB.

Résumé

L'unité de Topping (U10) de la raffinerie de Skikda (RA1K) traite le pétrole brut en utilisant la distillation. Elle fractionne le brut en différentes coupes d'hydrocarbures, caractérisées par leurs points d'ébullition initial et final.

Cette étude se concentre sur la coupe kérosène (160-219°C), extraite du 46ème plateau de la colonne de distillation atmosphérique 10-C-1. Réalisée à l'aide du logiciel de simulation Aspen HYSYS V11 sur l'unité Topping, elle s'inscrit dans le cadre d'un projet de fin d'études visant à améliorer la qualité du kérosène produit par RA1K. L'objectif est de répondre aux spécifications requises pour la charge du projet LAB tout en respectant les paramètres de fonctionnement de l'unité.

Les spécifications clés pour cette charge incluent les n-paraffines (C10-C13), les points 5% et 95% de la distillation ASTM D86, ainsi que la masse moléculaire.

Mots clés : colonne de distillation atmosphérique, Kérosène, spécification, n-paraffines, simulation optimisation. LAB.

ملخص

تقوم وحدة التكرير (U10) في مصفاة سكيكدة (RA1K) بمعالجة النفط الخام باستخدام عملية التقطير. تقوم هذه الوحدة بتجزئة النفط الخام إلى مقاطع مختلفة من الهيدروكربونات، تتميز بنقاط غليانها الابتدائية والنهائية.

تركز هذه الدراسة على مقطع الكيروسين (160-219 درجة مئوية)، المستخرج من الطبقة 46 من عمود التقطير الجوي C-1-10. تم إجراء الدراسة باستخدام برنامج المحاكاة Aspen HYSYS V11 على وحدة التكرير، وهي جزء من مشروع تخرج يهدف إلى تحسين جودة الكيروسين المنتج من قبل RA1K. الهدف هو تلبية المواصفات المطلوبة لتغذية مشروع LAB مع الالتزام بمعايير تشغيل الوحدة.

تشمل المواصفات الرئيسية لهذه التغذية البارافينات العادية (C10-C13)، نقاط 5% و95% من تقطير ASTM D86، والكتلة الجزيئية.

الكلمات المفتاحية: عمود التقطير الجوي، الكيروسين، المواصفات، البارا فينات الخطية، المحاكاة، التحسين، LAB.

Abbreviations and acronyms list

ABS	acrylonitrile-butadiene-styrene
API	American petroleum institute
ASTM	American society for testing and materials
BPA	Bottom pump around
CFR	Cooperative fuel research
C.W	Colling water
d^{15}	Density at 15°C
DEFINE	Di-olefin conversion to mono olefin
DETAL	Detergent alkylation
DMW	Demeneralized water
ETP	Effluent treatment plant
FBP	Final boiling point
FMCG	Fast-moving consumer goods
HAB	Heavy alkyl benzene
HF	Hydrofluoric acid
HO	Hot oil
HOH	Hot oil heater
HGO	Heavy gasoil
HVGO	Heavy vacuum gasoil
IBP	Initial boiling point
JFTOT	Jet Fuel Thermal Oxidation Tester
K_{UOP}	Characterization factor
LAB	Linear alkyl benzene
LAS	Linear alkyl benzene sulfonate
LCV	Level control valve
LP	Low pressure
LIC	Level indicator control
LPG	Liquefied petroleum gas
LV	Level valve
L/V	Liquid to vapor ratio
LGO	Light gasoil

LVGO	Light vacuum gasoil
MON	Motor octane number
MOLEX	Molecular extraction
MP	Medium pressure
MW	Molecular weight
NP	Normal paraffin
NNP	Non normal paraffin
OWS	Oil-Water Separation
PACOL	Paraffin converted to olefin
PEP	Pacol enhancement process
PF	Pre-fractionation
PIC	Pressure indicator control
PV	Pressure valve
RA1K	Skikda Refinery
RON	Research octane number
RVP	Reid vapor pressure
SBR	Styrene butadiene rubber
SP.gr	Specific gravity
TBP	True boiling point
TIC	Temperature indictor control
TPA	Top pump around
TV	Temperature valve
UF	Union fining
UOP	Universal oil products

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General introduction

Petroleum is a complex mixture of hydrocarbons from different families (paraffinic, naphthenic, aromatic) associated with oxygenated, nitrogenous, and sulfurous compounds, as well as traces of specific metals (vanadium, molybdenum, nickel). It remains to this day the main source of energy thanks to refining, which involves several unit operations.

Petroleum refining is a heavy industry that transforms a mixture of hydrocarbons, called crude oil, into energy products, such as fuels and combustibles, and non-energy products, such as petrochemical feedstocks, lubricants, paraffins, and bitumen. The processes and operations of petroleum refining can be divided into five basic areas:

Fractionation (distillation): This is the separation of crude oil in atmospheric and vacuum distillation columns into groups of hydrocarbon compounds with different boiling point ranges called fractions or 'cuts.'

Conversion processes: These modify the size and/or structure of hydrocarbon molecules.

Hydrocarbon treatment processes: These prepare streams for further treatments and finished products by removing unwanted impurities and contaminants through methods such as desalting, drying, and hydrodesulfurization.

Formulation and blending: This is the process of mixing and combining hydrocarbon fractions, additives, and other components to produce finished products with specific performance properties.

Other refining operations: These include the recovery of light fractions, treatment of sour and wastewater, storage, handling, hydrogen production, sulfur recovery, steam and electricity production, backup systems, and pollution control.

The atmospheric distillation unit (Topping-U10) at Skikda, where our study was conducted, is of critical importance for the operation of the refining complex. Fractionation of crude oil not only yields finished products (LPG, kerosene, diesel) that can be directly consumed in domestic and foreign markets but also provides semi-finished products essential for the operation of other units such as catalytic reforming, aromatic extraction, or isomerization, or as raw materials for the petrochemical industry (naphtha, kerosene).

To promote the petrochemical industry in Algeria and enhance the exploitation of these products, SONATRACH signed a contract with TECNIMONT Spa on March 7, 2024, for the construction of a Petrochemical Complex for the production of Linear Alkyl Benzene (LAB) in Skikda. LAB is produced from n-paraffins extracted from kerosene and benzene (raw materials).

Linear Alkyl Benzene is a family of organic compounds with the formula $C_6H_5CnH2n_{+1}$. Generally, 'n' is between 10 and 16, and it is used as an intermediate material for manufacturing detergents.

In studying the basic quality data of the required kerosene, it was found that the kerosene produced by RA1K meets one of the LAB project's specifications, particularly the n-paraffins. However, the ASTM D86 5% and 95% points and the molecular weight do not meet the requirements, especially the 95% point where the deviation is quite significant.

The main objective of this work is to optimize the operation of the main distillation column to adjust the quality of the kerosene by increasing the 5% and 95% points of the ASTM D86 distillation and the molecular weight to meet the LAB project requirements.

This thesis is divided into five chapters, organized as follows:

Chapter 1: Presentation of the Skikda refinery (RA1K) and the atmospheric distillation unit (U10).

Chapter 2: Concepts of distillation.

Chapter 3: General information on LAB production.

-Chapter 4: General information on the simulation and validation of the two cases: design and real, of the column (10-C-1) of the atmospheric distillation unit (U10) of the refinery (RA1K).

Chapter 5: Optimization of the kerosene quality from unit 10 of RA1K to meet the LAB project requirements, based on simulation using Aspen HYSYS V11.

Chapter I: Skikda's refinery presentation (RA1K) and description of the assignment unit

I.A First part:

I.A.1 Mission of the refinery (RA1K)

The Skikda Refinery (RA1K) is dedicated to transforming crude oil from Hassi Messaoud into valuable finished or semi-finished petroleum fractions for both domestic and international markets. Its processing capacity, initially 15,000,000 tons per year, was increased to 18,000,000 tons per year after its renovation, making it the largest refinery in Africa. Additionally, it processes imported reduced crude with a capacity of 277,000 tons per year to produce road and oxidized bitumen.[1]

I.A.2 Geographic location

This refinery is located in the industrial zone 7 km east of Skikda and 2 km from the sea. It covers an area of 190 hectares and currently employs approximately 1,300 workers. The refinery is supplied with Algerian crude oil from Hassi Messaoud. The crude oil is transported via a pipeline covering a distance of 760 km from the oil fields to the complex.

Figure I.1: Geographical location of RA1K in the industrial zone of Skikda. [2]

I.A.3 Presentation of the different production units

The refinery is equipped with the following units:

I.A.3.1 Units 10-11 (Atmospheric Distillation)

The Topping or atmospheric distillation aims to fractionate crude oil into different stabilized cuts that can be used to obtain finished products.

Units U10-11 process crude oil from Hassi Messaoud to produce the following products: LPG, iso-pentane, Naphtha A, Naphtha B, Naphtha C, kerosene, light gas oil, heavy gas oil, and residue.

I.A.3.2 Units 100 and 103 (Magnaforming and Platforming Units)

The Magnaforming and Platforming units aim to convert the medium and heavy naphtha obtained from the Topping into reformate, which is used as feedstock for the aromatics units (units 200 and 400). This transformation increases the octane rating, allowing the reformate to be used in the production of gasoline.

I.A.3.3 Unit 200 (Aromatics Extraction)

The aromatics extraction installation is designed to extract aromatics from reformed gasoline, which will subsequently be fractionated into very pure benzene and toluene. The feedstock consists of the light reformate cut coming directly or via a reservoir from the C5 splitter column of the reformate from Unit 100.

I.A.3.4 Unit 400 (Paraxylene Separation)

This unit is designed to recover the highly sought-after paraxylene produced in the market. The feedstock from the Magnaforming unit allows for the separation of paraxylene from other xylenes (meta- and ortho-) and ethylbenzene through crystallization. Paraxylene is marketed as it is, while the rest can be used as a base for gasoline production or sold as a xylene mixture, which can be used as a solvent in paint manufacturing, etc.

I.A.3.5 Unit 500 (Isomerization of M-xylene)

The aromatics isomerization installation is designed to process the filtrate from the crystallizers of Unit 400 (the paraxylene extraction unit) and isomerize it. The resulting isomerate is then separated into two essential fractions:

- A benzene-rich fraction sent to Unit 200.

- A paraxylene-rich fraction sent to Unit 400.

The main objective of this unit is to increase the production of paraxylene.

I.A.3.6 Units 700/701/702/703 (Light Naphtha Isomerization Units)

Their purpose is to convert normal paraffins into iso-paraffins, a reaction increasingly sought by refiners to achieve a high octane rating without the addition of additives. Paraffins ranging from butane to hexane can be isomerized using modern, highly active platinum-based catalysts.

Isomerization can be pushed to the extreme through the use of distillation and/or molecular sieves to separate unconverted normal paraffins. C5-C6 cuts can also be completely isomerized into high-octane components, which are highly valued for the gasoline pool.

The isomerization process has become a valuable tool for refiners to expand their product range and improve quality while increasing operational flexibility and profitability. Additionally, producing high-octane constituents free of aromatics reduces the need for reformate, which is rich in aromatics, in the gasoline pool. This enhances gasoline quality in terms of environmental protection, which is a very important factor today.

At the Skikda refinery, two trains have been installed for the isomerization of the light naphtha fraction produced in the topping units (U10 & U11) to provide an aromatic-free additive to the gasoline pool for fuel production.

I.A.3.7 Unit 70 (Bitumen Production)

Unit 70 is designed to process 271,100 tons per year of imported reduced crude (IRC), which can include:

- Feed A: Residue TIA Juan Medium 372°C plus.

- Feed B: Residue TIA Juan Heavy 450°C plus.

- Feed C: Residue from Kuwaiti crude.

The unit mainly consists of a vacuum distillation column and a bitumen oxidation reactor. The bottom product from the column is ordinary road bitumen, which is sent:

- Partly to storage.

- Partly as feed to the oxidation section, where it will be oxidized with air to produce oxidized bitumen.

I.A.3.8 Units 30-31-104 (Gas Separation and Treatment)

These units are intended to process liquid gases coming from units 10, 11, 100, and 103 in the following order:

Unit 30: Processes the liquid gas from unit 100, particularly from the top of column C7, where LPG is separated from pentane.

Unit 31: Receives gases from the top of the gasoline stabilization columns of the two Topping units.

Unit 104: This unit was recently designed along with the new Platforming unit 103 to process the LPG coming from this unit.

I.A.3.9 Unit 600 (Melexe Unit)

The Melexe unit handles the following tasks:

- Storage tanks for various feeds and products from the units.

- Dispatching products to different storage depots, for example, the ElKheroub depot.

- Blending of gas oils.

- Monitoring product loading operations at the Skikda port.

I.A.3.10 Thermo-Electric Power Plant

It's the nerve center of the refinery. The thermo-electric power plant consists of 11 sections, namely:

- Section 62: For the production of demineralized water.

- Section 1020: For water cooling towers.

- Section 1030: For storage and pumping of dam water or potable water.

- Section 1040: For storage and pumping of firewater.

- Section 1050: For steam generation (boilers).

- Section 1060: For condensate recovery and treatment.

- Section 1070: Or fuel-gas system.

- Section 1080: For instrument air and service air production.

- Section 1100: For effluent treatment.

- Section 1110: For nitrogen (N2) production.

- Electricity production section.

I.A.3.11 Unit 900 (Hydrogen Purification Unit)

Its purpose is to increase the purity of hydrogen from Unit 100, before sending it to other hydrogen-consuming units (e.g., Unit 500...).[1]

- Our internship was conducted in the atmospheric distillation **unit 10 (U10).**

I.B **Second part:**

I.B.1 Process description

The atmospheric distillation unit (U10) is designed to fractionate crude oil into petroleum cuts, which are either finished and sent directly to storage or used as feedstock for other units. It comprises the following sections:

- ✓ Crude oil desalting,
- ✓ Feed preheating and heating,
- ✓ Crude oil fractionation column,
- ✓ Stripping columns for side draws,
- ✓ Pumps around,
- ✓ Stabilization columns for the naphtha cut,
- ✓ Separation column for the C6 cut,
- ✓ Separation columns for the naphtha cuts (B and C).

The process of atmospheric distillation at the Skikda refinery (RA1K) is illustrated in Figures 2.1 and 2.2

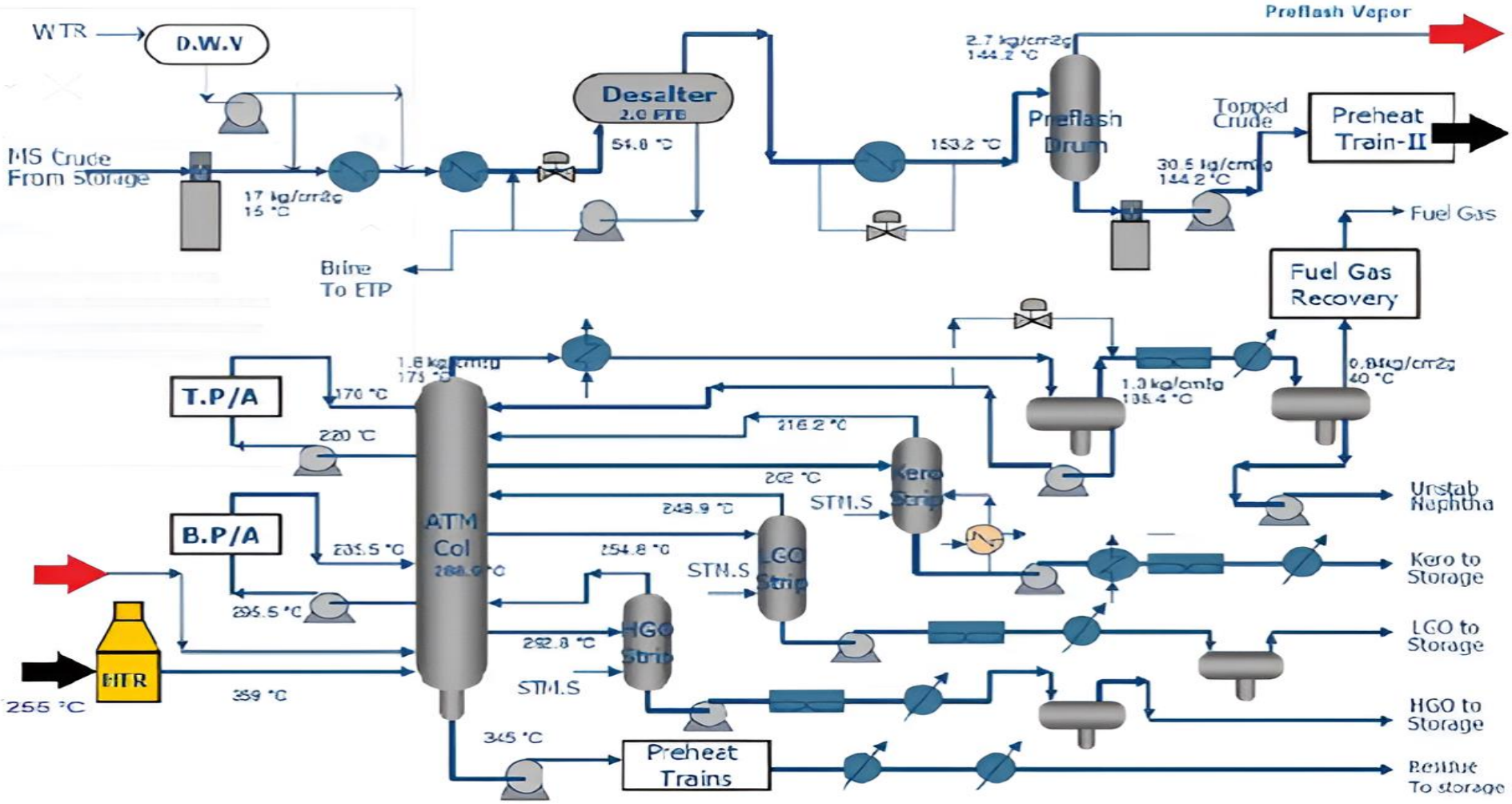


Figure I.2: Diagram of the atmospheric distillation unit (U10) – part 1.[3]

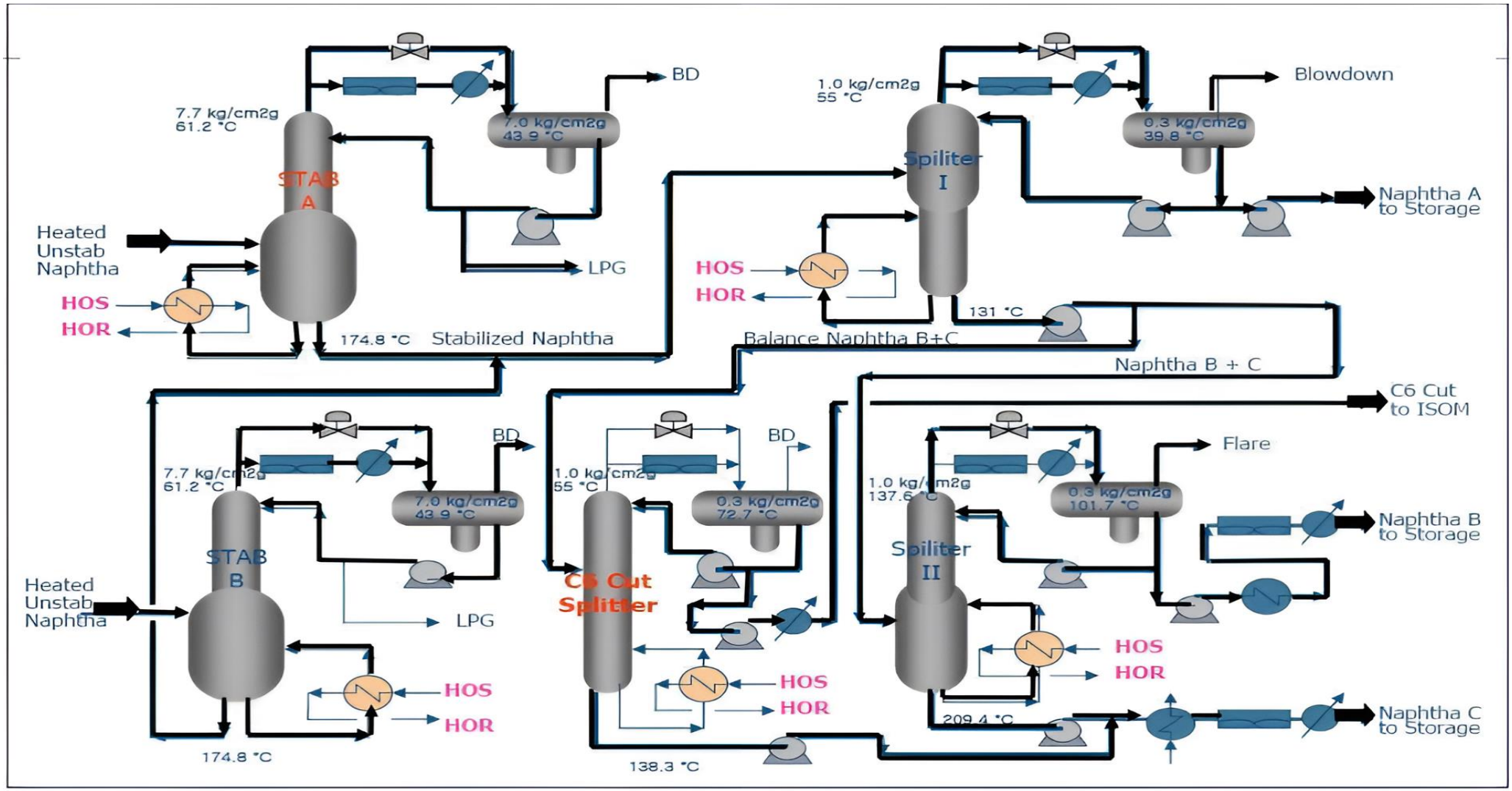


Figure I.3: Diagram of the atmospheric distillation unit (U10) – part 2.[3]

I.B.1.1 Crude oil desalting

The feed for the atmospheric distillation unit (U10) is drawn from storage tanks at an absolute pressure of 1.3 kg/cm² and a temperature of 15 to 36 °C by the feed pump (P71A/B) and then discharged at an absolute pressure of 18 kg/cm². The crude oil is then preheated, on the tube side, in the exchangers (E107 A/B) by a portion of the light gas oil at a temperature of 33 °C and, on the tube side, in the exchanger (E72) by the other portion of the light gas oil at a temperature of 55 °C. If the temperature of the crude oil from the storage tanks is 36 °C, the exchangers (E107 A/B) should be completely bypassed.

The crude oil, heated to 55 °C, is sent to the desalter to remove the salts contained in the crude oil. Water from the vessel is mixed with the crude oil before entering the desalter. approximately 90% of the salts contained in the crude oil are removed by the desalter.

I.B.1.2 Feed preheating and heating:

The desalted crude, at a temperature of 50 °C, is sent, on the tube side, to the exchangers (E93 A-H) where it is heated by the overhead vapors from the column (C1). These exchangers are arranged in two series of four exchangers in parallel each.

The crude is then sent to the flash drum which operates at an absolute pressure of 4.0 kg/cm² and a temperature of 140 °C, where it is separated into two phases: a vapor phase (approximately 7.1% by mass) and a liquid phase. The overhead vapors from the drum are heated in the exchanger (E64) by hot oil circulating on the tube side, then conveyed at a temperature of 226 °C to the flash zone of the atmospheric distillation column (C1). The bottom liquid is sent by pumps (P72 A/B/C) to the flash zone of the column (C1) through a series of exchangers and then two furnaces.

Thus, the crude, stripped of light hydrocarbons, enters the exchangers (E82 A/B) on the shell side, arranged in series, where it is heated to a temperature of 151 °C by heavy gas oil, then on the tube side in the exchangers (E61 A-D), arranged in two series of two exchangers in parallel each, where it is heated to a temperature of 174 °C by the upper circulating reflux, then on the shell side in the exchangers (E83 A/B), arranged in series, where it is heated to a temperature of 186 °C by atmospheric residue, then on the tube side in the exchanger (E91) where it is heated to a temperature of 195 °C by the upper circulating reflux, then on the shell side in the exchangers (E90 A/B), arranged in series, where it is heated to a temperature of 226 °C by the lower circulating reflux, then on the shell side in the exchanger (E62) where it is

heated to a temperature of 233 °C by the lower circulating reflux, and finally enters, on the shell side, the exchangers (E63 A-D), arranged in series, where it is heated to a temperature of 260 °C by the atmospheric residue.

The crude, at a temperature of 260 °C, is sent to the two furnaces (F1A/B) arranged in parallel where it is partially vaporized and then conveyed at a temperature of 356 °C to the flash zone of the atmospheric distillation column (C1).

I.B.1.3 Crude oil fractionation

The fractionation of the crude oil is carried out in an atmospheric distillation column (C1) operating at an absolute pressure of 2.8 kg/cm². The height of the column (C1) is 50.55 meters, the diameter of the enrichment section is 8.1 meters, and the diameter of the stripping section is 3.8 meters.

The column is equipped with 52 trays and is subdivided into three zones: the feed or flash zone located between the 5th and 6th trays, the enrichment or fractionation zone between the 6th and 52nd trays, and the stripping zone between the 1st and 5th trays. The crude oil heated to a temperature of 356 °C and the overhead vapors (light hydrocarbons and water vapor) from the flash drum are sent into the flash zone of the column (C1).

- **Overhead Vapors**

The overhead vapors from the atmospheric distillation column (C1), composed of light gases (C2-), LPG, and naphtha at a temperature of 172 °C, are sent to the shell side of the exchangers (E93 A-H). These exchangers are arranged in two sets of four exchangers in parallel, forming two series. In these exchangers, the vapors are cooled by crude oil to a temperature of 135 °C. The partially condensed vapors are then sent to the reflux drum (V2), which operates at an absolute pressure of 2.3 kg/cm².

The bottom liquid from the reflux drum (V2) is sent by the pump (P73 A/B) as reflux to the column (C1), The vapor is sent to the air coolers (EA1 A-L), where it is cooled to a temperature of 48 °C, and then enters, on the shell side, the water condensers (E92 A/B) arranged in parallel, where it is further cooled to a temperature of 40 °C. This partially condensed mixture is sent to the drum (V3), operating at an absolute pressure of 1.59 kg/cm², where it is separated into three phases: a vapor phase, a liquid phase, and an acid water phase.

The acid water is collected in the drum's nipple and then sent to the acid water treatment section by the pump (P70 A/B). The liquid (hydrocarbons), constituting unstabilized naphtha, is sent by the pump (P92 A/B), after preheating, to the stabilization columns (C5 and C62), with level control acting in cascade with the regulators that control the flow of naphtha to the two columns. The non-condensable gases are sent to the flare, with pressure control in the drum (V3) managed by the regulator. However, if the pressure drops below the setpoint, combustible gas is introduced into the circuit through the valve.

Two corrosion inhibitors (filming and neutralizing) are injected at the inlet of the air coolers to protect the equipment in the overhead circuit of the atmospheric distillation column from corrosion.

- **Kerosene Draw-Off**

The kerosene cut, drawn from the 46th tray at a temperature of 199 °C, is sent to the stripping column (C2), which has eight (8) trays. The stripping of the kerosene is carried out by reboiling, on the tube side, in the thermosiphon reboiler (E20) in counter-current with the lower circulating reflux. After stripping, the light fractions consisting of naphtha are reintroduced into the column (C1) at the 47th tray, while the bottom liquid, at a temperature of 230 °C, is sent by the pump (P94 A/B), on the tube side, into the exchangers (E10 A/B) where it is cooled by unstabilized naphtha, then into the air cooler (EA8), and finally into the exchanger (E21). After being cooled to a temperature of 40 °C, it is sent to the kerosene treatment section or to storage. In case of excess kerosene, part of it is directed to light gas oil storage.

- **Light Gas Oil (LGO) Draw-Off**

The light gas oil cut, drawn from the 20th tray at a temperature of 241 °C, is sent to the light gas oil stripping column (C3), which has five (5) trays. The stripping of the light gas oil is carried out by injecting medium-pressure (MP) steam below the 1st tray, with the flow controlled by the regulator (FIC1851). After stripping, the light fractions are reintroduced into the column (C1) at the 21st tray, while the bottom liquid, at a temperature of 248 °C, is sent on the shell side into the exchanger (E72), where it is cooled by crude oil to a temperature of 153 °C. It is then further cooled in the exchangers (E1075 A/B) by crude oil to a temperature of 97 °C, and finally sent by the pump (P74 A/B) into the air coolers (EA9 A/B) and then into the condensers (E65 A/B).

The light gas oil, at a temperature of 40 °C, is freed of water droplets in a coalescer before being sent to storage, with flow control managed by the regulator (FIC47) operating in cascade

with the level regulator (LIC12). The coalescer is equipped with a drain pot, through which oily water is drained into the OWS (Oil-Water Separation) network, with level control managed by the regulator (LIC1851) acting on the valve (LV1851).

- **Heavy Gas Oil (HGO) Draw-Off**

The heavy gas oil cut, drawn from the 15th tray at a temperature of 294 °C, is sent to the heavy gas oil stripping column (C4A), which has five (5) trays. The stripping of the heavy gas oil is carried out by injecting medium-pressure (MP) steam below the 1st tray, with the flow controlled by the regulator (FIC185). After stripping, the light fractions are reintroduced into the column (C1) at the 16th tray, while the bottom liquid is sent on the tube side into the exchangers (E82 A/B), where it is cooled by crude oil. It is then sent by the pump (P95 A/B) into the air cooler (EA10) and then into the condensers (E66 A/B).

The heavy gas oil, at a temperature of 40 °C, is freed of water droplets in a coalescer and finally sent to storage, with flow control managed by the regulator (FIC47) operating in cascade with the level regulator (LIC12). The coalescer is equipped with a drain pot, through which oily water is drained into the OWS (Oil-Water Separation) network, with level control managed by the regulator (LIC1854) acting on the valve (LV1851).

- **Atmospheric Residue**

The liquid hydrocarbons from the flash zone descend from the 5th tray to the bottom of the column, where they are stripped by superheated low-pressure (BP) steam injected below the 1st tray, with the flow controlled by the regulator (FIC1752) acting on the valve (FV1752). Steam stripping adjusts the flash point and consequently the gas oil content of the atmospheric residue. The residue, freed of light constituents and at a temperature of 338 °C, is sent by the pump (P76 A/B) on the tube side into the exchangers (E63 A-D) arranged in series, where it is cooled by crude oil to a temperature of 242 °C. The residue is then sent to the exchangers (E83 A/B), where it is further cooled by crude oil to a temperature of 200 °C. It then goes on the shell side into the exchangers (E8 A/B), where it is cooled by unstabilized naphtha to a temperature of 119 °C, and finally into the coolers (E22 A/B and E67), where it is cooled by tempered water to a temperature of 80 °C before being sent to storage. The temperature of the residue after cooling must be above 70 °C to prevent clogging.

- **Top Pump Around**

The upper circulating reflux, drawn from the 33rd tray of the column (C1) at a temperature of 219°C, is sent by the pump (P75 A/B) on the shell side into the exchanger (E91), and then

into the exchangers (E61 A-D), where it is cooled by crude oil to a temperature of 163°C. It is reintroduced into the column (C1) at the 34th tray. The temperature of the cooled circulating reflux is controlled by the regulator (TIC17), which operates in split-range on the valves (TV17 A/B) located on the return line of the upper circulating reflux and the bypass line of the exchangers (E91) and (E61 A-D).

- **Bottom Pump Around**

The lower circulating reflux, drawn from the 15th tray of the column (C1) at a temperature of 294°C, is sent by the pump (P15 A/B) into the reboiler (E20) of the kerosene stripping column, then on the tube side into the exchanger (E62), where it is cooled by crude oil to a temperature of 275°C, and finally into the exchangers (E90 A/B), where it is further cooled by crude oil to a temperature of 231°C before being reintroduced into the column (C1) at the 16th tray under temperature control.

I.B.1.4 Stabilization of Naphtha Cut

The unstabilized naphtha, coming from the vessel (V3A) at a temperature of 39°C, is sent by pumps (P92 A/B) to the stabilization columns A and B after being preheated. It first goes through the tube side of exchangers (E8A/B) where it is heated by atmospheric residue to 104°C, then through the shell side of exchanger (E9) in countercurrent with the bottom product of splitter II, and finally through exchangers (E10 A/B) in countercurrent with kerosene, reaching a temperature of 140°C. After preheating, the unstabilized naphtha is split into two streams. One stream, containing 70% of the unstabilized naphtha, is sent to stabilization column (C5), while the other stream, containing 30%, is sent to stabilization column (C62).

- **Stabilization Column (C5)**

Column (C5) has 38 trays and operates at an absolute pressure of 8.7 kg/cm². The feed (70% of unstabilized naphtha) is introduced in the flash zone between the 18th and 19th trays under flow control. The overhead vapors at 60°C are partially condensed in air coolers (EA2 A-G) and then in the condenser (E11), before being sent to the reflux drum (V8) at a temperature of 43°C. The vapor phase from the reflux drum (V8) is sent to the fuel gas network or possibly to the flare through valve (PV21 A). The liquid phase from the reflux drum (V8) is partially sent by pump (P93 A/B) back as reflux to column (C5) under flow control by regulator (FIC53) acting on valve (FV53). The other part, as distillate (LPG fraction), is sent to the gas treatment and separation unit (U30) under flow control by regulator (FIC55) operating in cascade with the level regulator (LIC21). The oily water drawn from the bottom of the reflux drum (V8) is

sent to the acid water treatment section under control of regulator (LIC30) acting on valve (LV30). A corrosion inhibitor is injected upstream of the air coolers (EA2 A-G) to protect the overhead system from corrosion.

A portion of the column (C5) bottom liquid is heated in reboilers (E69 A/B) by hot oil and reintroduced into the column below the 1st tray. The other portion (residue), constituting stabilized naphtha, is sent to the naphtha splitting column under the bottom level control of column (C5) by regulator (LIC20) operating in cascade with flow regulator (FIC54) on valve (FV54).

- **Stabilization Column (C62)**

Column (C62), installed during the renovation, also has 38 trays and operates at an absolute pressure of 8.7 kg/cm². The feed (30% of unstabilized naphtha cut) is introduced in the flash zone between the 18th and 19th trays under flow control. The overhead vapors at 60°C are partially condensed in air coolers (EA62 A/B) and then in the condenser (E71), before being sent to the reflux drum (V62) at a temperature of 43°C.

The non-condensable vapors from the reflux drum (V62) are sent to the fuel gas network or possibly to the flare through valve (PV2252 B). The liquid from the reflux drum (V62) is partially sent by pump (P63 A/B) back as reflux to column (C62) under flow control by regulator (FIC2252) acting on valve (FV2252); the other part, as distillate (LPG fraction), is sent to the gas treatment and separation unit (U30) under flow control by regulator (FIC2251) operating in cascade with the level regulator (LIC2253). The oily water drawn from the bottom of the reflux drum (V62) is sent to the acid water treatment section under control of regulator (LIC2255) acting on valve (LV2255). A corrosion inhibitor is injected upstream of the air coolers (EA62 A/B) to protect the overhead system from corrosion.

A portion of the column (C62) bottom liquid is heated in the reboiler (E70) by hot oil and reintroduced into the column below the 1st tray. The other portion (residue), constituting stabilized naphtha, is sent to the naphtha splitting column under the bottom level control of column (C62) by regulator (LIC2251) operating in cascade with flow regulator (FIC2254) on valve (FV2254).

I.B.1.5 Naphtha Splitter (Separation of Naphtha Cut A)

The stabilized naphtha from the two stabilization columns (C5 and C62) is sent to the separation column (C63) under flow control by regulators (FIC 54 and FIC2254), which operate in cascade with level regulators (LIC20 and LIC 2251) to maintain constant levels at the

bottoms of columns (C5) and (C62) respectively. Column (C63) has 36 trays and operates at an absolute pressure of 2.0 kg/cm². The overhead vapors of column (C63), at 57°C, are partially condensed in air coolers (EA63 A-F) and condensers (E78 A-H) to 40°C, then sent to the reflux drum (V67).

The vapor phase (light hydrocarbons) from the reflux drum (V67) is sent to the flare under pressure control in the reflux drum (V67) by regulator (PIC2372) acting on valve (PV2372). A part of the liquid phase is sent by pump (P29 A/B) as reflux to column (C63) under flow control by regulator (FIC2356); the other part, constituting the distillate (naphtha A), is sent by pump (P87 A/B) to storage under flow control by regulator (FIC2353) in cascade with level regulator (LIC2352).

A part of the column bottoms product is heated in reboilers (E75 A/B) by hot oil circulating in the tube side and reintroduced into the column below the 1st tray. The other part, constituting the residue of the column (naphtha B+C), is sent by pump (P65 A/B) to separation column (C61) and to the C6 cut separation column (C6) with flow rates controlled by regulators (FIC2351 and FIC2352) acting on valves (FV2351 and FV2352).

I.B.1.6 Separation of C6 Cut

A portion of the residue from the separation column (C63), consisting of the naphtha (B+C) mixture, is sent to the C6 cut separation column (C6), which mainly separates paraffinic C6 compounds. Column (C6) has 36 trays and operates at an absolute pressure of 2 kg/cm². The feed is introduced at the 13th tray.

The overhead vapors, at 88°C, are partially condensed in the air cooler (EA3) to 73°C and sent to the reflux drum (V9). The vapor phase from the reflux drum (V9) is sent to the flare under control by regulator (PIC22) operating in split range on valve (PV22) and valve (PV22A) on the nitrogen line connected to the reflux drum (V9) for nitrogen supply in case of pressure drop.

A portion of the liquid phase is sent by pump (P84 A/B) as reflux to the column above the 36th tray under flow control by regulator (FIC56); the other part (distillate) is sent by pump (P88 A/B) to the isomerization unit under flow control by regulator (FIC2159) operating in cascade with the reflux drum level regulator (LIC24).

The column (C6) bottoms, at 140°C, are partially heated in the reboiler (E87) by hot oil circulating in the tube side and reintroduced into the column below the 1st tray at 147°C under temperature control by regulator (TIC2180) acting on valves (TV2180 A/B) on the return and

bypass lines of the hot oil. The other part (residue), constituting the naphtha C cut, is sent by pump (P85 A/B) to storage under flow control by regulator (FIC2155) operating in cascade with level regulator (LIC23) acting on valve (FV2155).

I.B.1.7 Separation of Naphtha Cut B

The new separation column (C61) was installed to separate naphtha B from naphtha C. The column has 36 trays and operates at an absolute pressure of 2.0 kg/cm². The feed is introduced at the 27th tray.

A portion of the residue from the naphtha A separation column (C63) is sent to column (C61). The overhead vapors, at a temperature of 140°C, are partially condensed in the air coolers (EA64 A-D) to a temperature of 102°C before being sent to the reflux drum (V63).
The vapor phase is sent to the flare under pressure control by the regulator (PIC2452) acting on valve (PV2452). Part of the liquid phase is sent by pump (P77 A/B) as reflux to the column above the 36th tray under flow control by the regulator (FIC2451). The other part, constituting the distillate (naphta B), is sent by pump (P5 A/B), after cooling in the air coolers (EA6 A/B) and the water condenser (E17) to a temperature of 38°C, to storage under flow control by the regulator (FIC57) operating in cascade with the level regulator (LIC2451).

The bottom liquid of column (C61), at a temperature of 204°C, is partially reheated in the reboilers (E73 A/B) by hot oil and reintroduced into the column below the 1st tray. The temperature at the reboiler outlet is controlled by the regulator (TIC2452) which acts on the hot oil flow valve.

The other part, constituting the residue of the column (naphtha C), is sent by pump (P86 A/B) to the exchanger (E9), then to the air coolers (EA7 A/B), and finally to the exchanger (E68 A/B) where it is cooled to a temperature of 38°C. The naphtha C cut is then mixed inline with the naphtha C cut from column (C61) and sent to storage. [3]

Chapter II: Distillation

II : Crude oil distillation

II.1 Historical background

Distillation is an ancient process dating back to 2000 B.C. The earliest distillations are believed to have occurred in China, Egypt, and Mesopotamia, primarily for medicinal purposes and the creation of balms, essences, and perfumes. Around 1810 B.C., the perfumery of King Zimrilim in Mesopotamia used distillation to produce hundreds of liters of balms, essences, and incense made from cedar, cypress, ginger, and myrrh each month.

These distillations were conducted to produce cosmetics, medicinal substances, and materials used for embalming the dead and performing spiritual rituals. Queen Cleopatra was skilled in the art of distillation and is believed to have written a report on the process, which has since been lost.

In the 1st century, the Greek physician Pedanius Dioscorides described the process after observing condensation on the lid of a vessel in which mercury had been heated. Historians suggest that the alembic was likely invented around 200 or 300 A.D. by Mary the Jewess or Zosimos of Panopolis, an Egyptian alchemist whose sister, the osebeia, designed many models of alembics and reflux condensers [4].

II.2 Definition

Distillation is the process of separating two or more components in a liquid mixture through selective boiling and condensation, or by exploiting their relative volatility within a distillation column. This process can lead to nearly complete separation, yielding almost pure components, or it can achieve partial separation to increase the concentration of specific components. In both scenarios, the process relies on differences in the relative volatility of the mixture's components.

In industrial settings, distillation is a physical separation technique. It is the most widely used separation technology in the process industry globally, accounting for up to approximately 50% of both operational and capital expenses. Additionally, distillation consumes about 50% of the total process energy utilized annually by the chemical and petroleum refining industries [5, 6, 7 8].

II.3 Distillation at Industrial Scale:

II.3.1 Atmospheric Distillation:

Atmospheric distillation is the primary method for processing crude oil. The crude is heated to about 350°C and distilled in a column that is 40 to 60 meters high. In this column, products are separated based on their boiling points under a pressure of 1 to 3 atmospheres. The lightest

products are collected at the top, while the heaviest products settle at the bottom. Heavy hydrocarbons remain liquid, while lighter and medium-weight molecules vaporize and rise in the column. As they ascend, they cool and condense back into liquid form, being collected at different stages on trays.

Each stage of the distillation column corresponds to an average temperature between the dew point (condensation) and the bubble point (vaporization) of the desired products. Figure 01 shows a simple diagram of an atmospheric distillation column. The pressure decreases from the bottom to the top of the column [9].

From the distillation column, the following are obtained:

- A top product (non-condensable gas, LPG, total gasoline).
- Three side cuts (kerosene, light gas oil, heavy gas oil).
- An atmospheric residue at the bottom.

Each lateral product from the main column has its own stripping column, where lighter components are removed. Stripping is done using low-pressure steam, superheated for light and heavy gas oil, and reboiling for kerosene.

II.3.2 Vacuum Distillation:

Vacuum distillation extracts cuts from the atmospheric residue at the bottom of the atmospheric distillation column. These distillates are fed into conversion units to produce high-value products. Vacuum distillation is used for fractionating products that would have too high a boiling point at atmospheric pressure, leading to thermal cracking. Its capacity is reduced by 50% to 70% compared to the atmospheric distillation unit that feeds it.

Several technologies are employed, depending on whether water vapor is used to lower the partial pressure of hydrocarbons:

- Dry Vacuum Distillation: Distillation without water vapor injection, operating at very low pressure (10 to 15 mm Hg at the top).
- Wet Vacuum Distillation: Distillation with water vapor injection into the furnace feed and stripping steam at the bottom. The total pressure is higher (40 to 60 mm Hg at the top).

An ejector (booster ejector) is often used upstream of the first top condenser to raise the process pressure enough for condensation. Bitumen production units fall into this category.

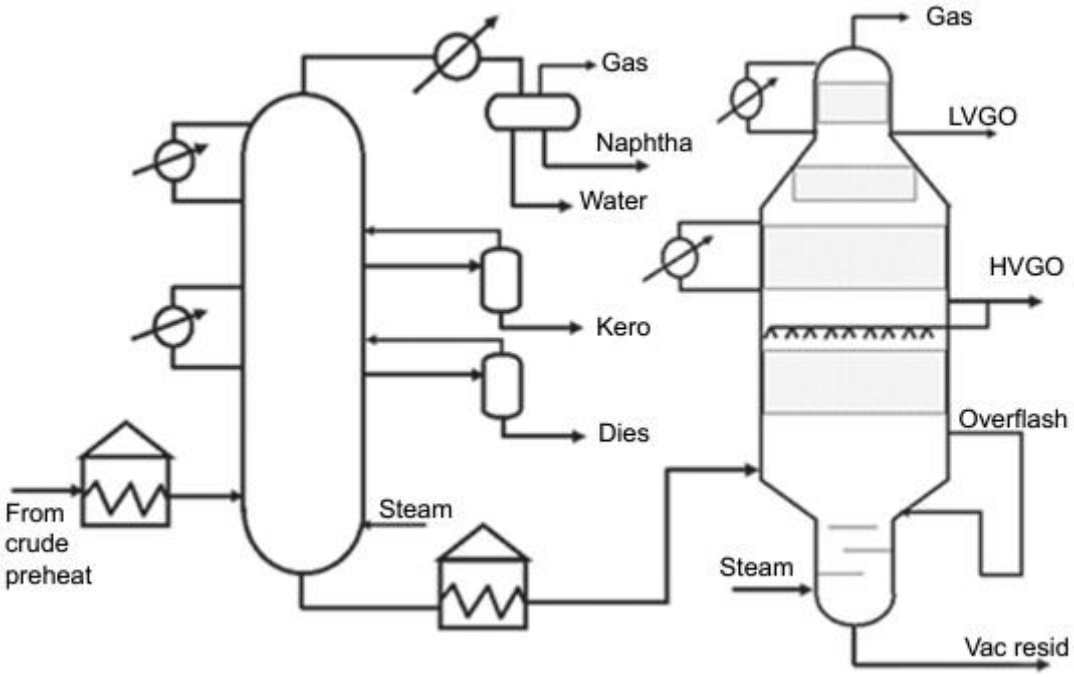


Figure II-1: Typical atmospheric and vacuum distillation configuration. [10]

II.4 Description of the Atmospheric Distillation Column

The atmospheric distillation column is a vertical cylindrical apparatus. Its height depends on the number of trays it contains and the spacing between them. These trays are ensuring effective contact between the descending liquid phase and the ascending vapor phase. [11]

The column consists of three sections:

- ✓ **Feed Section (Flash Section):**

This is where the heated feed, at 350°C, is injected. Separation into liquid and vapor phases occurs here. This section ensures proper phase separation and protects the walls from erosion. This section is located between the 5th and 6th tray [9].

- ✓ **Rectification Section:**

This section contains trays numbered between 42 and 46, where rectification occurs. It separates light products from gas to heavy diesel through stripping and side draws. [11]

- ✓ **Bottom Section:**

Located at the lower part of the column, this section includes about 5 trays. It produces atmospheric residue, used as feedstock for vacuum distillation.

Superheated low-pressure steam is injected to remove the remaining volatile components in the residue. [9]

To ensure optimal operation and improve product quality, the following methods are used:

- **Stripping**:

Withdrawn products, whether from the column bottom or laterally, often require correction. To limit light hydrocarbon content, superheated steam at 400°C and low pressure is injected.

Reflux:

- Temperature control in different parts of the column is achieved through:

  - ✓ Top Reflux: Injected at the column's top, these are condensed top vapors, helping regulate the top temperature.
  - ✓ Hot Reflux: Injected at the column's bottom after heating by the reboiler to increase residue temperature and evaporate volatile components.
  - ✓ Intermediate and Internal Circulating Reflux Used to control temperatures at lateral withdrawal trays.

Table II-1: Temperature ranges of petroleum fractions [12]

Fraction	LPG	Naphtha A	Naphtha B	Naphtha C	Kerosene	Light gasoil	Heavy gasoil	Residue
Range(°C)	<28	28-65	65-150	150-180	180-225	225-360	320-380	>380

II.5 Phsico-chemical characteristics of petroleum fractions

II.5.1 Liquefied petroleum gas LPG:

II.5.1.1 Definition:

LPG is a mixture of paraffinic hydrocarbons mostly propane and butane. It is used as fuel and stored and handled in liquid form under pressure. Its main qualities, in terms of workplace safety and health, are its low vapor pressure and low contaminant content.

II.5.1.2 Physicochemical Characteristics:

- **Vapor Pressure**

The vapor pressure of commercial propane ranges from 11.5 to 19.3 bars at 50°C, while commercial butane has a vapor pressure of 6.9 bars or less at 50°C. Vapor pressure limits are necessary for safety in storage and transport, as the test pressures of the containers are based on the authorized vapor pressures.

- **Sulfur Content**

The sulfur compounds, such as H_2S and mercaptans, must pass a satisfactory Doctor test. Odorous mercaptans should not be completely removed as they help detect potential leaks in the installation. Limiting sulfur compounds is necessary because they are corrosive to metal containers and piping. [9]

- **Water Content**

Commercial propane and butane must not contain any traces of water, especially propane. The presence of water can cause ice formation during the rapid temperature drop when liquid propane expands, leading to blockages.

- **Heavy Element Content**

This is determined by the evaporation test of liquefied gas in an open test tube. Commercial butane should leave less than 5% liquid residue when the temperature reaches 1°C, and commercial propane should not exceed 2%. This limitation ensures complete consumption of the liquefied gas from the bottle. [9]

II.5.2 Automotive Gasoline:

II.5.2.1 Definition:

Gasoline is a fuel for spark-ignition automotive engines. It is a mixture of hydrocarbon fractions with relatively low boiling points, including reformate, alkylate, aliphatic naphtha (light naphtha obtained by direct distillation), aromatic naphtha (naphtha obtained by thermal and catalytic cracking), and additives.

II.5.2.2 Physicochemical Characteristics:

- **Density**

Density alone cannot characterize gasoline quality. It indicates power and consumption. Users should prefer the densest fuel compatible with other specifications, as it offers the best LCV and lowest consumption. Density is 0.780 for unleaded premium gasoline. [6]

- **Reid Vapor Pressure**

The maximum allowable Reid vapor pressure is 800 g/cm2 in winter and 650 g/cm2 in summer. Volatile elements aid cold starts in winter but may cause carburetor icing during engine warm-up due to atmospheric humidity. This issue is mitigated by limiting RVP and

adding antifreeze additives. In summer, too high a proportion of light hydrocarbons can cause engine stalling due to vapor lock. Vapor pressure also affects storage and handling losses. [9]

- **Distillation**

The distillation curve represents the volume fraction distilled at atmospheric pressure as a function of temperature in appropriate apparatus (NF M 07-002). This characteristic indicates the fuel's behavior in terms of carburetion. [6]

- 10% distilled before 70ºC indicates ease of cold start.

- 50% distilled before 140ºC indicates smooth acceleration and rapid evaporation.

- 90% distilled before 195ºC indicates a low content of heavy hydrocarbons, which are harmful to the engine and reduce coke formation, enhancing engine longevity.

Octane Rating

This is the crucial characteristic for gasoline used in spark-ignition engines, often referred to as explosion engines. It determines combustion quality and optimal use conditions, closely linked to efficiency. It is measured in the lab using a CFR engine, compared to a reference scale based on heptane (octane number 0) and isooctane (octane number 100). [9]

Two methods exist:

- Research Method (RON): engine runs at 600 rpm.

- Motor Method (MON): engine runs at 900 rpm.

The difference between RON and MON is the fuel's sensitivity.

II.5.3 Kerosene:

II.5.3.1 Definition:

Kerosene is a mixture of hydrocarbons, mainly paraffins, ranging from $C_{10}H_{22}$ to $C_{14}H_{30}$. It is produced through the refining of petroleum and obtained by drawing off a fraction during distillation with an initial boiling point (IBP) between 150°C and 180°C, and a final boiling point (FBP) between 225°C and 250°C. Kerosene is used primarily for jet aircraft and in general aviation. It is classified into:

- TR0 (165°C – 240°C): used in commercial aviation.

- TR4 (55°C – 240°C): used in military aviation.

- TR5 (high flash point with an average density of 0.81): used on aircraft carriers.

II.5.3.2 Physico-chemical characteristics:

- **Density:**

Density directly affects the aircraft's range. Using high-density jet fuels maximizes energy within a given volume (the fuel tanks) and reduces the weight and volume of the engines. The typical density is around 0.800 [6].

- **Distillation:**

The fuel must vaporize quickly and mix well with air. [6]

- The 10% distillation point must be reached before 204°C.

- The final boiling point must be below 300°C.

- **Viscosity:**

Viscosity impacts the quality of spray and penetration of the jet. It should be less than 8 mm^2/s at -20°C. [3]

- **Smoke point:**

The smoke point is the maximum flame height without smoke formation in a standardized wick lamp (NF M 07-028). Typical values range from 10 to 40 mm, with a minimum specification of 25 mm. The smoke point is linked to the fuel's chemical structure; it is higher with linear paraffins, lower with branched paraffins, and much lower with naphthenes and aromatics. [13]

- **Calorific value:**

This is a fundamental characteristic of jet fuel, determining the aircraft's range. It is related to density; as density increases, the mass lower calorific value (LCV) increases, but the volumetric LCV decreases. [9]

- **Freezing point:**

The freezing point is set at -40°C for TR0 and -60°C for TR4, ensuring fuel pumpability at high altitudes, where temperatures can reach -50 to -55°C. The freezing point is closely related to the final boiling point of distillation. The presence of water, even in small amounts, complicates meeting this specification, so the jet fuel must be water-free. [9]

II.5.4 Diesel Fuel:

II.5.4.1 Definition:

Is a mixture of hydrocarbons paraffinic naphthenic and aromatics, ranging from C_{14} to C_{25} with boiling temperatures (250-385°C).

II.5.4.2 Physicochemical Characteristics:

- **Density**

Density must be between 0.820 kg/l and 0.860 kg/l. A minimum density ensures sufficient engine power via a volume-regulated injection pump. [6]

- **ASTM Distillation Curve**

Specifications concern only the heavy fractions of diesel: less than 65% distilled at 250°C and more than 85% at 350°C. Diesel has a PI around 220°C. The 50% point on the distillation curve represents average properties: volatility, viscosity, freezing point. The 85% point below 350°C limits heavy product content, easily achieved at the distillation unit. The flash point must be between 55 and 120°C. [9]

- **Viscosity**

Below 9 cSt at 20°C, viscosity affects flow and spray quality, influencing combustion. Viscosity should be below 12 cSt and must not exceed 40 cSt at the injector holes for proper atomization. [9]

- **Cloud Point**

Typically, between 0 and -10°C, determined visually (NF T 07-105), it is the temperature at which paraffin crystals, normally dissolved, begin to separate and affect product clarity. [6]

- **Pour Point**

At lower temperatures, crystals increase in size, forming networks that trap the liquid, preventing flow. Pour points range from -15 to -30°C.

- **Plugging Point**

The minimum temperature at which a specific volume of diesel passes through a filter in a limited time. For standard diesel, it is between -15 and -25°C, but for very cold climates, it ranges from -20 to -45°C. [6]

- **Cetane Index**

Comparable to gasoline's octane rating, it measures the fuel's ability to ignite quickly. Measured using a CFR Diesel engine, it compares the ignition delay of the test fuel to a reference mixture of alpha-methylnaphthalene (index 0) and n-cetane (index 100).

II.5.5 Bitumen:

II.5.5.1 Definition:

Petroleum bitumen is the heaviest fraction from crude oil, obtained by high vacuum distillation. Used for road surfacing. [9]

II.5.5.2 Physicochemical Characteristics:

- **Penetration**

Depth in tenths of a millimeter that a standard steel needle penetrates bitumen at 25°C under a 100 g load for 5 seconds, related to viscosity. [6]

- **Density**

Measured with a pycnometer at 25°C, typically slightly above 1.

- **Solubility**

Defines bitumen content as the part soluble in carbon disulfide (or other specified solvents).

- **Volatility**

Characterized by loss of mass on heating or flash point for fluidized bitumens.

II.6 Key Factors Affecting the Fractionation Quality:

There are several parameters that significantly impact the quality of distillate separation. [10] Here's a summary:

II.6.1 Liquid to Vapor Ratio or Reflux Ratio

Among these parameters, the reflux ratio (L/V ratio) stands out as the most influential factor on separation efficiency. To understand its significance, let's revisit the fundamental principles of a distillation column: hot vapor, generated in the heater, ascends the column and undergoes cooling through colder reflux (see Figure 2). The operation of a distillation column hinges on the exchange of heat and mass between hot vapor and colder reflux. This exchange leads to the condensation of less volatile components from the vapor phase and the vaporization of more volatile components from the liquid phase. The degree of heat and mass transfer is heavily influenced by the Liquid to Vapor Ratio (L/V ratio) at each section of the column.

Modern process simulations provide invaluable insights into these ratios, particularly in complex fractionators like crude units.

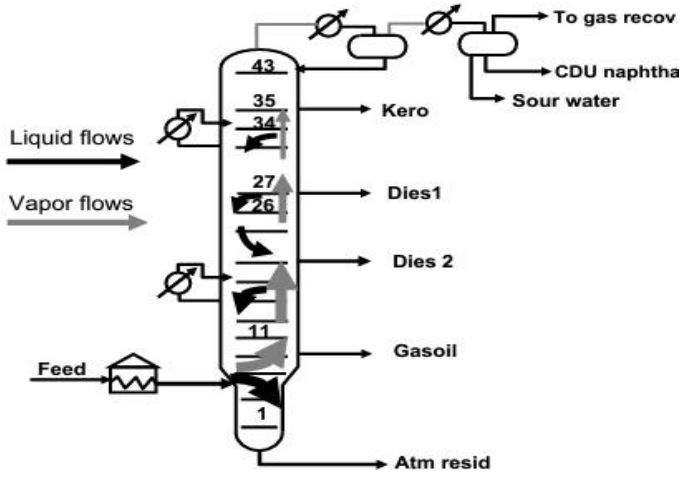


Figure II-2: Vapor/liquid flows in crude unit. [10]

II.6.2 Operating Pressure

Operating pressure plays a role in separation efficiency, albeit modestly, as it affects relative volatility. However, the flexibility to adjust operating pressure is often limited, as it's largely determined by condensing temperatures. Lower pressures enhance separation but may require adjustments for specific product condensation.

II.6.3 Heater Operating Temperature

Heater temperature is pivotal in crude and vacuum units, impacting vaporization rates and distillate recovery, especially in zones like the wash zone where maximizing L/V ratio is critical. Side distillate cuts' number and width significantly influence separation efficiency, with narrower cuts posing greater challenges. Minimizing side draws and overlaps between distillates is key for optimal fractionation.

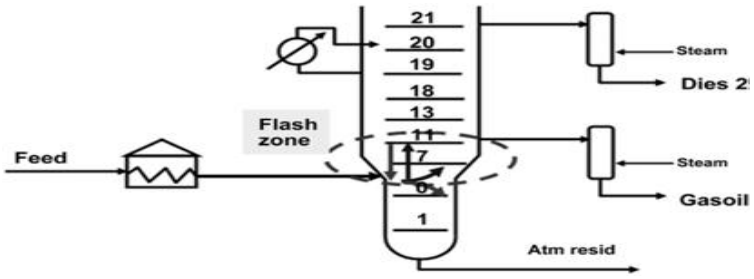


Figure II-3: Liquid from trays 7 in crude over flash. [10]

II.6.4 Cut Widths of Side Distillates

The number and the cut width of side distillates have a significant impact on the separation efficiency. Narrow cuts are more difficult to separate from wider cuts and, when possible, the number of side distillates should be minimized to achieve the best possible separation. If we consider the example shown in Figure 4, crude unit A has four side distillate draws, but some of these are blended outside the column. Crude unit B has only two side distillate draws. From a fractionation viewpoint, crude unit B is a better design, and this flow scheme will allow easier separation and a higher distillate yield for whatever product specifications are set. For example, if the most valuable product is kerosene, then the yield achievable for crude unit B could be typically 5% higher than that of crude unit

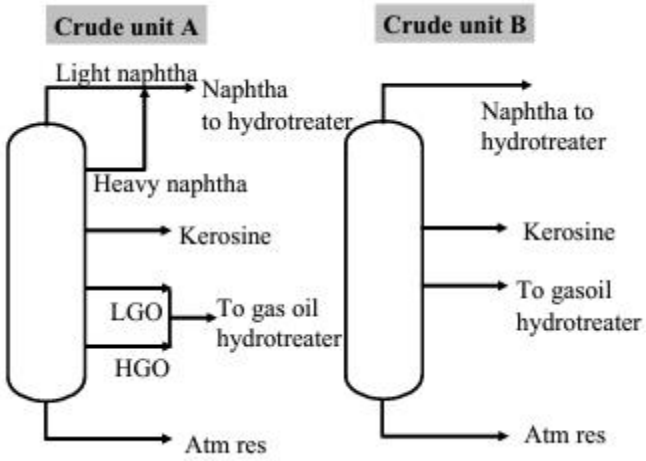


Figure II-4: Impact of cut widths on fractionation quality. [10]

II.6.5 Stripping Steam Ratio

Increasing heater temperature and stripping steam ratio reduces the vacuum residue rate.

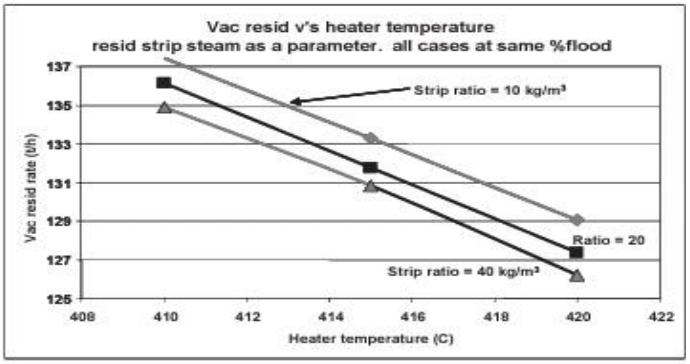


Figure II-5: Impact of heater temperatures and stripping steam on distillate yield. [10]

II.6.6 Efficiency of Column Internals

The efficiency of column internals contributes to separation efficiency provided an adequate L/V ratio is maintained. Insufficient reflux, despite a high number of theoretical stages, results in poor fractionation.

II.7 Crude oil cuts characterization

Crude oil contains thousands of pure components, and therefore it is not possible to characterize these by pure component speciation. Crude oil laboratory distillations or assays are used to characterize the raw crude. These are shortcut batch distillations carried out under laboratory conditions using standardized equipment and processes (e.g. ASTM D2892, ASTM D86 …).

- **TBP or ASTM D2892**

This method involves distillation applied to crude oil to determine its composition in fractions, using 15 to 18 theoretical plates and a reflux ratio of 5. The boiling temperatures are plotted or tabulated against the distilled volume (Figure 5). [14]

- **ASTM D86**

This distillation method is used to characterize petroleum fractions such as gasoline and kerosene (Figure 6).

- **ASTM D1160**

This method involves the analytical distillation of heavy petroleum fractions that cannot be processed using ASTM D86. [13]

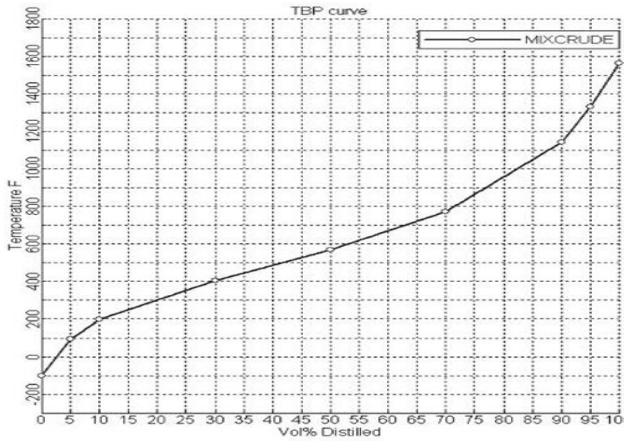


Figure II-6: TBP curve of crude oil. [14]

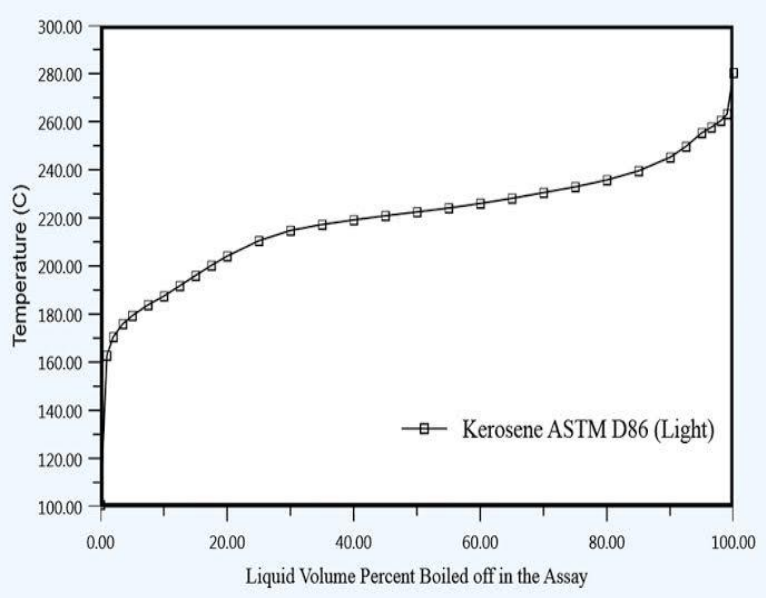


Figure II-7ASTMD86 curve of kerosene. [14]

The conversion of TBP data to ASTM D86 for crude oil is done using Riazi equation [9], which is:

$$T' = aT^b \quad \textbf{II.1}$$

Here, T': is the TBP test temperature, T: is the ASTM D86 test temperature, a and b are coefficients dependent on the distilled fraction, presented in Table

Table II-2: Conversion TBP to ASTM. [14]

% Volume Distilled	Coefficient a	Coefficient b
0	0,9177	1,0019
10	0,5564	1,0900
30	0,7617	1,0425
50	0,9013	1,0176
70	0,8821	1,0226
90	0,9552	1,0110
95	0,8177	1,0355

II.7.1 Characterization factor KUOP

To classify crude oils based on the dominance of a particular chemical family, a characterization factor is used [10], expressed as follows

$$KUOP = \frac{\sqrt[3]{Tb}}{SP.gr60/60} \quad \textbf{II.2}$$

- Tb Boiling temperature (°R).
- $SP.gr60/60$ specific gravity

With $$SP.gr60/60 = \frac{d15}{0.99904} \quad \textbf{II.3}$$

For each KUOP value, there is a corresponding description of the respective crude oil nature. This summary is summary in table

Table II-3: Values of KUOP and crude oil type.

	KUOP=13	KUOP=12	KUOP=11	KUOP=10
Type of crude	Normal and iso-paraffins	Mixed hydrocarbons	Aromatics and naphthenics	Pure aromatics

- **Weighted Average Boiling Temperature**

This temperature is defined by the temperatures at which 10%, 20%, 50%, 80%, or 90% of the product is distilled, replacing the boiling temperature of a pure substance.[14]

⇨ For crude oil from TBP

$$T = \frac{T_{20} + T_{50} + T_{80}}{3} \quad \textbf{II.4}$$

⇨ For the petroleum cut from its ASTMD86 distillation curve

$$T = \frac{T_{10} + 2T_{50} + T_{90}}{4} \quad \textbf{II.5}$$

T is Average Boiling Temperature (°C).

T_{10} temperature at boiling 10% of total volume(°C).

T_{20} temperature at boiling 20% of total volume(°C).

T_{50} temperature at boiling 50% of total volume(°C).

T_{80} temperature at boiling 80% of total volume(°C).

T_{90} temperature at boiling 90% of total volume(°C).

II.8 Distillate Overlaps and Separation Quality

The quality of separation in fractional distillation is determined using the designated cut points at 5% volume (vol) and 95% vol for two adjacent fractions, referred to as light and heavy fractions. This evaluation is based on the temperature difference (ΔT) between the 5% vol temperature of the heavy fraction and the 95% vol temperature of the light fraction. [10]

- Positive ΔT (ASTM Gap): Indicates good separation between the fractions. A positive ΔT, termed as the ASTM gap, means that the temperature at 5% vol of the heavy fraction is higher than the temperature at 95% vol of the light fraction.

- Negative ΔT (ASTM Overlap): Indicates poor separation between the fractions. A negative ΔT, termed as the ASTM overlap, occurs when the temperature at 5% vol of the heavy fraction is lower than the temperature at 95% vol of the light fraction.

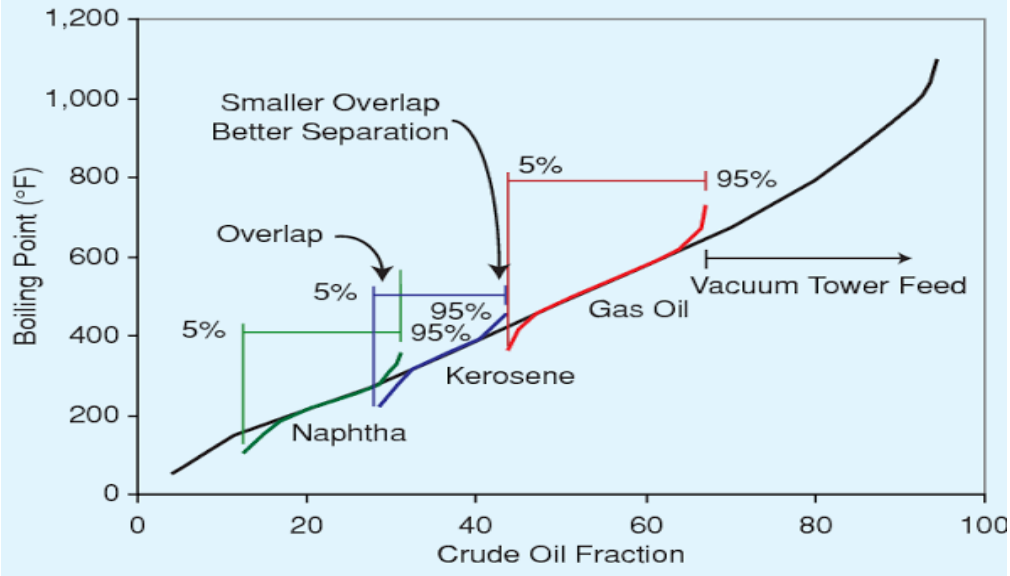


Figure II-8: Overlap description. [10]

Chapter III: Linear Alkyl Benzene production

III : Linear Alkyl Benzene production

III.1 Generalities:

Linear alkyl benzenes (LAB) are crucial organic compounds primarily utilized as intermediates in surfactant production for the detergent industry. The sustained demand for LAB globally is closely tied to the fast-moving consumer goods (FMCG) industry, with over 95% of LAB production allocated to detergent powders and liquids. This demand surge stems from population growth across various industrial sectors. Kerosene, a crude oil derivative, plays a vital role in LAB production. Raw kerosene undergoes distillation to remove light and heavy ends, yielding the desired normal paraffin for LAB production. Conversely, the escalating trend in energy consumption underscores the importance of energy management and the development of industries toward environmentally sustainable processes to reduce energy costs and enhance production benefits. [15]

III.2 Historical Background:

Before the 1940s, natural soaps, derived from alkaline saponification of triglycerides sourced from plants or animals, dominated the cleansing market. However, with the emergence of sodium alkyl benzene sulfonates in the 1940s, synthetic surfactants surpassed natural soaps due to their superior detergency properties, cost-effectiveness, and versatility. These synthetic surfactants quickly replaced natural soaps in household laundry and dishwashing applications, marking a significant shift in the detergent industry.

The discovery of synthetic alkyl benzene sulfonates laid the foundation for this industry. Initially, alkyl benzene sulfonates were synthesized through the Friedel–Crafts alkylation of benzene with propylene tetramer, resulting in highly branched alkyl benzene sulfonates derived from the tetramer's mixture of C_{12} olefins. These branched detergents were effective but exhibited slow rates of biodegradation, contributing to environmental pollution by forming stable foams in lakes and streams.

In the early 1960s, linear alkyl benzene sulfonates were introduced as a solution to this environmental concern due to their superior biodegradability. This innovation led to the gradual replacement of branched dodecylbenzene sulfonates with linear alkyl benzene sulfonates. By the late 1960s, this transition was evident in the United States, Japan, and many European countries, with linear alkyl benzene sulfonates becoming the preferred choice.

By the late 1970s, the production capacity of linear alkyl benzene sulfonates experienced rapid growth worldwide, with manufacturing facilities established across various regions, further solidifying their position as the primary synthetic surfactant in the detergent industry. [16]

III.3 Commercial and World Production

The raw materials that are available can determine the capacity of production of linear alkyl benzene. In 2013 the demand for the production of alkyl benzene increased about 5% from the previous year in Asia and Middle East. The demand and consummation in Asia, Middle East and North Africa was about 5.4 million tons per year [3]. The capacity to produce alkyl benzene of different companies around the world per year is mention in table (1):

Table III-1: LAB plants Capacity of different plants around the world. [17]

Company	Location	Capacity (tons/year)
Lukoil Neftochim Burgas	Bulgaria	50,000
Emalab	Dubai	30,000
Ameriya Petroleum Refining	Egypt	50,00
Formosan Union Chemical	Taiwan	90,000
CEPSA Quimica	Spain	220,000
Sasol	US	125,000

The capacity of LAB is different from one region to another where the half of LAB capacity is located in the region of Asia Pacific and East Europe while Africa and Latin America counts the least between these regions. The first technology installed in Saudi Arabia to produce linear alkyl benzene was in 2002 using UOP Detal technology by Farabi Petrochemical company. The capacity of linear alkyl benzene is about 70,000 million tons per year. [18], In bellow figure, it shows the capacity of LAB for every region:

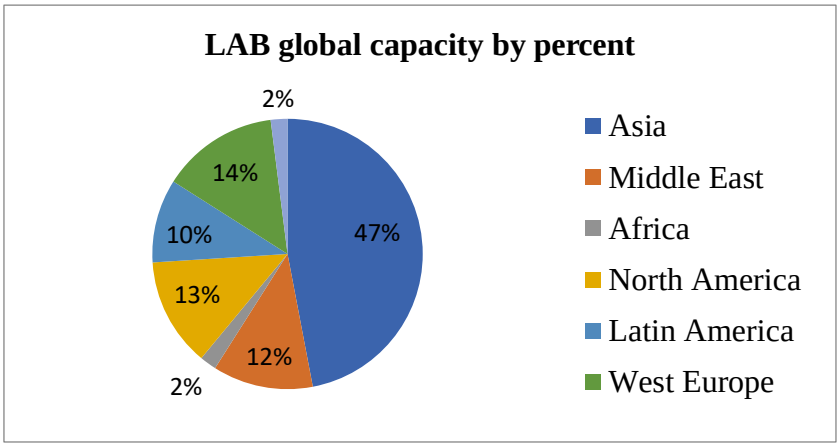


Figure III-1: Linear alkyl benzene global capacity by percent. [19]

III.4 Linear alkyl benzene definition

Linear alkyl benzene (LAB) is a group of organic compounds with the formula $C_6H_5C_nH_{2n+1}$, where n typically ranges from 10 to 16. However, for detergent applications, LAB is usually supplied in narrower cuts, such as C_{12}-C_{15}, C_{12}-C_{13}, and C_{10}-C_{13}.[20,21]

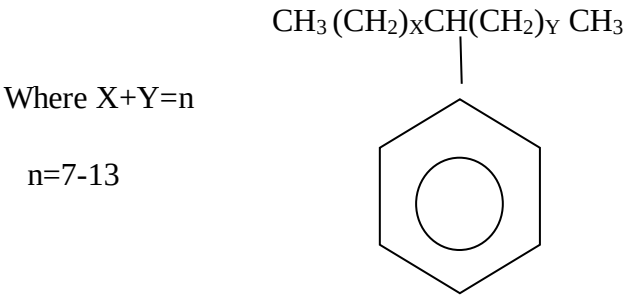


Figure III-2: Chemical structure of linear alkyl benzene (LAB). [22]

III.5 Various applications of linear alkyl benzene:

Linear Alkylbenzene (LAB) is a versatile chemical compound with a variety of applications, particularly in the production of detergents, lubricants, and agricultural chemicals, as well as in polymer manufacturing. Here's a detailed look at its uses and properties. [23]:

III.5.1 Detergents:

LAB is a key ingredient in the production of Linear Alkylbenzene Sulfonate (LAS), which is one of the most common surfactants used in household and industrial detergents. LAB-based detergents are known for their excellent cleaning properties, biodegradability, and cost-effectiveness. These detergents effectively remove dirt and grease, making them ideal for use in households, hotels, and other institutions.

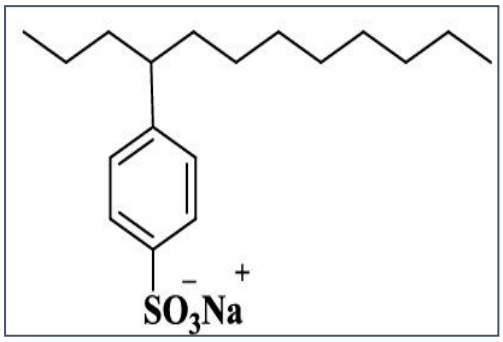


Figure III-3:: Structural formula of linear alkyl benzene sulfonate. [24]

III.5.2 Lubricants:

LAB serves as a fundamental component in the manufacturing of high-quality lubricants. These lubricants benefit from LAB's outstanding thermal stability and its ability to withstand high temperatures and pressures, making them suitable for various industrial applications where these conditions are prevalent.

III.5.3 Agricultural Chemicals:

LAB acts as a highly effective solvent for herbicides and insecticides. Its unique properties facilitate the efficient application of these agricultural chemicals onto crops, ensuring proper absorption and maximum effectiveness. This helps in protecting crops from pests and weeds, thereby enhancing agricultural productivity.

III.5.4 Polymers:

LAB is also crucial as a co-monomer in the production of certain polymers. It contributes to the development of polymers with specific desirable properties, although the exact types of polymers were not specified in the provided text. Generally, LAB can be involved in creating polymers used in various industrial applications due to its chemical stability and effectiveness. It is an essential co-monomer in the production of key polymers like styrene-butadiene rubber (SBR) and acrylonitrile-butadiene-styrene (ABS). These polymers are widely used in industries such as automotive, construction, and consumer goods. Additionally, it is utilized in the manufacture of various products, including drilling fluids, printing inks, and adhesives.

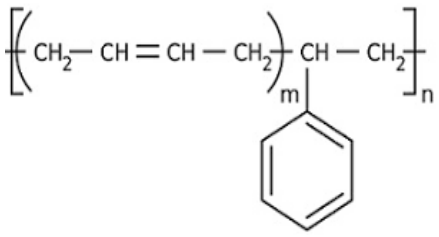


Figure III-4:: Structural formula of SBR. [25]

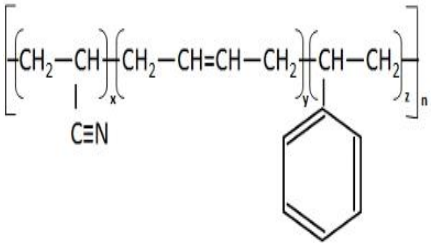


Figure III-5: Structural formula of ABS. [26]

III.6 Various types of LAB

There are several types of LAB summarized as follow [23]

Table III-2: Types of linear alkyl benzene

	Chemical formula
Dodecylbenzene	$C_{18}H_{30}$
Tetradecylbenzene	$C_{20}H_{34}$
Tridecyl benzene	$C_{19}H_{32}$
Decylbenzene	$C_{16}H_{26}$
Undecylbenzene	$C_{17}H_{28}$
Pentadecylbenzene	$C_{21}H_{36}$
Hexadecylbenzene	$C_{22}H_{38}$

III.7 Properties of linear alkyl benzene

The properties of linear alkyl benzene are summarized in the following table. [27]

Table III-3: LAB properties and compostion

Properties	Units	Limits
Appearance		(NOTE)

Odor		free of all offensive odors
sayoblt Color		Min +30
Ph-C $_{09}$	wt %	0-1 %
Ph-C $_{10}$	wt %	8-16 %
Ph-C $_{11}$	wt %	26-39 %
Ph-C $_{12}$	wt %	26-40 %
Ph-C $_{13}$	wt %	15-28 %
Ph-C $_{14}$	wt %	0-0.5 %
Linear Alkyl Benzene	wt %	Min 92
Non-Linear Alkyl Benzene	wt %	Max 8.0
2- Phenyl Alkanes	wt %	25-33
Paraffins	wt %	Max 0.40
Heavier Than C $_{14}$ LAB	wt %	Max 0.50
Molecular Weight	g/ mol	239-242
Refractive Index at 20 °C		1.4826
Doctor Test		Negative
Water	wt %	0.02
Bromine Index		< 5
Specific Gravity at 20 °C		855-870

- (NOTE) APPERANCE: clear, bright and visually free from solid matter.

- **Doctor Test**: this is a qualitative test for the presence of hydrogen sulfide, or mercaptans in gasoline, jet fuel, kerosene and similar petroleum products. [28]

- **Bromine index:** the bromine index measures the reactivity of a sample with bromine, expressed as the number of milligrams of bromine that can react with 100 mg of the sample. It is defined as one-thousandth of the bromine number. In alkyl benzene (LAB), bromine does not react with the benzene ring due to its high stability and resonance. Instead, it reacts with double bonds present in the alkyl side chain. Thus, the bromine

index reflects the number of double bonds in the linear alkyl chain. For LAB produced using solid and liquid catalysts, a bromine index of less than 5 is desirable, as it indicates fewer double bonds. The bromine index significantly affects the product's price. [29]

- **sayoblt Color:** The color of chemical compounds is influenced by the presence of chromophores, auxochromes, and resonance groups. In LAB, there are no chromophores or auxochromes, making resonance the primary factor affecting color. Increased double bonds in the alkyl chain enhance resonance, leading to a more colorful product. [29]

III.8 Environmental aspects of LAB production

In the petrochemical industry, the production of Linear Alkyl Benzene (LAB) poses significant environmental challenges. Benzene, a known carcinogen according to the World Health Organization, may be present in the company's wastewater systems, necessitating effective treatment of benzene derivatives. Traditional wastewater treatment methods are inadequate for effluents containing LAB, as these methods typically transfer pollutants from one phase to another without substantial degradation. Therefore, advanced oxidation processes, which utilize active hydroxyl radicals, are employed to effectively degrade these biodegradable effluents. [30, 31]

III.9 Proposed paths for linear alkyl benzene manufacturing:

There are four commercial paths:

a. Chlorination of n-paraffins to monochloroparaffins, then benzene alkylation with aluminum chloride (Friedel-Craft Alkylation).

b. Chlorination of n-paraffins to monochlorinated paraffins, followed by dechlorination to produce olefins and benzene alkylation (no longer used commercially). These processes have difficulties in control, produce many side products, and leave residual catalysts, resulting in lower LAB quality.

c. Dehydrogenation of n-paraffins to internal olefins, followed by benzene alkylation using HF catalyst (UOP/HF n-Paraffin Process). This method boasts efficient catalysts and high LAB quality but requires specialized equipment due to the handling and retrieval of HF, increasing costs and posing environmental risks due to HF waste.

d. Dehydrogenation of n-paraffins to internal olefins, followed by benzene alkylation using a fixed-bed reactor (DETAL). This process offers highly efficient catalysts and simplicity

compared to others. After comparing the characteristics of four alternative processes, the Detal process stands out as the most suitable choice. [28]

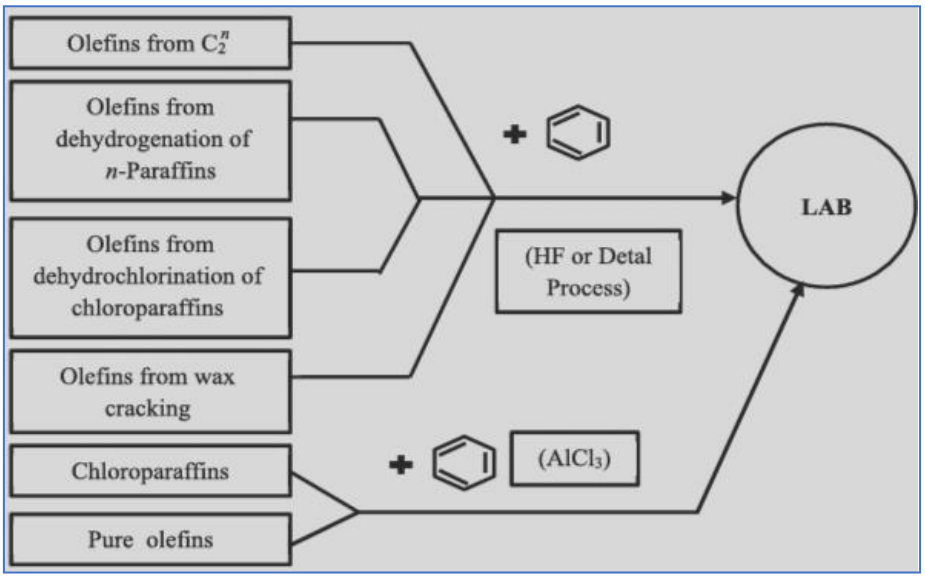


Figure III-6: Schematic of LAB production methods. [28]

III.10 Process Overview:

The process plant is divided into two main sections. These two sections contain process units [32]:

a) Front end

- Pre-fractionation (PF).
- Union fining (UF).
- Molecular extraction (MOLEX)

b) Back end

- Paraffin converted to olefin (Pacol).
- Pacol Enhancement Process (PEP).
- Define unit (di-olefine conversion to mono olefin).
- Detergent Alkylation (Detal).

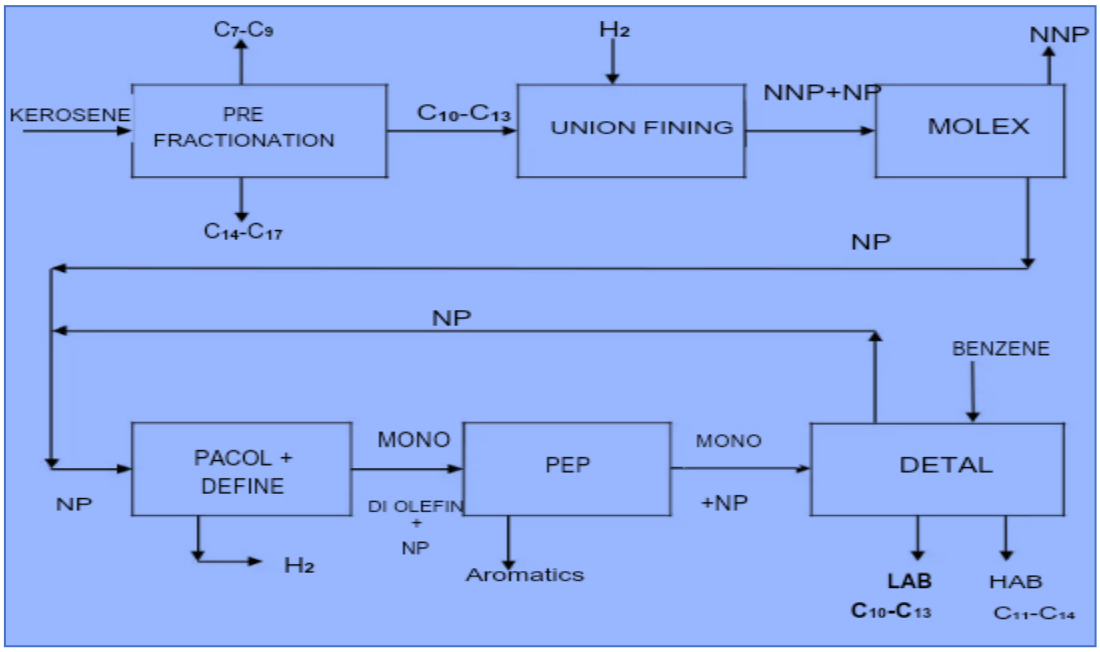


Figure III-7: Block diagram of process. [32]

III.11 Process description

III.11.1 Front end

III.11.1.1 Pre-fractionation (PF) unit

In LAB manufacturing, a specific feed is needed, for which Pre-fractionation is employed. The feed, straight run Kerosene, with a carbon range of C_7 to C_{17}, contains more nonlinear hydrocarbons than linear ones. The Pre-fractionation section consists of a stripper column and a rerun column. The desired LAB feed ranges from nC_{10} to nC_{13}. The stripper column removes lighter components up to C9, while the rerun column removes heavier components from C14 to C17. The product stream from the rerun column, termed "Heart-cut," includes the C10 - C13 carbon range alongside contaminants like organic sulfur, nitrogen, and metal compounds. [32]

Process Flow description

a. Kerosene Pre-heating and Stripping [33]**:**

- Kerosene from storage is pre-heated in two exchangers to 138°C before entering the stripper column.

- In the stripper column, lighter ends (C7-C9) are stripped off and removed from the top.

b. Handling Stripper Column Overhead

- Overhead vapors are cooled from 158°C to 77°C in a fin fan cooler after water wash to remove halide impurities.

- Condensed liquid in the receiver separates into water (sent to ETP) and kerosene.

- Non-condensable gases go to the flare header, while liquid streams are either refluxed back to the column or sent to storage tanks.

c. Rerun Column Processing:

- The bottom product from the stripper column, at 236°C, is fed the rerun column.

- The rerun column operates under vacuum, with heat supplied by a thermosiphon reboiler using hot oil.

- Overhead vapors (C10-C13) are condensed and split into three streams: hot reflux, cold reflux, and feed to the UF unit.

- Bottom products (C14-C17) are pumped to kerosene storage tanks.

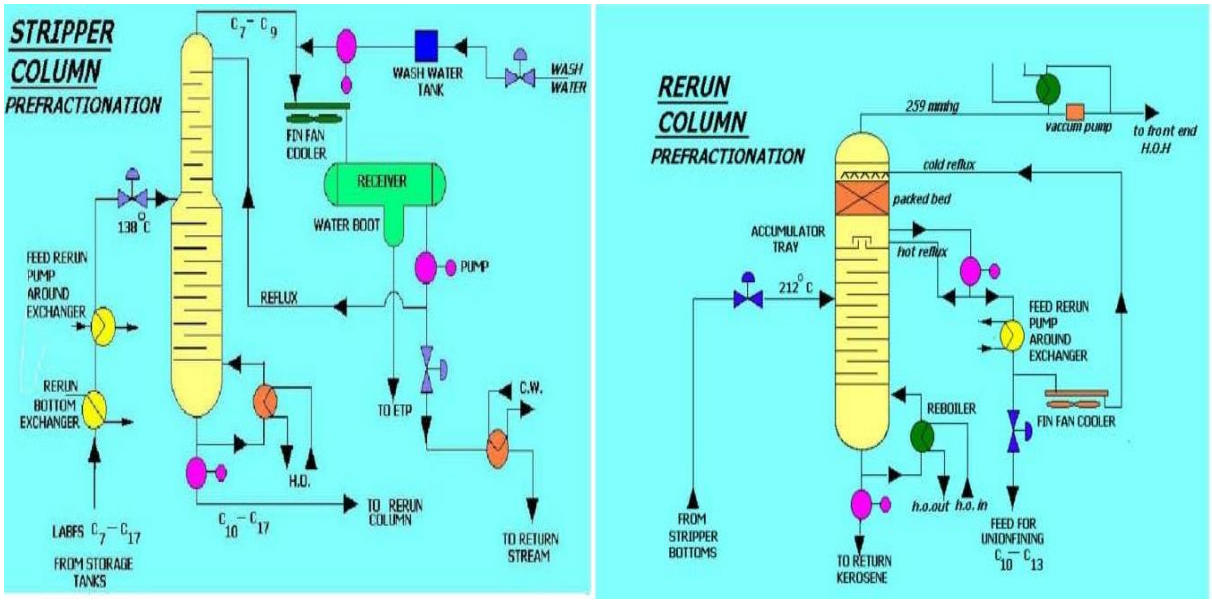


Figure III-8: Process flow diagram of Pre-fractionation unit. [32]

III.11.1.2 Union fining (UF) unit

- The Union fining process, developed by UOP, is a fixed-bed catalytic hydrotreating method designed to improve the quality of petroleum distillates. It removes contaminants such as sulfur, nitrogen, olefinic and aromatic compounds, and organometallic compounds.
- This process enhances the product quality with minimal impact on the feed's boiling range, reducing air pollution and equipment corrosion while facilitating further processing. [32]

Process flow description

- The feed and hydrogen are heated to 390°C in the furnace section before entering the reactor.
- This reaction occurs at high temperature and pressure with an excess of hydrogen.
- The reactor's bottom product, now free of these poisons, is cooled to 155°C in an exchanger and then sent to an air cooler with water and additional hydrogen, where it is further cooled to 50°C, allowing the recovery of water and hydrogen. After passing through two exchangers to reheat the hydrotreated feed to 180°C, it enters the stabilization section.
- In this section, unstable liquids and gases are removed in a stabilizer column: the overhead product is cooled in an air cooler and separated into gas and unstable liquid in a separator drum.
- The gases are directed to the hot oil system,
- The overhead liquid, consisting of n C4 to C7, is cooled to 40°C before being sent to the crude tank at the refinery.
- The column bottom at 268°C is cooled in an exchanger and directed to the next unit. [33]

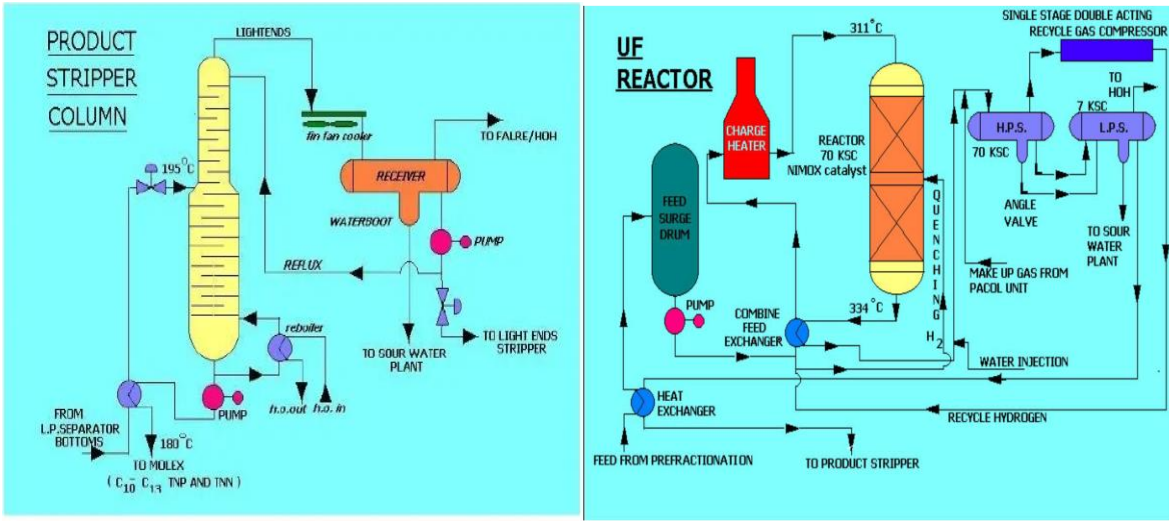


Figure III-9: Process flow diagram of Union fining unit [32]

III.11.1.3 Molex unit

The Molex processes utilize liquid-phase adsorption and desorption to separate normal paraffins from isoparaffins. The linear molecules of normal paraffins are fixed in the pores of the 5A adsorption support, while the branched isoparaffins cannot be fixed due to their branching dimension. This effectively separates the two types of paraffins. [33]

Process flow description

The feed supplies the adsorption chambers through the rotary valve that controls the inputs of the feed and desorbent into the first adsorption chamber and the outputs of raffinate and extract. The raffinate (rich in n-paraffins), containing the desorbent, exits the adsorption section and enters the raffinate column. In this column, the desorbent will be separated from the raffinate (at the top of the column) and recycled back to the adsorption chambers.

The extract will be separated from the desorbent in another column (extract column) and recycled back to the adsorption chambers. [33].

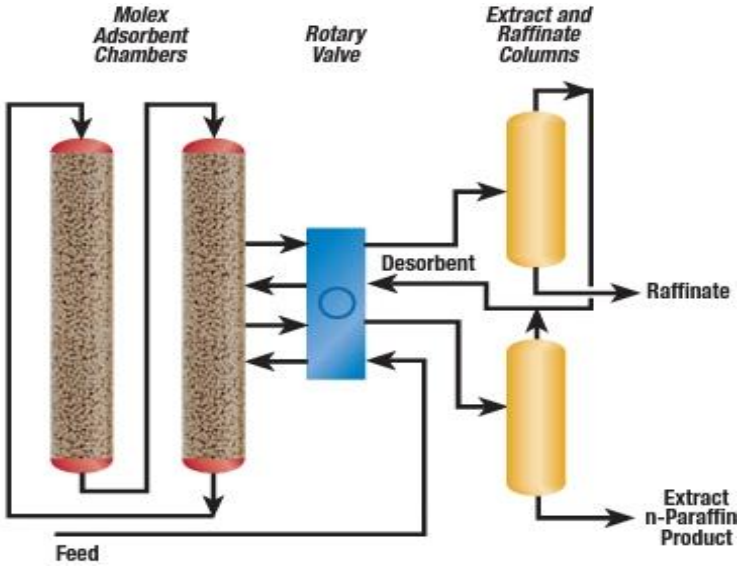


Figure III-10: UOP Molex unit. [34]

III.11.2 Back end

III.11.2.1 Pacol unit

- The primary reaction of Pacol unit is dehydrogenation of normal paraffin into mono-ole-fins, the desired product (Saturated to unsaturated).
- The dehydrogenation reaction of n-paraffin is an endothermic reaction.
- Pacol catalyst: The catalyst is a 1/16" spherical dehydrogenation catalyst of stabilized platinum on alumina base and it is non- regenerable. It is dark gray in color and is odorless. It is in the form of spheres. [32]

Process Flow and Description

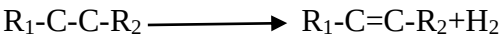
The feed of the Pacol unit is a mixture of n-paraffins from the Molex unit, recycled n- paraffins from the Detal unit, and n-paraffins from storage.

1. The feed, heated in a heat exchanger by the product of the Pacol reactor, then passes through the furnace before feeding the Pacol reactor, where the dehydrogenation reaction takes place on a heterogeneous platinum catalyst, in the vapor phase, at high temperature and low pressure.

2. The product is then cooled and sent to the separator, where the gas is separated from the liquid and pre-compressed in a compression section. This gas is rich in hydrogen and is used in the hydrotreatment unit and the Define unit. The bottom of the separator feeds the Define hydrogenation unit. [32]

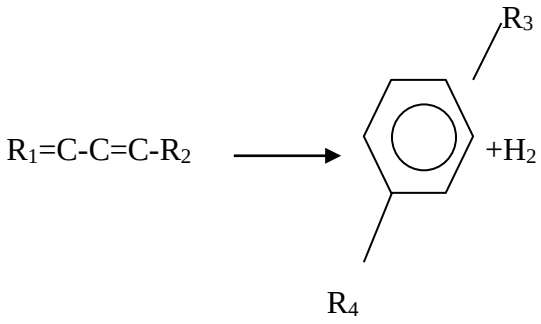
Hydrogenation reactions

a. Olefin formation (n-paraffin to mono olefin)



b. Diolefin formation (mono olefin to diolefin)

c. Aromatic formation



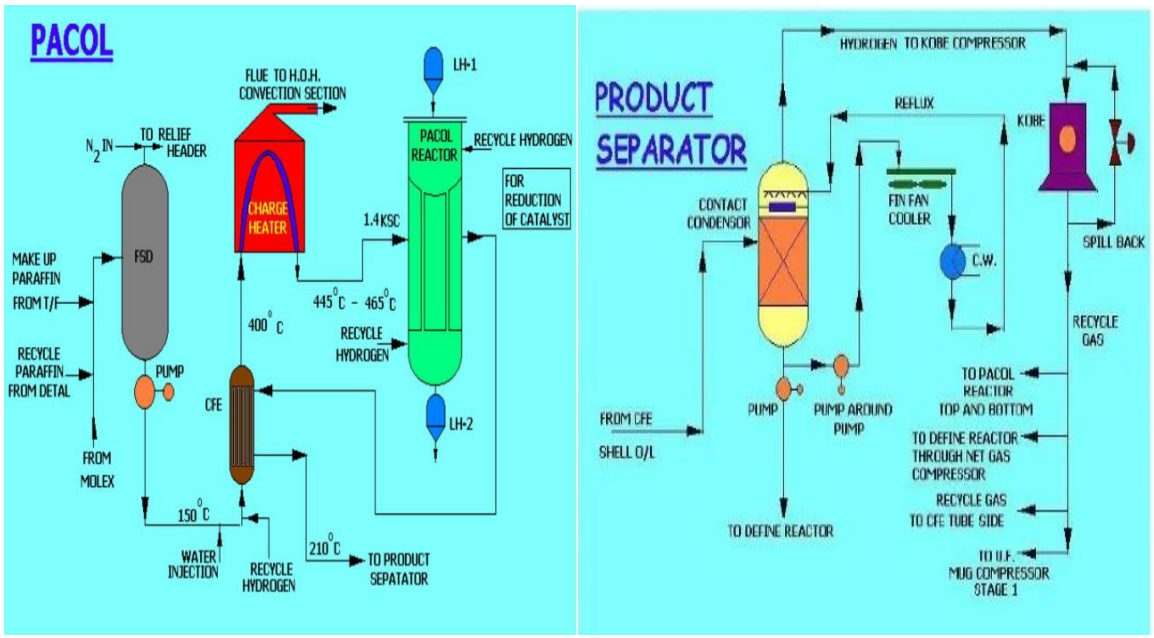


Figure III-11: Process flow diagram of Pacol unit [18].

III.11.2.2 Define unit

UOP introduced the Define unit to reduce by-products and safeguard the Detal unit. This unit enhances LAB production by selectively hydrogenating di-olefins into mono-olefins in a liquid phase at approximately 220°C. Within the Define unit, the liquid is blended with compressed hydrogen and heated to 180-210°C using nickel catalyst. The resulting effluent is directed to a stripper to separate gases and light liquid from the bottom product. [32]

Hydrogenation reactions

a) Diolefine to mono olefin

$$R_1\text{-}C\text{=}C\text{-}C\text{-}C\text{=}C\text{-}R_2 + H_2 \longrightarrow R_1\text{-}C\text{=}C\text{-}C\text{-}C\text{-}C\text{-}R_2$$

b) Mono olefin to paraffin

$$R_1\text{-}C\text{=}C\text{-}C\text{-}C\text{-}C\text{-}R_2 + H_2 \longrightarrow R_1\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}R_2$$

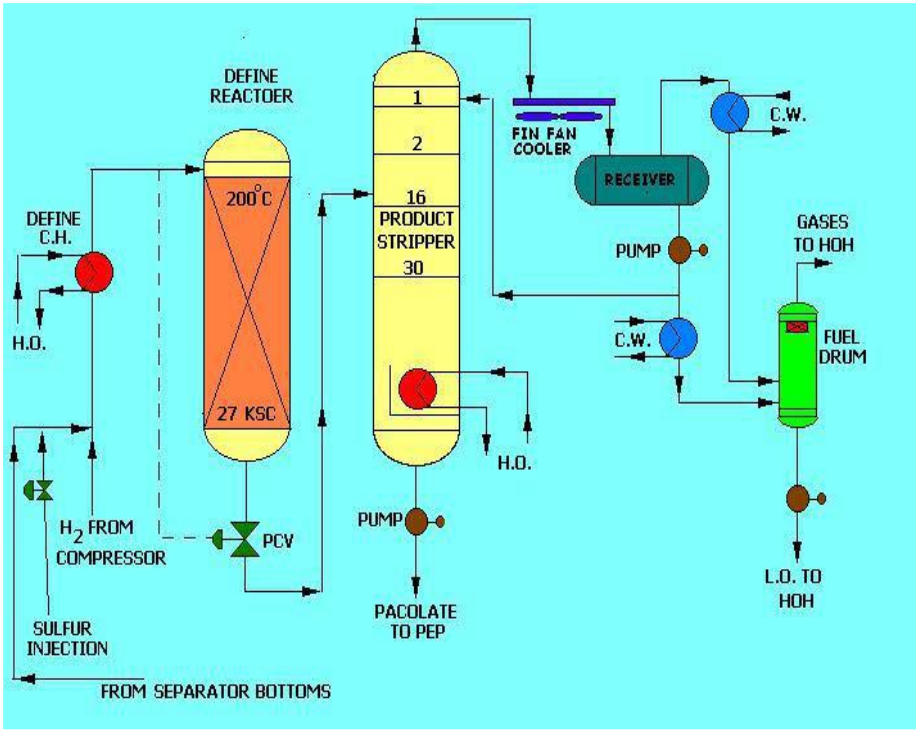


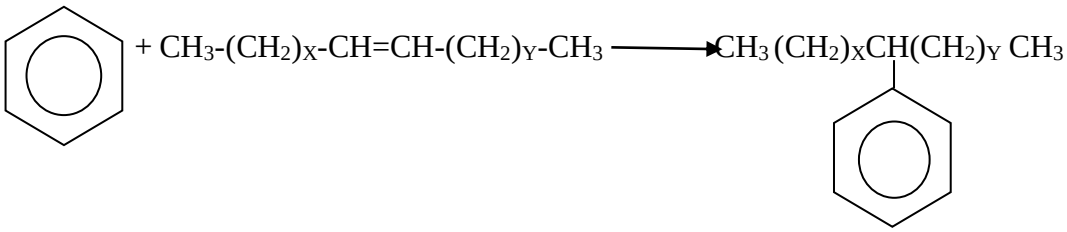
Figure III-12: Process flow diagram of Define unit. [32]

III.11.2.3 Pacol enhancement Unit

- The Pacol Enhancement Process (PEP) is designed to remove aromatic compounds from the C_{10} to C_{13} paraffins/olefin product from the process. The unit is typically designed to remove about 80% of the aromatics that are normally present in the Pacol product with minimum loss of Paraffins and olefins.
- Aromatics can deposit on the catalyst in the Detal unit and deactivate it. They can also attach to olefins, resulting in undesirable products. Additionally, they can be carried with paraffins, accumulate, and re-enter the Detal reactor. The adsorbent can be installed in multiple stages either in series or in parallel (parallel installation is preferable as it allows for bypassing a deactivated bed).
- The adsorbents can be molecular sieves of type 13 A, operating at 100°C or 200°C, under a pressure that keeps the phase liquid. Separation can occur in the vapor phase, but this requires a significantly higher temperature and results in lower efficiency compared to the liquid phase. [35]

III.11.2.4 Detergent Alkylation (Detal) unit:

- The Detal Process is a catalytic method for alkylation benzene with linear olefins, resulting in linear alkyl benzene (LAB) production. [29]



Process flow description

The process involves several key steps [32].:

a) **Feed Preparation**: The feed contains mostly olefins is mixed with excess benzene before entering the Detal reactors.

b) **Reaction in Detal Reactors:** Two identical Detal reactors, each with three catalyst beds, facilitate the alkylation process. The feed is divided into three equal streams, with each stream sequentially entering a catalyst bed along with recycled benzene. This split-feed, series-flow benzene scheme ensures efficient utilization of benzene without increasing utility costs.

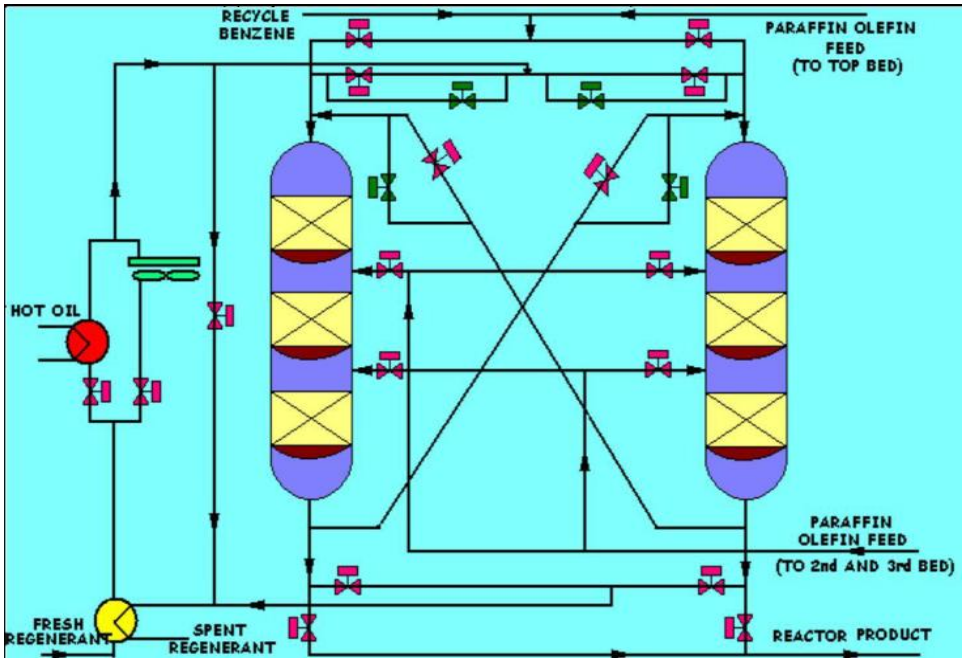


Figure III-13: DETAL reactors. [32].

c) **Benzene Column:** The reactor effluent, along with regenerant benzene, enters the benzene column. This column separates excess benzene, which is recycled to the reactors, from heavier hydrocarbons. The separated benzene is utilized as regenerant benzene for catalyst regeneration.

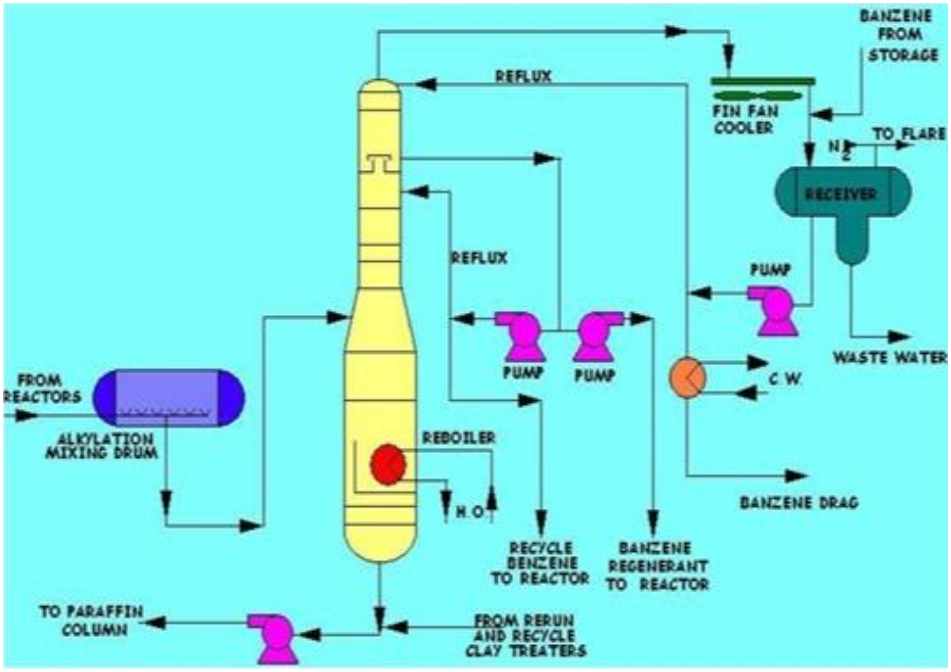


Figure III-14: Benzene column. [32]

d) Regeneration System: The Detal catalyst undergoes regeneration approximately every 24 hours using hot benzene wash. Regenerant benzene, heated to 250°C, removes heavy hydrocarbons from the catalyst surface before being mixed with the reactor effluent.

e) Separation in Paraffin Column: The paraffin column separates n-paraffin overhead from LAB and heavier hydrocarbons. Operating under vacuum prevents excessive thermal cracking.

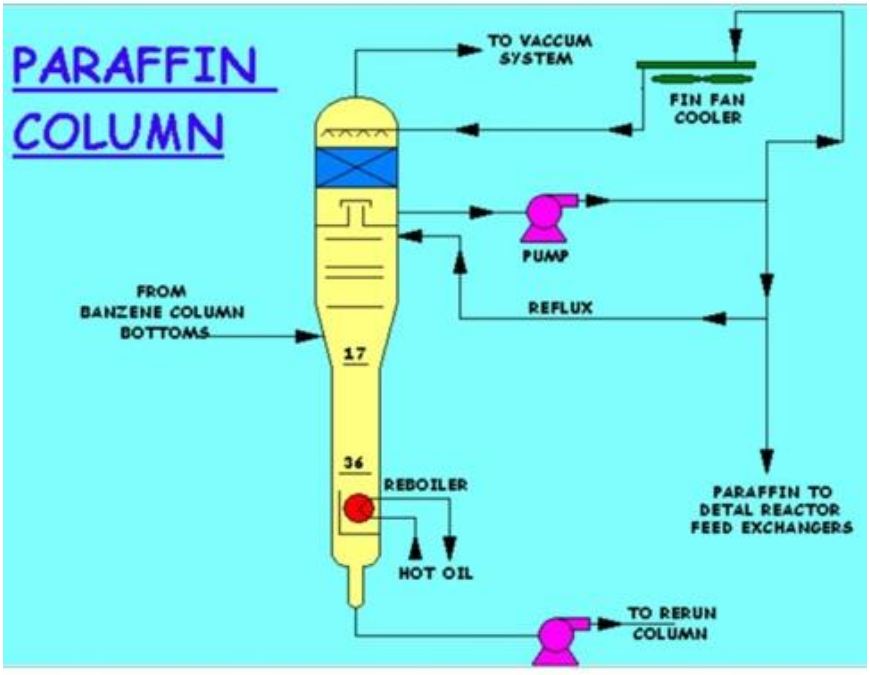


Figure III-15: Paraffin column.

f) Rerun Column: The rerun column further separates LAB product from heavier alkylbenzenes (HAB). The net overhead LAB stream is sent to the clay treater for purification.

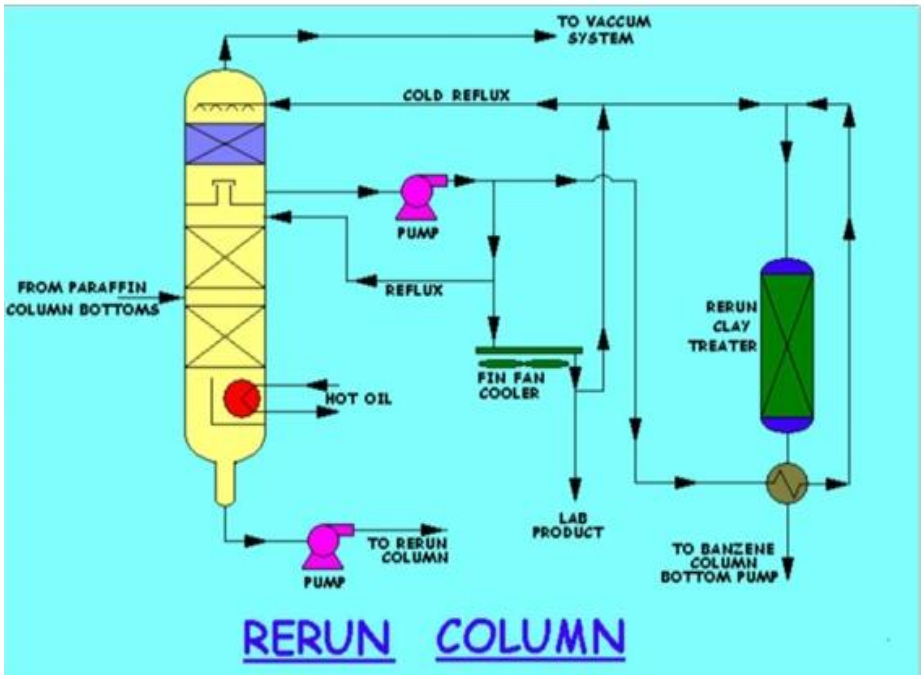


Figure III-16: Rerun column. [32]

g) Clay Treaters: Clay treaters reduce the bromine index of the LAB product by adsorbing trace impurities and facilitating reactions to form heavier hydrocarbons.

Chapter IV: Simulation and verification:

generalities and cases verification: design and actual.

IV : Simulation and verification: generalities and cases verification: design and actual.

IV.1 Generalities in simulation science

Simulation remains a widely used tool in various fields of engineering and research.

It enables the analysis of a system's behavior before implementation and facilitates optimizing its operation by testing different solutions and operating conditions.

Several simulators have been developed to solve complex problems in cases where manual calculation proves impossible

IV.2 Definition of process simulation

Simulation is defined as the representation of a physical phenomenon using mathematical models to describe its behavior.

Process simulation allows manufacturers to enhance the efficiency and profitability of an existing process, as well as to design and simulate a new production unit.

It is a vital tool for process engineers to describe a system (process) using one or more mathematical models.

Concepts encountered in unit operations, such as transfer phenomena, thermodynamics, kinetics, and chemical reactor design, as well as separation units (distillation, extraction, etc.), are all combined to simulate process behavior.

IV.3 Objectives of process simulation

The main objectives of process simulation are:

- Solving the material and energy balance equations for all process equipment.
- Calculating the characteristics of the fluids (flow rate, composition, temperature, pressure, physical properties) circulating between the equipment.
- Estimating the investment and operating costs from a sustainable development perspective, as well as the impact on the environment and safety.
- Optimizing the operating conditions of the process.

IV.4 The uses of the simulators

- ✓ **During the design of an industrial process to:**

Establish material and energy balances for an industrial process.

Size the equipment for this process.

- ✓ **During the monitoring of processes that are already installed in order to:**

To readjust operating parameters in case of changes in feed compositions or operating conditions of certain equipment.

To determine equipment performance.

There are a vast number of chemical process simulation software available.

Here's a list of some globally popular software for chemical process simulation **[**35**]**:

- Aspen plus.
- Chemcad.
- DesignII.
- Hysys.
- Ideas.
- Indiss.
- Prosim.
- ProII.
- Sim42.
- The software we used is **HYSYS** from Hyprotech, a subsidiary of the Aspentech group.

IV.5 Selection of the thermodynamic model

Simulation software provides access to several thermodynamic models for predicting liquid-vapor equilibrium, enthalpy, and entropy, as well as transport properties.

The success of the simulation depends on the choice of the thermodynamic model, as it is established for a class of fluid and a recommended range of P and T conditions using practical assumptions and suppositions.

Some of the existing thermodynamic models are:

- ✓ Redlich-Kwong.
- ✓ Soave-Redlich-Kwong.
- ✓ Peng-Robinson [38].

IV.5.1 Equations of state:

IV.5.1.1 Redlich-Kwong's equation of state:

Considered among the simplest equations of state, it is widely used to predict the state of the vapor phase.

$$P = \frac{RT}{V_M - b} - \frac{a}{\sqrt{T} V_M (V_M + b)} \quad \textbf{IV.1}$$

where:

P is the pressure.

R is the universal gas constant.

T is the absolute temperature.

V_M is the molar volume.

α and b are substance-specific constants.

IV.5.1.2 Soave-Redlich-Kwong's equation of state:

The Soave-Redlich-Kwong (SRK) equation of state is a modification of the Redlich-Kwong equation. It introduces a temperature-dependent function α(T) that accounts for the acentric factor, enhancing the equation's accuracy for predicting the properties of real gases, especially non-polar and moderately polar substances. The SRK equation is written as:

$$P = \frac{RT}{V_M - b} - \frac{a a(T)}{V_M (V_M - b)} \quad \textbf{IV.2}$$

where:

P is the pressure,

R is the universal gas constant,

T is the absolute temperature,

V_M is the molar volume,

α is a constant specific to the gas,

b is another constant specific to the gas,

α(T) is a temperature-dependent function that incorporates the acentric factor w

The function α(T) is typically given by:

$$a(T) = [1 + (0.48 + 1.574w - 0.176w^2)(1 - \sqrt{\frac{T}{T_c}})]^2 \quad \textbf{IV.3}$$

where w is the acentric factor and T_c is the critical temperature of the substance.

This modification improves the original Redlich-Kwong equation by providing better accuracy for substances with non-spherical molecules and varying polarities.

IV.5.1.3 Peng Robinson's equation of state:

It is written as follows:

$$P = \frac{\mathrm{RT}}{V_M - \mathrm{B}} - \frac{a(T)}{V_M(V_M+b)+b(V_M-b)} \quad \textbf{IV.4}$$

Where:

P is the pressure.

T is the temperature.

R is the universal gas constant.

V_M is the molar volume.

α(T) and b are substance-specific parameters.

The parameter a(T) is temperature-dependent and is defined as:

$$a(T) = a_c[1 + c(1 - \sqrt{T_r})^2] \quad \textbf{IV.5}$$

Where

α_c is a substance-specific constant.

c is another substance-specific constant.

T_r is the reduced temperature, $T_r = \frac{T}{T_c}$, with T_c being the critical temperature of the substance.

The parameter b is defined as:

$$b = 0.0778\frac{RT_C}{P_C} \quad \textbf{IV.3}$$

Where P_c is the critical pressure of the substance.

The constant α_c is defined as:

$$a_c = 0.45724\frac{R^2T^2}{P_C} \quad \textbf{IV.3}$$

And the constant c is given by:

$$c=0.37464+1.54226\omega-0.26992\omega^2 \quad \textbf{IV.3}$$

Where ω is the acentric factor of the substance.

The thermodynamic model used in our work is governed by the **Peng-Robinson** equation. It is the most recommended for industrial applications related to oil refining, gas processing, and petrochemicals.[36]

IV.6 work methodology

In this study, we will commence with an initial simulation using Aspen HYSYS V11 to verify the compatibility of the PR model with the design operating parameters.

Subsequently, we will proceed with simulating the real case, based on the April 2024 stream summery and may 2023 CRD data, to validate our results.

Once this validation is achieved, our objective will be to optimize the quality of kerosene produced by column 10-C-1 of the atmospheric distillation unit 10 at the Skikda Refinery (RA1K).

IV.7 Verification of the design case

The characteristics of the feed supplying the atmospheric distillation unit (U10) are shown in the following table, knowing that the composition of the feed and operating parameters is brought from the material balance and stream summary of the unit. (See Annexes A and B)

Table IV-1: Crude oil design characteristics.

Properties	Values
Temperature (°C)	15
Pressure (Kg/cm^2_g)	0.3
Mass flow (Kg/h)	1130618
Molecular weight (g/mol)	144.1
Density (Kg/m^3)	807
KUOP	12

To validate the simulation of the Design case, we will compare the simulation results with those of the design case.

The simulation diagram for the Design case of the atmospheric distillation unit, carried out using Aspen HYSYS software, is presented in the following figure:

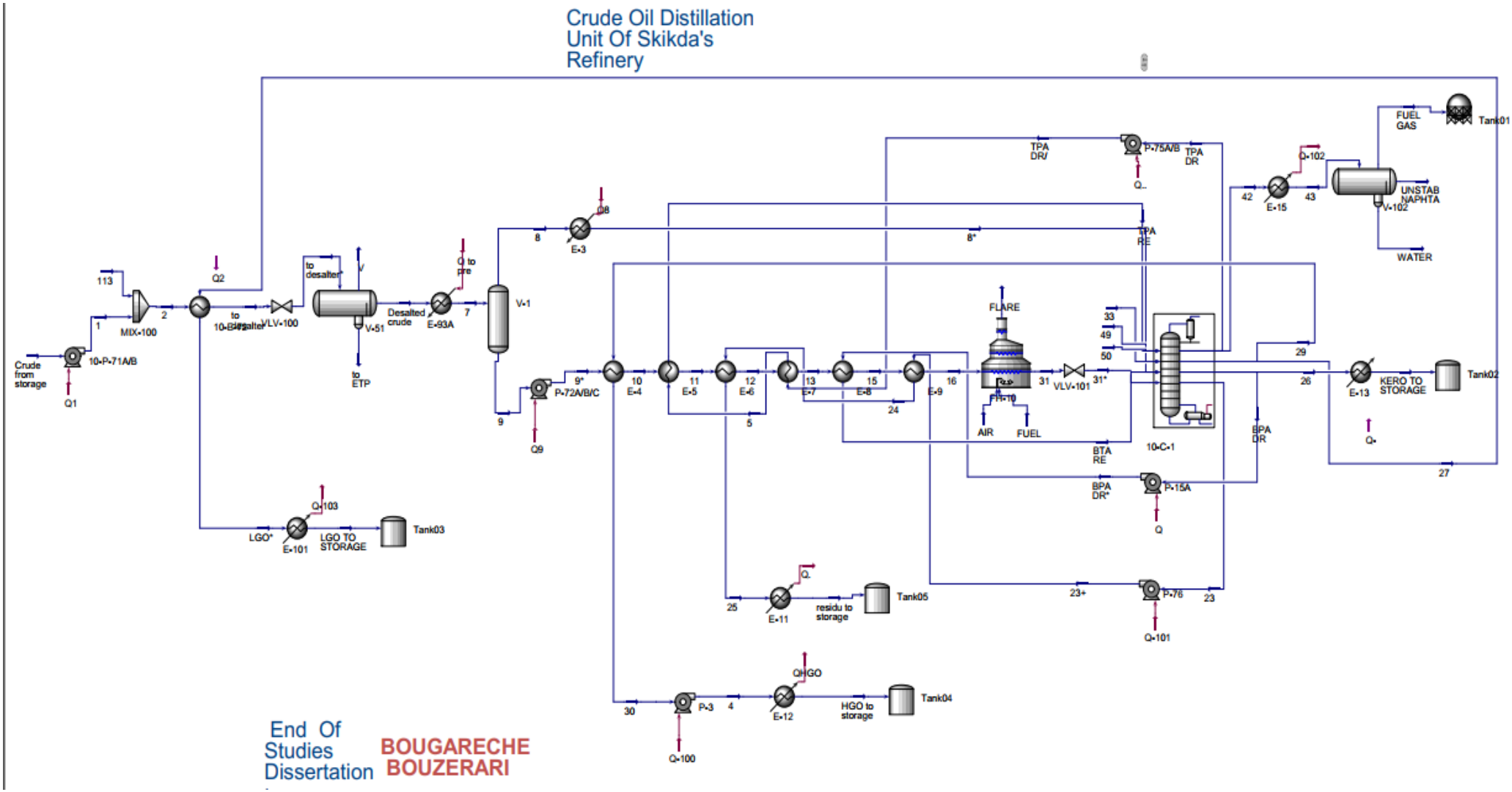


Figure IV-1: The simulation diagram for the Design case of the atmospheric distillation unit.

The results obtained are presented in the figures below:

Name	Crude from st...	1	113	2	to desalter	to desalter*	Desalted crude	7
Vapour Fraction	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Temperature [C]	15,00	15,42	52,60	20,02	54,80	54,97	54,97	147,5
Pressure [kg/cm2_g]	0,3000	17,00	19,20	17,00	14,10	10,70	10,70	9,702
Molar Flow [kgmole/h]	7883	7883	3886	1,177e+004	1,177e+004	1,177e+004	7582	7582
Mass Flow [kg/h]	1,131e+006	1,131e+006	7,000e+004	1,201e+006	1,201e+006	1,201e+006	1,125e+006	1,125e+006
Liquid Volume Flow [m3/h]	1401	1401	70,15	1471	1471	1471	1395	1395
Heat Flow [kJ/h]	-2,485e+009	-2,482e+009	-1,104e+009	-3,585e+009	-3,497e+009	-3,497e+009	-2,308e+009	-2,075e+009
Name	8	9	8*	9*	10	11	12	13
Vapour Fraction	1,0000	0,0000	1,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Temperature [C]	139,3	139,3	226,3	140,3	150,6	174,2	186,2	196,2
Pressure [kg/cm2_g]	2,342	2,342	2,342	31,00	30,10	28,90	27,50	26,50
Molar Flow [kgmole/h]	1121	6461	1121	6461	6461	6461	6461	6461
Mass Flow [kg/h]	7,957e+004	1,046e+006	7,957e+004	1,046e+006	1,046e+006	1,046e+006	1,046e+006	1,046e+006
Liquid Volume Flow [m3/h]	124,1	1271	124,1	1271	1271	1271	1271	1271
Heat Flow [kJ/h]	-1,359e+008	-1,939e+009	-1,199e+008	-1,933e+009	-1,907e+009	-1,846e+009	-1,814e+009	-1,787e+009

Figure IV-2: Design case stream simulation results part-1.

Name	15	16	23	5	30	23+	24	25
Vapour Fraction	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Temperature [C]	254,2	260,1	335,6	203,0	189,6	336,3	316,2	278,9
Pressure [kg/cm2_g]	24,90	23,50	2,300	9,200	1,300	18,60	17,10	15,60
Molar Flow [kgmole/h]	6461	6461	853,5	4192	354,3	853,5	853,5	853,5
Mass Flow [kg/h]	1,046e+006	1,046e+006	2,990e+005	5,900e+005	9,063e+004	2,990e+005	2,990e+005	2,990e+005
Liquid Volume Flow [m3/h]	1271	1271	323,5	730,2	103,3	323,5	323,5	323,5
Heat Flow [kJ/h]	-1,621e+009	-1,603e+009	-4,211e+008	-1,026e+009	-1,638e+008	-4,201e+008	-4,379e+008	-4,699e+008
Name	31*	** New **						
Vapour Fraction	0,8781							
Temperature [C]	356,1							
Pressure [kg/cm2_g]	2,300							
Molar Flow [kgmole/h]	6461							
Mass Flow [kg/h]	1,046e+006							
Liquid Volume Flow [m3/h]	1271							
Heat Flow [kJ/h]	-1,139e+009							

Figure IV-3: Design case stream simulation results part-2.

Specifications

	Specified Value	Current Value
TOP PA_Rate(Pa)	5,900e+005 kg/h	5,900e+005
TOP PA_TRet(Pa)	163,0 C	162,8
BTM PA_Rate(Pa)	8,450e+005 kg/h	8,450e+005
BTM PA_TRet(Pa)	237,0 C	236,8
Btms Prod Rate	2,990e+005 kg/h	2,990e+005
LGO STR Prod Flow	2,518e+005 kg/h	2,518e+005
HGO STR Prod Flow	9,063e+004 kg/h	9,063e+004
Vap Prod Rate	3,992e+005 kg/h	3,966e+005
Reflux Ratio	<empty>	1,287
Reflux Rate	<empty>	5,105e+005
SS1 Prod Flow	1,016e+005 kg/h	1,016e+005
SS1 BoilUp Ratio	0,7500	0,7500
ATM Column Top Tempera	172,1 C	173,5

Figure IV-4: Atmospheric column properties simulation results at design case.

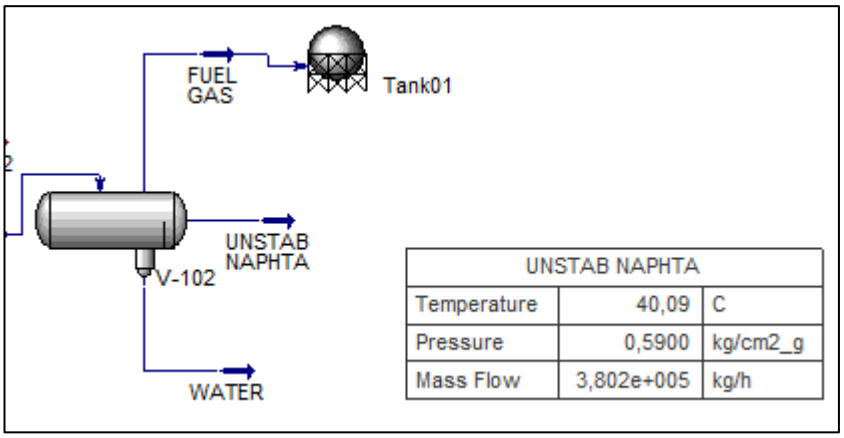


Figure IV-5: Unstabilized naphtha simulation results at design case.

Liquid Pump Around Summary

	Draw Stage	Return Stage	Flow [kg/h]	Duty [kJ/h]	Draw T [C]	Return T [C]
TOP PA	33_Main Tower	34_Main Tower	5,900e+005	-8,733e+007	219,6	162,8
BTM PA	15_Main Tower	16_Main Tower	8,450e+005	-1,651e+008	305,8	236,8

Figure IV-6: Top and bottom pump arounds simulation results at design case.

IV.7.1 Gap calculation

We use the next formula

$$(1): \text{Gap} = \frac{|Vdesgin - Vsim\ | * 100}{Vdesign}$$

Table IV-2: Temperature Gap calculation for crude processing streams at design case.

Stream Number	Temperature °C Design	Temperature °C (Simulated)	Gap
Crude from storage	15	15	0
1	15	15,41888801	2,792586715
113	52,6	52,6	0
2	20	20,01730695	0,086534752
to desalter	54,8	54,8	1,81526E-13
to desalter*	54,8	54,96505292	0,301191464
Desalted crude	50	51,96505319	3,930106386
7	148	147,5	0,337837838
8	140	139,2781516	0,515605978
9	140	139,2781516	0,515605978
8*	226,3	226,3	0
9*	139,6	140,3248712	0,519248713
10	151	150,6	0,264900662
11	174	174,2	0,114942529
12	186	186,2	0,107526882
13	195	196,2305801	0,631066742
15	233	233,2090825	0,089734968
16	260	260,1	0,038461538
23	338	335,6478356	0,695906615
30	155	156,25558	0,810051613
23+	338	336,2600664	0,514773242
24	242	243,266755	0,523452479
25	200	200,156874	0,078437
31*	356	356,1	0,028089888

Table IV-3: Pressure Gap calculation for crude processing streams at design case.

Stream Number	Pressure kg/cm2_g (Design)	Pressure kg/cm2_g (Simulated)	Gap
Crude from storage	0,3	0,3	0
1	17	17	0
113	19	19,2	1,052631579

2	15,5	15,5	0
to desalter	14,1	14,1	7,05503E-13
to desalter*	10,7	10,7	0
Desalted crude	10,7	10,7	0
7	9,7	9,701604524	0,016541488
8	3	2,741604524	8,613182521
9	3	2,741604524	8,613182521
8*	3	2,741604524	8,613182521
9*	31	31	0
10	30,1	30,1	3,42288E-13
11	28,9	28,9	3,44208E-13
12	27,5	27,5	0
13	26,5	26,5	0
15	24,9	24,9	3,99502E-13
16	23,5	23,5	0
23	2,3	2,3	4,24781E-13
30	1,3	1,3	0
23+	18,6	18,6	0
24	17,1	17,1	0
25	15,6	15,6	0
31*	2,3	2,3	4,24781E-13

Table IV-4: Mass flow Gap calculation for crude processing streams at design case.

stream Number	Mass Flow kg/h Design	Mass Flow kg/h Simulated	Gap
Crude from storage	1130618	1130618	0
1	1130618	1130618	0
113	70004	70004	0
2	1200622	1200622	0
to desalter	1200622	1200622	0
to desalter*	1200622	1200622	0
Desalted crude	1127730	1125194,724	0,22481228
7	1127730	1125194,724	0,22481228
8	79574	79574,07306	9,182E-05
9	1048156	1045620,651	0,24188657
8*	79574	79574,07306	9,182E-05
9*	1048156	1045620,651	0,24188657
10	1048156	1045620,651	0,24188657
11	1048156	1045620,651	0,24188657
12	1048156	1045620,651	0,24188657
13	1048156	1045620,651	0,24188657
15	1048156	1045620,651	0,24188657

16	1048156	1045620,651	0,24188657
23	299001	299001	4,1378E-09
30	90629	90628,9993	7,7412E-07
23+	299001	299001	4,1378E-09
24	299001	299001	4,1378E-09
25	299001	299001	4,1378E-09
31*	1048156	1045620,651	0,24188657

Table IV-5: Gap calculation of mass flow and draw, return temperature in top and bottom pump arounds at design case

	Mass Flow (kg/h)			Draw Temperature (°C)			Return Temperature (°C)		
	Design	simulated	Gap	Design	simulated	Gap(1)	Design	simulated	Gap(1
TPA	590023	590023	0.00	218.8	219.6	0.365	163	162.8	0.122
BPA	844991	844991	0.00	292	305.8	4.726	237	236.8	0.084

Table IV-6: Characteristics of the products from (10-C-1) obtained through design cas and Gap calculation

ATM Column Top Temperature (°C)		
Design	simulated	Gap
172.1	173.5	0.813

Table IV-7: Gap calculation of atmospheric column top temperature at design case

Products	Mass Flow (kg/h)			Temperature (°C)		
case	Design	simulated	Gap (1)	Design	simulated	Gap (1)
Naphtha	380 249	380247,871	0.00001	39	40.09	2.794
Kerosene	101 550	101550	0.0000	230	230.6	0.26
Light gasoil	251 800	251800	0.0000	241	233.6	3.07
Heavy gasoil	90 629	90628,999	0.000001	284	294.2	3.591
Atmospheric residue	299 001	299001	0.0000	338	335.6	0.71

IV.7.2 Results discussion

The results obtained following convergence with the Peng-Robinson model demonstrate a difference of

- 0% compared to the design values for products flow rates.
- Less than 5% in the worst case compared to the design values for temperatures.

This validation of the design case confirms the reliability of the model to simulate the real case.

IV.8 Verification of the actual real case:

To validate the simulation, we compared the results of the simulation with those of the current real case.

The simulation is established for the day 25 April, 2024.

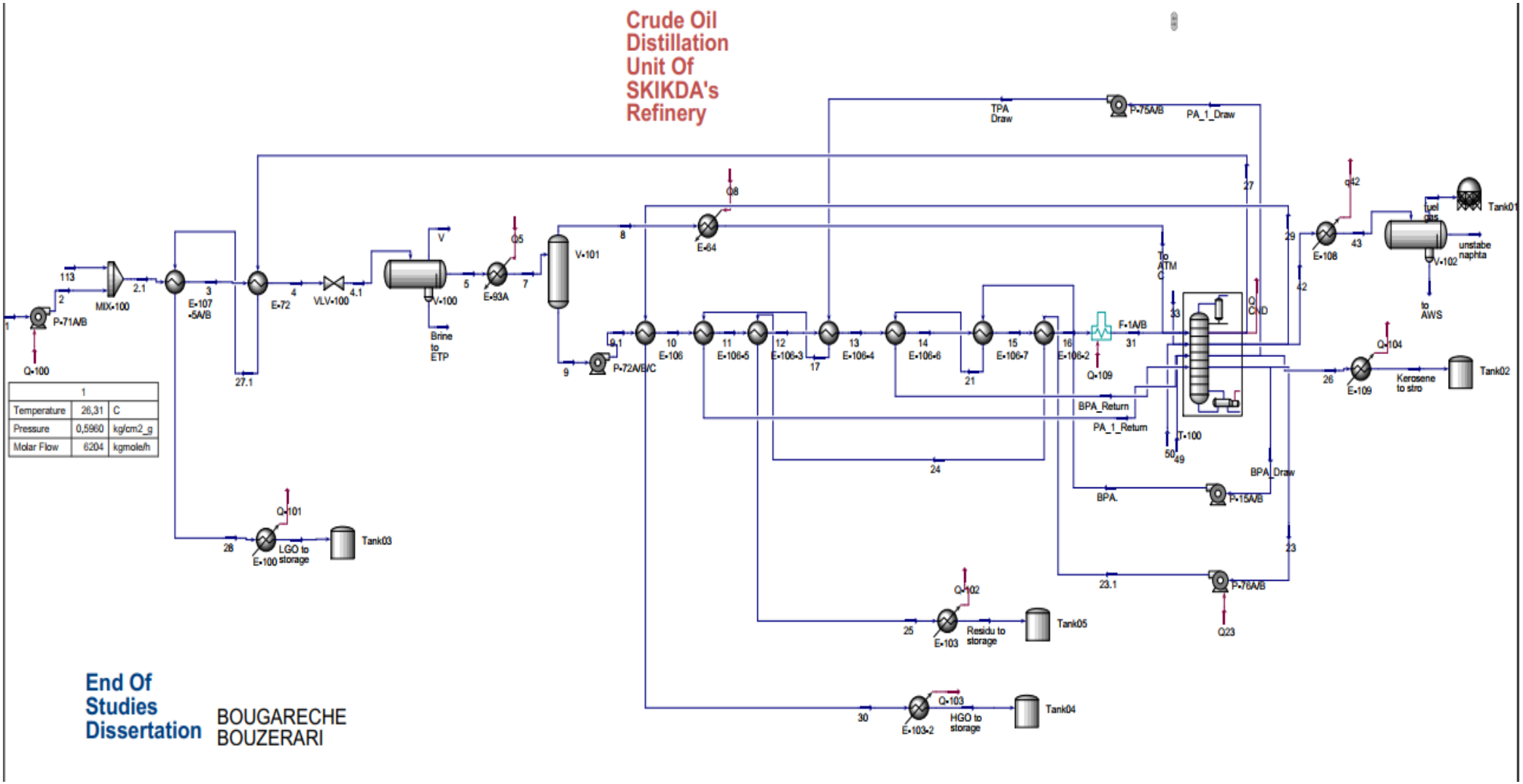
The composition of the feed as well as the operating conditions of the unit used for the simulation are taken from the TBP carried out in May 2023 and from the DCS data, respectively. (see annexes C and D)

The operating parameters of the feed to unit 10 are provided in the following table:

Table IV-8: Crude oil actual characteristics

Operating parameters	Crude Inlet
Temperature (°C)	26.31
Pressure (Kg/cm^2_g)	0.596
Liq Vol Flow(m^3/h)	1267
Density (Kg/m^3)	798

The simulation diagram of the real case is shown in the following figure



1		
Temperature	26,31	C
Pressure	0,5960	kg/cm2_g
Molar Flow	6204	kgmole/h

Figure IV-7: The simulation diagram for the actual case of the atmospheric distillation unit.

The results obtained are presented in the figures below:

Name	1	2	113	2.1	3	4	4.1	5
Vapour Fraction	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Temperature [C]	26,31	26,79	52,60	27,95	49,22	78,30	78,56	78,56
Pressure [kg/cm2_g]	0,5960	17,00	19,20	17,00	14,80	14,10	8,330	8,330
Molar Flow [kgmole/h]	6204	6204	1239	7443	7443	7443	7443	6229
Mass Flow [kg/h]	1,020e+006	1,020e+006	2,233e+004	1,042e+006	1,042e+006	1,042e+006	1,042e+006	1,020e+006
Liquid Volume Flow [m3/h]	1276	1276	22,37	1298	1298	1298	1298	1276
Heat Flow [kJ/h]	-2,192e+009	-2,190e+009	-3,510e+008	-2,541e+009	-2,496e+009	-2,431e+009	-2,431e+009	-2,090e+009
Name	7	8	9	To ATM C	10	11	12	13
Vapour Fraction	0,0140	1,0000	0,0000	1,0000	0,0000	0,0000	0,0000	0,0000
Temperature [C]	149,7	144,0	144,0	229,0	152,7	174,7	187,4	196,5
Pressure [kg/cm2_g]	5,590	3,009	3,009	1,960	30,10	28,90	27,50	26,50
Molar Flow [kgmole/h]	6229	784,2	5445	784,2	5445	5445	5445	5445
Mass Flow [kg/h]	1,020e+006	5,725e+004	9,628e+005	5,725e+004	9,628e+005	9,628e+005	9,628e+005	9,628e+005
Liquid Volume Flow [m3/h]	1276	87,70	1188	87,70	1188	1188	1188	1188
Heat Flow [kJ/h]	-1,922e+009	-1,034e+008	-1,819e+009	-9,199e+007	-1,796e+009	-1,744e+009	-1,713e+009	-1,691e+009

Figure IV-8: Actual case stream simulation results part-1.

Name	14	15	9.1	16	31	26	30	24
Vapour Fraction	0,0000	0,0000	0,0000	0,0000	0,8762	0,0000	0,0000	0,0000
Temperature [C]	221,1	244,6	145,1	249,0	339,0	220,5	152,0	308,9
Pressure [kg/cm2_g]	25,80	24,90	31,00	23,50	1,960	1,375	1,300	17,10
Molar Flow [kgmole/h]	5445	5445	5445	5445	5445	707,4	177,6	599,7
Mass Flow [kg/h]	9,628e+005	9,628e+005	9,628e+005	9,628e+005	9,628e+005	1,076e+005	5,234e+004	2,767e+005
Liquid Volume Flow [m3/h]	1188	1188	1188	1188	1188	136,9	60,96	303,5
Heat Flow [kJ/h]	-1,628e+009	-1,565e+009	-1,814e+009	-1,553e+009	-1,169e+009	-1,831e+008	-9,745e+007	-3,993e+008
Name	25	17	21	27.1	28	18	20	32
Vapour Fraction	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Temperature [C]	268,9	200,1	265,3	143,0	64,79	70,00	40,00	40,00
Pressure [kg/cm2_g]	15,60	7,000	9,000	1,400	1,000	3,000	1,000	0,8000
Molar Flow [kgmole/h]	599,7	4131	2960	1201	1201	599,7	177,6	1201
Mass Flow [kg/h]	2,767e+005	6,733e+005	8,146e+005	2,603e+005	2,603e+005	2,767e+005	5,234e+004	2,603e+005
Liquid Volume Flow [m3/h]	303,5	847,3	956,2	314,1	314,1	303,5	60,96	314,1
Heat Flow [kJ/h]	-4,304e+008	-1,183e+009	-1,276e+009	-4,932e+008	-5,377e+008	-5,628e+008	-1,100e+008	-5,505e+008

Figure IV-9: Actual case stream simulation results part-2.

Specifications

	Specified Value	Current Value
Reflux Rate	649,0 m3/h	649,0
PA_1_Rate(Pa)	847,0 m3/h	847,3
PA_1_TRet(Pa)	170,0 C	169,9
BPA_Rate(Pa)	956,0 m3/h	956,2
BPA_TRet(Pa)	237,0 C	236,8
Btms Prod Rate	303,5 m3/h	303,5
STRIP KERO Prod Flow	136,8 m3/h	136,8
LGO STRIP Prod Flow	313,9 m3/h	313,8
HGO STRIP Prod Flow	61,00 m3/h	61,02
Vap Prod Rate	505,9 m3/h	470,6
Reflux Ratio	1,226	1,379
STRIP KERO BoilUp Ratio	0,5306	0,7913
Temperature	163,6 C	157,2

Figure IV-10: Atmospheric column properties simulation results at actual case.

D86 à 5% kero	166,9 C	173,4
D86 à 95% kero	216,0 C	216,3
D86 à 5% LGO	226,0 C	226,4
D86 à 95% LGO	338,0 C	345,6
D86 à5% HGO	278,0 C	275,0
D86 à95% HGO	386,0 C	380,6

Figure IV-11: Kerosene, LGO and HGO ASTM D86 (5%, 95%) simulation results at actual case.

Liquid Pump Around Summary

	Draw Stage	Return Stage	Flow [m3/h]	Duty [kJ/h]	Draw T [C]	Return T [C]
PA_1	32_Main Tower	33_Main Tower	847,3	-7,382e+007	212,3	169,9
BPA	14_Main Tower	15_Main Tower	956,2	-1,243e+008	292,2	236,8

Figure IV-12: Top and bottom pump arounds simulation results at actual case.

IV.8.1 Gap calculation

Table IV-9: Temperature Gap calculation for crude processing streams at real case.

Stream number	Temperature °C (Actual)	Temperature °C (simulated)	Gap
1	26,3	26,3	0
2	26,79	26,79	3,7132E-13
113	52,6	52,6	0

2.1	27,9	27,94953769	0,17755444
3	49,22	49,22	2,021E-13
4	78,3	78,3	1,2704E-13
4.1	78,3	78,55823461	0,32980154
5	78,3	78,55823461	0,32980154
7	149,7	149,7	6,645E-13
8	144,9	143,9825727	0,63314515
9	144,9	143,9825727	0,63314515
To ATM C	229	229	0
10	151,1	152,7490992	1,09139587
11	174,6	174,6667326	0,03822025
12	187,4	187,4	0
13	196,5	196,5	0
14	221,1	221,1	4,4991E-13
15	232,9	235,6359753	1,17474251
16	240,4	243	1,08153078
31	339	339	0
30	152	152	0
24	306,2	308,9422979	0,89559044
25	265,33	268,8771353	1,33687685
17	199,35	200,0723303	0,36234279
21	263,2	265,316882	0,80428649
27.1	144,5	143,0276071	1,01895703

Table IV-10: Tressure Gap calculation for crude processing streams at real case.

Stream number	Pressure kg/cm2_g (Actual)	Pressure kg/cm2_g (simulated)	Gap
1	0,596	0,596	1,6765E-13
2	17	17	0
113	19,2	19,2	5,181E-13
2.1	17	17	0
3	14,8	14,8	0
4	14,1	14,1	7,055E-13

4.1	8,33	8,33	0
5	8,33	8,33	0
7	5,59	5,59	1,7478E-13
8	3	3,009098804	0,30329347
9	3	3,009098804	0,30329347
To ATM C	1,96	1,96	0
10	30,1	30,1	3,4229E-13
11	28,9	28,9	3,4421E-13
12	27,5	27,5	0
13	26,5	26,5	0
14	25,8	25,8	0
15	24,9	24,9	3,995E-13
16	23,5	23,5	0
31	1,96	1,96	0
30	1,3	1,3	0
24	17,1	17,1	0
25	15,6	15,6	0
17	7	7	0
21	9	9	0
27.1	1,4	1,4	7,1371E-13

Table IV-11: Liquid volume flow Gap calculation for crude processing streams at real case

Stream number	Liquid Volume Flow m3/h (Actual)	Liquid Volume Flow m3/h (simulated)	Gap
1	1276	1275,667849	0,02603066
2	1276	1275,667849	0,02603066
113	22,37081137	22,27081137	0,44701106
2.1	1299,37	1297,93866	0,11015645
3	1299,37	1297,93866	0,11015645
4	1299,37	1297,93866	0,11015645
4.1	1299,37	1297,93866	0,11015645
5	1276	1276,124363	-0,00974635
7	1276	1276,124363	-0,00974635

8	88	87,69913922	0,34188725
9	1188	1188,425224	0,03579328
To ATM C	88	87,69913922	0,34188725
10	1188	1188,425224	0,03579328
11	1188	1188,425224	0,03579328
12	1188	1188,425224	0,03579328
13	1188	1188,425224	0,03579328
14	1188	1188,425224	0,03579328
15	1188	1188,425224	0,03579328
16	1188	1188,425224	0,03579328
31	1188	1188,425224	0,03579328
30	61	60,95682975	0,07077089
24	303,5	303,5016209	0,00053407
25	303,5	303,5016209	0,00053407
17	847,3	847,3358208	0,00422764
21	956,2	956,1836364	0,00171131
27.1	314,2	314,1143489	0,02726005

Table IV-12: Gap calculation of liquid volume flow and draw, return temperature in top and bottom pump arounds at real case

	Liquid Volume Flow (m^3/h)			Draw Temperature (°C)			Return Temperature (°C)		
	current	simulated	Gap	current	simulated	Gap(1)	current	simulated	Gap(1
TPA	847	847	0.00	216.2	212.3	1.803	170.5	170	0.122
BPA	956	956	0.00	296	292.2	1.283	240.8	237	1.578

Table IV-13: Gap calculation of atmospheric column top temperature at real case.

ATM Column Top Temperature (°C)		
current	simulated	Gap
166.2	157.2	5.415

Table IV-14: The calculation of the ASTM D86 Gap of kerosene, LGO and HGO at real case

Products	Kerosene		LGO		HGO	
ASTM D86	5%	95%	5%	95%	5%	95%
current	176	216	226	338	278	386
simulated	173.4	216.3	226.4	339.6	275	380.6
$Gap^{(1)}$	1.477	0.1388	0.1769	0.4733	1.0791	1.398

Table *IV*-15*:* Characteristics of the products from (10-C-1) obtained through actual case and Gap calculation

Products	Liquid Volume Flow (m^3/h)			Temperature (°C)		
case	current	simulated	$Gap^{(1)}$	current	simulated	$Gap^{(1)}$
Naphtha	446.5	449.3	0.627	47.55	47.55	0.00
Kerosene	136.8	136.8	0.0000	226.4	220.5	2.606
Light gasoil	313.9	313.9	0.0000	242.9	241.5	0.576
Heavy gasoil	61	61	0.0000	269.2	282.2	4.829
Atmospheric residue	301.6	303.5	0.6299	329.8	323.2	2.001

IV.8.2 Results discussion

The results obtained, after convergence, exhibit a small deviation of:

- less than 1% compared to the actual values for product flow rates.
- less than 1% compared to the actual values for pressures.
- less than 6% compared to the actual values for temperatures.
- less than 2% compared to the actual values for cut points.

These results allow us, first and foremost, to validate the real simulation and then proceed towards studying the optimization of both the quality and quantity of kerosene produced from column 10-C-1 of unit 10 in the atmospheric distillation process.

Chapter V: Optimization of Kerosene for Linear Alkyl Benzene production

V : Optimization of Kerosene for LAB production

V.1 Project description

On March 7th, 2024, SONATRACH has signed, a contract with TECNIMONT Spa. This contract, entrusted to the Italian Company following a Call of tenders' process, consists on the realization in Engineering, Procurement and construction mode of a petrochemical complex for the production of Linear Alkyl Benzene (LAB) at PEC, in the industrial zone of Skikda.

The feedstock for the production of linear alkylbenzene consists of benzene and kerosene sourced from the Skikda refinery (RA1K). Only the n-paraffins present in the feedstock are utilized for the production of linear alkylbenzene from a hydrocarbon fraction (C_{10} to C_{13}) derived from kerosene. Other products from the kerosene cut are either returned to the Skikda refinery (RA1K) or sold as by-products. The iso-paraffins from the hydrocarbon fraction (C_{10} to C_{13}), after the extraction of n-paraffins, are returned to the Skikda refinery (RA1K) to be sold as Jet A1. (annexe E)

The production capacity of this complex is 100,000 t/year of linear alkyl benzene.

The quantity of the hydrocarbon cut (C_{10} to C_{13}) used excluding light kerosene and heavy kerosene separated is 4.5095 t/t of LAB, or for 100,000 t/year of linear alkyl benzene, a quantity of 450,950 t/ year. The quantity of benzene is 0.3588 t/t of linear alkyl benzene, or for 100,000 t/year of linear alkyl benzene, a quantity of 35,880 t/year. (annexe E)

V.2Specifications of Kerosene required by the LAB complex

The kerosene specifications, the most important for the production of linear alkylbenzene, are the minimum n-paraffin content and the ASTM D86 distillation points (05% and 95%).

The kerosene specifications required by the LAB project are shown in the table below:

Table V-1: Specifications of kerosene required by the LAB project (annexe E).

specification	value
Minimum n-paraffin content	18 %
ASTM D86 05% distillate between (°C)	175-180
ASTM D86 95% distillate between (°C)	230-240
Average molecular weight of kerosene (g/mol)	164

V.3Specifications of Kerosene produced by the RA1K

The specifications of kerosene, currently produced by the Skikda refinery (RA1K) and whose analyzes were carried out at the RA1K laboratory and the research and development center (CRD) of SONATRACH, are shown in the table below:

Table V-2: Specifications of kerosene produced by the Skikda refinery.

specification	value
Minimum n-paraffin content	25.68 %
ASTM D86 05% distillate between (°C)	176
ASTM D86 95% distillate between (°C)	216
Average molecular weight of kerosene (g/mol) (calculated, Annexe F)	153.38

(Kerosene composition and specifications are shown respectfully in Annexe G, H)

V.4Work methodology

The n-paraffin content of kerosene produced by the Skikda refinery (RA1K) corresponds to the specifications required by the LAB project; while the ASTM D86 95% distillation point and molecular weight are lower than those required by the LAB project.

Our approach will be to study the different possibilities of modifying the operating parameters of the atmospheric distillation column (10-C-1) in order to increase the ASTM D86 95% distillation points and the molecular weight of the kerosene cut without affecting on:

- JET A1 specifications. [37]
- The specifications of other petroleum fractions and avoiding over-lap. (annex H)
- Respect the operating parameters recommended by the designer. (annex I)

V.4.1 JET A-1 specifications

Table V-3: Specifications of JET A-1.

Specification	value
Fuel recovered 10% by volume at °C	205 Max
Final Boiling Point °C	300 Max

Flash Point °C.	38 Min
Density at 15 °C kg/m3	775-840
Freezing point, °C	-47 Max
Smoke Point, °C	19 Min
Autoignition	230 Min
Kin. Viscosity at - 20°C mm^2/s	8 Max

V.5 Adjustment impacts of the operating parameters

In order to satisfy the demand of kerosene required by LAB project (ASTM D86 5%, ASTM D86 95% and molecular weight), we must look for the best operational conditions without affecting on those mentioned previously.

Before that, we need to study the impact of the following changes on our requirements (ASTM D86 5%, ASTM D86 95% and molecular weight):

- Return temperatures of the pump arounds. (TPA, BPA)
- The pump arounds flows.
- Reflux flow.
- LGO flow.
- HGO flow.
- Column pressure.
- Feed temperature.
- Residue flow.

The operating parameters, specifications of cuts, and molecular weight of kerosene before adjustments:

Specifications

	Specified Value	Current Value
Reflux Rate	649,0 m3/h	648,9
PA_1_Rate(Pa)	847,0 m3/h	847,1
PA_1_TRet(Pa)	170,0 C	170,0
BPA_Rate(Pa)	956,0 m3/h	956,0
BPA_TRet(Pa)	237,0 C	237,0
Btms Prod Rate	303,5 m3/h	303,5
STRIP KERO Prod Flow	136,8 m3/h	136,8
LGO STRIP Prod Flow	313,9 m3/h	313,9
HGO STRIP Prod Flow	61,00 m3/h	61,00
Vap Prod Rate	505,9 m3/h	470,6
Reflux Ratio	1,226	1,379
STRIP KERO BoilUp Ratio	0,5306	0,7926
Temperature	163,6 C	157,2
Temperature - 2	132,5 C	126,5
D86 à 5% kero	176,0 C	173,5
D86 à 95% kero	216,0 C	216,3
D86 à 5% LGO	226,0 C	226,4
D86 à 95% LGO	338,0 C	339,6
D86 à5% HGO	278,0 C	275,0
D86 à95% HGO	386,0 C	380,6

Figure V-1: The operating parameters, specifications of cuts before adjustments results**.**

Molecular weight of kerosene :152.1g/mole

For unstable naphtha, ASTM D86 95% is shown in figure blow:

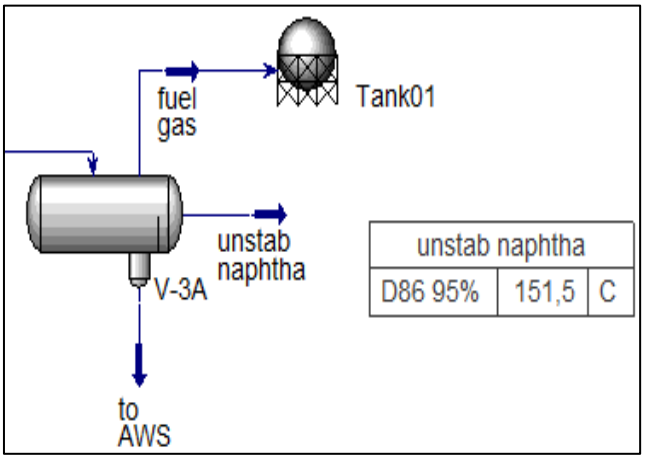


Figure V-2: Unstabilized naphtha ASTM D86 (95%) before adjustments results.

V.5.1 Top pump around return temperature effect:

Table V-4: the effect of changing the Top pump around return temperature on ASTM D86 (5%, 95%) and molecular weight.

	Current value	Changed value
first adjustment: TPA Ret T (°C)	170	180
ASTM D86 5% (°C)	173.5	156.1
ASTM D86 95 % (°C)	216.3	217
Molecular weight(g/mole)	152.1	150.4
second adjustment: TPA Ret T (°C)	170	160
ASTM D86 5% (°C)	173.5	178.3
ASTM D86 95 % (°C)	216.3	215.8
Molecular weight(g/mole)	152.1	152.6

V.5.1.1 Results interpretation

- ✓ TPA Return Temperature and Distillation Temperatures:

There is an inverse relationship between TPA Return Temperature and the ASTM D86 5%. As the TPA Return Temperature increases, the ASTM D86 5% decreases, and as the TPA Return Temperature decreases, ASTM D86 5% increases.

The ASTM D86 95% shows minor changes, indicating it is less sensitive to variations in TPA Return Temperature compared to the ASTM D86 5%.

- ✓ TPA Return Temperature and Molecular Weight:

There is an inverse relationship between TPA Return Temperature and molecular weight. As the TPA Return Temperature increases, the molecular weight decreases, indicating lighter components in the mixture. Conversely, as the TPA Return Temperature decreases, the molecular weight increases, indicating heavier components in the mixture.

V.5.2 Bottom pump around return temperature effect:

Table V-5*:* The effect of changing the bottom pump around return temperature on ASTM D86 (5%, 95%) and molecular weight.

	Current value	Changed value
first adjustment: BPA Ret T (°C)	237	241
ASTM D86 5% (°C)	173.5	171.3
ASTM D86 95 % (°C)	216.3	216.2
Molecular weight(g/mole)	152.1	151.7
second adjustment: BPA Ret T (°C)	237	232
ASTM D86 5% (°C)	173.5	175.5
ASTM D86 95 % (°C)	216.3	216.5
Molecular weight(g/mole)	152.1	152.5

V.5.2.1 Results interpretation

- ✓ BPA Return Temperature and Distillation Temperatures:

There is an inverse relationship between BPA Return Temperature and the ASTM D86 5%. As the BPA Return Temperature increases, the ASTM D86 5% decreases, and as the BPA Return Temperature decreases, the ASTM D86 5%increases.

The ASTM D86 95% shows minimal changes, indicating it is relatively stable and less sensitive to variations in BPA Return Temperature compared to the ASTM D86 5%.

- ✓ BPA Return Temperature and Molecular Weight:

There is an inverse relationship between BPA Return Temperature and molecular weight. As the BPA Return Temperature increases, the molecular weight decreases, indicating lighter components in the mixture. Conversely, as the BPA Return Temperature decreases, the molecular weight increases, indicating heavier components in the mixture.

V.5.3 Top pump around flow effect:

Table V-6: The effect of changing Top pump around flow on ASTM D86 (5%, 95%) and molecular weight.

	Current value	Changed value
first adjustment: TPA flow (m^3/h)	847	880
ASTM D86 5% (°C)	173.5	174.4
ASTM D86 95 % (°C)	216.3	216.2
Molecular weight(g/mole)	152.1	152.2
Second adjustment: TPA flow(m^3/h)	847	820
ASTM D86 5% (°C)	173.5	172.6
ASTM D86 95 % (°C)	216.3	216.4
Molecular weight(g/mole)	152.1	152

V.5.3.1 Results interpretation

After changing the top pump around flow value, we noticed a slight change in all values.

V.5.4 Bottom pump around flow effect:

Table V-7: The effect of changing bottom pump around flow on ASTM D86 (5%, 95%) and molecular weight

	Current value	Changed value
first adjustment: BPA flow (m^3/h)	956	995
ASTM D86 5% (°C)	173.5	174.3
ASTM D86 95 % (°C)	216.3	216.4
Molecular weight(g/mole)	152.1	152.3
Second adjustment: BPA flow(m^3/h)	956	920
ASTM D86 5% (°C)	173.5	172.5
ASTM D86 95 % (°C)	216.3	216.2
Molecular weight(g/mole)	152.1	151.9

V.5.4.1 Results interpretation

After changing the bottom pump around flow value, we noticed a slight change in all values.

V.5.5 Reflux flow effect:

Table V-8: The effect of changing the reflux flow on ASTM D86 (5%, 95%) and molecular weight.

	Current value	Changed value
first adjustment: Reflux flow (m^3/h)	649	600
ASTM D86 5% (°C)	173.5	149.9
ASTM D86 95 % (°C)	216.3	217.2
Molecular weight(g/mole)	152.1	149.7
Second adjustment: Reflux flow(m^3/h)	649	700
ASTM D86 5% (°C)	173.5	178.8
ASTM D86 95 % (°C)	216.3	215.7
Molecular weight(g/mole)	152.1	152.7

V.5.5.1 Results interpretation

Decreasing the reflux flow rate results in a significant reduction in the ASTM D86 5% temperature. This decrease in reflux flow rate also leads to a decrease in the molecular weight of the mixture.

Conversely, increasing the reflux flow rate results in a notable increase in the ASTM D86 5% temperature.

Additionally, this increase in reflux flow rate leads to an increase in the molecular weight of the mixture.

Concerning ASTM D86 95%, the value varies by ± 1 °C in both cases.

V.5.6 Light gas oil flow effect:

Table V-9: The effect of changing LGO flow on ASTM D86 (5%, 95%) and molecular weight.

	Current value	Changed value
first adjustment: LGO flow (m^3/h)	313.9	305
ASTM D86 5% (°C)	173.5	178.9
ASTM D86 95 % (°C)	216.3	218.9
Molecular weight(g/mole)	152.1	154.7
Second adjustment: **LGO** flow(m^3/h)	313.9	317
ASTM D86 5% (°C)	173.5	171.8
ASTM D86 95 % (°C)	216.3	214.9
Molecular weight(g/mole)	152.1	151.1

V.5.6.1 Results interpretation

The ASTM D86 5% and 95% distillation temperatures show an inverse relationship with the flow rate. As the flow rate decreases, the distillation temperatures increase, and as the flow rate increases, the distillation temperatures decrease.

Molecular weight appears to be inversely proportional to the LGO flow rate. As the flow rate increases, the molecular weight decreases and vice versa.

V.5.7 Heavy gas oil flow effect:

Table V-10: The effect of changing HGO flow on ASTM D86 (5%, 95%) and molecular weight.

	Current value	Changed value
first adjustment: HGO flow (m^3/h)	61	58
ASTM D86 5% (°C)	173.5	175.1
ASTM D86 95 % (°C)	216.3	217.3
Molecular weight(g/mole)	152.1	153

Second adjustment: HGO flow(m^3/h)	61	64
ASTM D86 5% (°C)	173.5	171.8
ASTM D86 95 % (°C)	216.3	214.9
Molecular weight(g/mole)	152.1	151.1

V.5.7.1 Results interpretation

The ASTM D86 5% and 95% distillation temperatures show an inverse relationship with the flow rate. As the flow rate decreases, the distillation temperatures increase, and as the flow rate increases, the distillation temperatures decrease.

Molecular weight appears to be inversely proportional to the HGO flow rate. As the flow rate increases, the molecular weight decreases and vice versa.

V.5.8 Top Column pressure effect:

Table V-11: The effect of changing Top Column pressure on ASTM D86 (5%, 95%) and molecular weight

	Current value	Changed value
first adjustment: Column pressure (kg/cm2.g)	1	1.4
ASTM D86 5% (°C)	173.5	176.5
ASTM D86 95 % (°C)	216.3	216.5
Molecular weight(g/mole)	152.1	153.6
first adjustment: Column pressure (kg/cm2.g)	1	0.85
ASTM D86 5% (°C)	173.5	171.6
ASTM D86 95 % (°C)	216.3	216.2
Molecular weight(g/mole)	152.1	151.7

V.5.8.1 Results interpretation

After changing the Top Column pressure value, we found that ASTM D86 5% is inversely proportional to it, and with a considered value.

Molecular weight also is inversely proportional to flow rate changes, but in slight values.

Concerning ASTM D86 95%, the value varies by ± 1 °C in both cases.

V.5.9 Feed temperature effect

Table V-12: The effect of changing Feed temperature on ASTM D86 (5%, 95%) and molecular weight.

	Current value	Changed value
first adjustment: Feed temperature (°C)	339	330
ASTM D86 5% (°C)	173.5	176
ASTM D86 95 % (°C)	216.3	216.6
Molecular weight(g/mole)	152.1	152.6
second adjustment: Feed temperature (°C)	339	349[(2)]
ASTM D86 5% (°C)	173.5	161.1
ASTM D86 95 % (°C)	216.3	216.1
Molecular weight(g/mole)	152.1	150.5

V.5.9.1 Results interpretation

Feed Temperature and Distillation Temperatures:

There is an inverse relationship between feed temperature and the ASTM D86 5%. As the feed temperature decreases, the ASTM D86 5% increases, and as the feed temperature increases, the initial boiling point decreases.

The ASTM D86 95% remains relatively stable with only minor changes, suggesting it is less sensitive to variations in feed temperature compared to the ASTM D86 5%.

Feed Temperature and Molecular Weight:

There is an inverse relationship between feed temperature and molecular weight. As the feed temperature decreases, the molecular weight increases, indicating heavier components in the feed. Conversely, as the feed temperature increases, the molecular weight decreases, indicating lighter components in the feed.

V.5.10 Residue flow effect

Table V-13: The effect of changing Residue flow on ASTM D86 (5%, 95%) and molecular weight

	Current value	Changed value
first adjustment: Residue flow (m^3/h)	303.5	313
ASTM D86 5% (°C)	173.5	162.7
ASTM D86 95 % (°C)	216.3	211
Molecular weight(g/mole)	152.1	148.7
Second adjustment: Residue flow (m^3/h)	303.5	290
ASTM D86 5% (°C)	173.5	182.8
ASTM D86 95 % (°C)	216.3	219.9
Molecular weight(g/mole)	152.1	156.2

V.5.10.1Results interpretation

- Residue Flow and Distillation Temperatures:

There is an inverse relationship between residue flow and the distillation temperatures. As the residue flow increases, both the initial and final boiling points decrease. Conversely, as the residue flow decreases, both the initial and final boiling points increase.

- Residue Flow and Molecular Weight:

There is an inverse relationship between residue flow and molecular weight. As the residue flow increases, the molecular weight decreases, indicating lighter components in the kerosene. Conversely, as the residue flow decreases, the molecular weight increases, indicating heavier components in the kerosene.

V.5.11 Results summary

To manage ASTM D86 5% temperatures effectively, we should focus on adjusting reflux flow rate, TPA return temperature LGO, HGO and residue flow rate. These parameters have significant impacts on the initial boiling point, in addition the BPA return temperature, also might help us to moderate slightly the ASTM D86 5%.

To manage ASTM D86 95% temperatures and molecular weight effectively, we should focus on adjusting LGO flow rate, HGO flow rate and residue flow. These parameters have significant impacts and should be carefully controlled to achieve the desired distillation outcomes.

The remaining operating parameters (TPA, BPA flow rates, column pressure, feed temperature) had a very slight effect and are not reliable during optimization procedures.

V.6 Starting the optimization

V.6.1 First case:

Increase the ASTM distillation cuts (95%, 5%) and MW by decreasing LGO flow rate. (HGO and Residue flow rates are maintained fix)

The results are mentioned in the figure bellow

Specifications

	Specified Value	Current Value
Reflux Rate	649,0 m3/h	649,0
PA_1_Rate(Pa)	847,0 m3/h	846,7
PA_1_TRet(Pa)	170,0 C	170,0
BPA_Rate(Pa)	956,0 m3/h	956,0
BPA_TRet(Pa)	237,0 C	237,0
Btms Prod Rate	303,5 m3/h	303,5
STRIP KERO Prod Flow	136,8 m3/h	136,8
LGO STRIP Prod Flow	313,9 m3/h	269,1
HGO STRIP Prod Flow	61,00 m3/h	61,00
Vap Prod Rate	505,9 m3/h	515,5
D86 à 5% kero	180,0 C	184,6
D86 à 95% kero	230,0 C	230,0
D86 à 5% LGO	226,0 C	235,1
D86 à 95% LGO	<empty>	342,2
D86 à5% HGO	<empty>	275,0
D86 à95% HGO	<empty>	380,6

Figure V-3: Atmospheric column operating parameters, cuts ASTM D86 results after first optimization.

This modification gives us a satisfactory results regarding the project LAB requirements.

However, we observe that the LGO flow rate has decreased significantly, dropping from 313.9m^3/h to 269.1m^3/h, such a situation would lead to a significant disruption in the supply to the national market.

V.6.2 Second case:

Increase the ASTM distillation cuts (95%, 5%) and MW by decreasing a maximal amount of LGO, HGO and residue flow rates successively, without affecting the supply of national market.

The results are mentioned in the figure bellow:

Specifications

	Specified Value	Current Value
Reflux Rate	649,0 m3/h	649,0
PA_1_Rate(Pa)	847,0 m3/h	847,1
PA_1_TRet(Pa)	170,0 C	170,0
BPA_Rate(Pa)	956,0 m3/h	955,9
BPA_TRet(Pa)	237,0 C	237,0
Btms Prod Rate	290,0 m3/h	290,0
STRIP KERO Prod Flow	136,8 m3/h	136,8
LGO STRIP Prod Flow	286,5 m3/h	286,5
HGO STRIP Prod Flow	58,00 m3/h	57,99
Vap Prod Rate	505,9 m3/h	514,7
D86 à 5% kero	180,0 C	190,0
D86 à 95% kero	230,0 C	230,0
D86 à 5% LGO	<empty>	235,9
D86 à 95% LGO	<empty>	354,5
D86 à5% HGO	<empty>	277,9
D86 à95% HGO	<empty>	391,5

Figure V-4: Atmospheric column operating parameters, cuts ASTM D86 results after Second optimization.

For unstable naphtha, ASTM D86 95% is shown in figure blow:

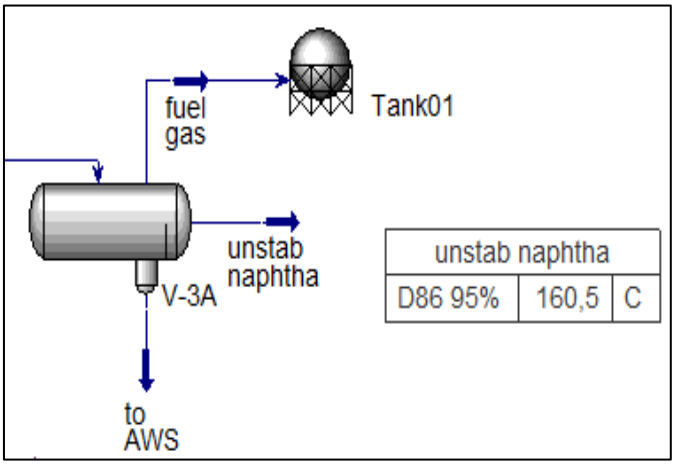


Figure V-5: Unstabilized naphtha ASTM D86 (95%) after Second optimization**.**

- **Kerosene specifications after second case**

Freezing point: -46.88°C.

Molecular weight:165.1g/mol.

Specific gravity: 0.7963

These modifications give us an unsatisfactory results regarding to the ASTM D86 5% and the freezing point required by project LAB and JET A-1 specification successively.

V.6.3 The last case:

Decreasing ASTM D86 5% distillation cut, molecular weight, and freezing point can be achieved by reducing the reflux rate or/and increasing the return temperature of TPA.

It is worth noting that the TPA return temperature can be changed from 163°C to 221°C. (See the operating manual)

V.6.3.1 The first option:

By reducing reflux rate only, the results are mentioned in the figure bellow:

Specifications

	Specified Value	Current Value
Reflux Rate	**520,0 m3/h**	520,0
PA_1_Rate(Pa)	**847,0 m3/h**	847,1
PA_1_TRet(Pa)	**170,0 C**	170,0
BPA_Rate(Pa)	**956,0 m3/h**	956,0
BPA_TRet(Pa)	**237,0 C**	237,0
Btms Prod Rate	**290,0 m3/h**	290,0
STRIP KERO Prod Flow	**136,8 m3/h**	136,8
LGO STRIP Prod Flow	**286,5 m3/h**	286,5
HGO STRIP Prod Flow	**58,00 m3/h**	58,00
Vap Prod Rate	**505,9 m3/h**	514,7
D86 à 5% kero	**180,0 C**	178,9
D86 à 95% kero	**230,0 C**	231,0
D86 à 5% LGO	**<empty>**	235,9
D86 à 95% LGO	**<empty>**	354,5
D86 à5% HGO	**<empty>**	277,9
D86 à95% HGO	**<empty>**	391,6

Figure V-6: Atmospheric column operating parameters, cuts ASTM D86 results after the first option of the last optimization.

V.6.3.2 The second option:

By increasing TPA return temperature only, the results are mentioned in the figure bellow:

Specifications

	Specified Value	Current Value
Reflux Rate	649,0 m3/h	649,0
PA_1_Rate(Pa)	847,0 m3/h	847,4
PA_1_TRet(Pa)	203,0 C	203,0
BPA_Rate(Pa)	956,0 m3/h	955,9
BPA_TRet(Pa)	237,0 C	237,0
Btms Prod Rate	290,0 m3/h	290,0
STRIP KERO Prod Flow	136,8 m3/h	136,8
LGO STRIP Prod Flow	286,5 m3/h	286,5
HGO STRIP Prod Flow	58,00 m3/h	57,99
Vap Prod Rate	505,9 m3/h	514,7
D86 à 5% kero	180,0 C	179,9
D86 à 95% kero	230,0 C	230,9
D86 à 5% LGO	<empty>	236,0
D86 à 95% LGO	<empty>	354,5
D86 à5% HGO	<empty>	277,9
D86 à95% HGO	<empty>	391,5

***Figure* V-7:** Atmospheric column operating parameters, cuts ASTM D86 results after the second option of the last optimization.

V.6.3.3 The third option:

by reducing the reflux rate and increasing the TPA return temperature, the results are mentioned in the figure bellow:

Specifications

	Specified Value	Current Value
Reflux Rate	580,0 m3/h	580,0
PA_1_Rate(Pa)	847,0 m3/h	847,0
PA_1_TRet(Pa)	185,0 C	185,0
BPA_Rate(Pa)	956,0 m3/h	955,9
BPA_TRet(Pa)	237,0 C	237,0
Btms Prod Rate	290,0 m3/h	290,0
STRIP KERO Prod Flow	136,8 m3/h	136,8
LGO STRIP Prod Flow	286,5 m3/h	286,5
HGO STRIP Prod Flow	58,00 m3/h	57,99
Vap Prod Rate	505,9 m3/h	514,7
D86 à 5% kero	180,0 C	180,0
D86 à 95% kero	230,0 C	230,9
D86 à 5% LGO	<empty>	235,9
D86 à 95% LGO	<empty>	354,5
D86 à5% HGO	<empty>	277,9
D86 à95% HGO	<empty>	391,5

Figure V-8: Atmospheric column operating parameters, cuts ASTM D86 results after the third option of the last optimization.

for unstable naphtha, ASTM D86 95% is shown in figure blow

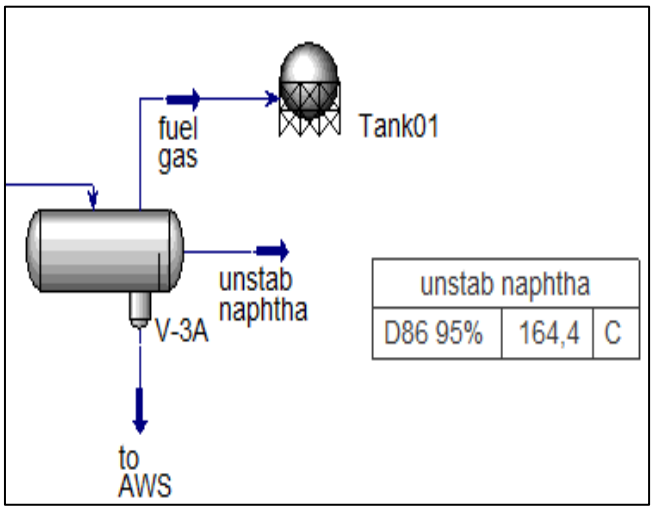


Figure V-9: Unstabilized naphtha ASTM D86 (95%) after last optimization.

- **kerosene specifications after the optimum case**

Freezing point: -48.5 (°C):

Molecular weight:163.9 (g/mol)

Specific gravity:0.7951

Flash point (°C):24(°C)

Smoke point:51(°C)

Operating with these parameters enables us to achieve our desired objective of producing linear alkylbenzene without affecting the properties of JET A-1, while also avoiding the over-lap between the ASTM D86 95% distillation cut for unstable naphtha and ASTM D86 5% distillation cut for kerosene, and ASTM D86 95% distillation cut for kerosene and the ASTM D86 5% distillation cut for LGO.

General Conclusion

During our internship at Skikda refinery, we gained invaluable professional experience that depended our understanding of the atmospheric distillation unit (U-10). Our graduation research topic focused on improving the quality of produced kerosene to meet the requirements of recently contracted project for linear alkyl benzene project. We acquired extensive information's to simulate this unit.

We carried out a simulation (design case) for the atmospheric distillation unit (U10) at the Skikda refinery (RA1K), verifying the suitability of Peng Robinson model for this simulation by calculating the Gap for various operational conditions and achieving low values. Subsequently, we performed an actual simulation (actual case) for the same unit on April 25th2024, validating it through similar Gap calculations and obtaining low values as well.

The main objective of our work is to improve the quality of kerosene produced by the atmospheric distillation unit (U10) at the Skikda refinery (RA1K). This involves optimizing the ASTM D86 (5 %, 95%) as well as the molecular weight, in order to satisfy the feedstock specifications required for the LAB project.

To understand the optimization mechanism, we initially studied the impacts of adjusting the operating parameters on the specifications of the kerosene mentioned previously.

We found that effectively managing ASTM D86 distillation temperatures and molecular weight requires a precise focus on key parameters such as reflux flow rate, TPA and BPA return temperatures, LGO and HGO flow rates, and residue flow rate. While other operational factors such as column pressure and feed temperature have minimal impact and can be ignored during the optimization procedure.

Based on the previous results, we implemented an improvement process that went through several cases to enhance ASTM distillation cuts and molecular weight (MW).

In the first case, reducing the light gas oil (LGO) flow rate yielded satisfactory outcomes for achieving LAB project requirements, but with possible effects on national market supply due to a significant reduction in LGO flow.

In the second case, to maintain national market supply stability, we minimized the maximum values of LGO, HGO and residue flow rates. However, this adjustment did not satisfy

the ASTM D86 5 % of kerosene required by the LAB complex and the freezing point of JET A1.

In the last case, based on the results obtains in the second case and in order to Decrease both of ASTM D86 5% and freezing point, we reduced the reflux rate and increase the TPA return temperature.

In this case, we obtained kerosene with the specifications of LAB project and maintained the properties of JETA1, while also avoiding the over-lap between petroleum fractions.

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Annexes

Annexe A: MATERIAL BALANCE FOR CRUDE DISTILLATION UNIT - I

PROPERTIES OF PSEUDO-COMPONENTS

S. No	Component	NBP °C	MW	Sp Gr
1	NBP[1]151*	150.84	115.64	0.773
2	NBP[1]162*	161.93	121.52	0.784
3	NBP[1]173*	173.49	127.27	0.793
4	NBP[1]185*	184.90	133.11	0.801
5	NBP[1]197*	196.77	140.33	0.809
6	NBP[1]208*	208.07	147.45	0.817
7	NBP[1]220*	219.94	155.37	0.822
8	NBP[1]231*	231.32	163.46	0.828
9	NBP[1]243*	243.30	171.98	0.836
10	NBP[1]254*	254.39	180.43	0.842
11	NBP[1]266*	265.87	188.90	0.846
12	NBP[1]278*	277.85	198.20	0.849
13	NBP[1]290*	289.70	208.87	0.852
14	NBP[1]301*	301.34	221.29	0.854
15	NBP[1]313*	312.92	234.30	0.856
16	NBP[1]324*	324.36	246.24	0.860
17	NBP[1]336*	335.91	256.47	0.869
18	NBP[1]348*	347.65	266.51	0.878
19	NBP[1]359*	359.42	277.63	0.886
20	NBP[1]367*	367.00	285.33	0.890
21	NBP[1]371*	370.96	289.20	0.892
22	NBP[1]375*	374.88	292.92	0.894
23	NBP[1]379*	378.83	296.39	0.896
24	NBP[1]383*	382.89	299.70	0.897
25	NBP[1]387*	386.86	303.02	0.898
26	NBP[1]391*	390.80	306.58	0.900
27	NBP[1]395*	394.77	310.51	0.901
28	NBP[1]399*	398.74	314.75	0.902
29	NBP[1]403*	402.72	319.19	0.904
30	NBP[1]407*	406.69	323.86	0.905
31	NBP[1]411*	410.60	328.61	0.907
32	NBP[1]415*	414.64	333.25	0.908
33	NBP[1]419*	418.61	338.00	0.910
34	NBP[1]423*	422.62	343.21	0.911
35	NBP[1]427*	426.66	349.01	0.913
36	NBP[1]431*	430.62	354.92	0.916
37	NBP[1]434*	434.49	359.53	0.918
38	NBP[1]438*	438.47	363.53	0.921
39	NBP[1]442*	442.44	367.38	0.923

PROPERTIES OF PSEUDO-COMPONENTS

S. No	Component	NBP °C	MW	Sp Gr
40	NBP[1]447*	446.54	371.92	0.926
41	NBP[1]450*	450.39	377.23	0.928
42	NBP[1]454*	454.26	382.91	0.931
43	NBP[1]458*	458.40	387.91	0.933
44	NBP[1]462*	462.40	392.24	0.936
45	NBP[1]466*	466.31	396.48	0.938
46	NBP[1]470*	470.28	400.62	0.940
47	NBP[1]474*	474.24	404.68	0.942
48	NBP[1]478*	478.21	408.66	0.944
49	NBP[1]482*	482.18	412.69	0.946
50	NBP[1]486*	486.16	417.00	0.948
51	NBP[1]490*	490.14	421.55	0.949
52	NBP[1]494*	494.12	426.07	0.950
53	NBP[1]498*	498.09	430.45	0.951
54	NBP[1]502*	502.07	434.70	0.953
55	NBP[1]506*	506.05	438.85	0.954
56	NBP[1]510*	510.03	442.88	0.956
57	NBP[1]514*	514.00	446.80	0.958
58	NBP[1]518*	517.97	450.63	0.960
59	NBP[1]522*	521.96	454.37	0.962
60	NBP[1]526*	525.94	457.94	0.964
61	NBP[1]530*	529.90	461.38	0.967
62	NBP[1]534*	533.87	464.80	0.969
63	NBP[1]538*	537.85	468.26	0.972
64	NBP[1]542*	541.83	471.77	0.974
65	NBP[1]546*	545.80	475.36	0.976
66	NBP[1]550*	549.77	479.04	0.979
67	NBP[1]554*	553.73	482.79	0.981
68	NBP[1]558*	557.75	486.62	0.983
69	NBP[1]562*	561.73	490.57	0.985
70	NBP[1]566*	565.71	494.67	0.987
71	NBP[1]570*	569.67	498.96	0.989
72	NBP[1]574*	573.63	503.46	0.990
73	NBP[1]578*	577.59	508.23	0.992
74	NBP[1]582*	581.56	513.30	0.994
75	NBP[1]586*	585.54	518.73	0.995

Stream Name	Feed	Desalter Water	Brine	Steam	Kerosene	LGO	LGO + EXCESS KERO
Flow Rate (kg/hr)	1130618	70004	72892	14421	93751	251800	259599
Composition, wt%							
H20	0.50	100.00	100.00	100.00	0.00	0.09	0.09
C1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2	0.05	0.00	0.00	0.00	0.00	0.00	0.00
C3	0.87	0.00	0.00	0.00	0.00	0.00	0.00
C4P	2.93	0.00	0.00	0.00	0.00	0.00	0.00
C5P	3.60	0.00	0.00	0.00	0.01	0.01	0.01
C6P	3.48	0.00	0.00	0.00	0.05	0.03	0.03
C7P	4.19	0.00	0.00	0.00	0.27	0.11	0.11
C8P	3.91	0.00	0.00	0.00	0.94	0.25	0.27
C9P	1.44	0.00	0.00	0.00	1.02	0.18	0.21
C10P	-	-	-	-	-	-	-
C5N	0.16	0.00	0.00	0.00	0.00	0.00	0.00
C6N	3.07	0.00	0.00	0.00	0.13	0.06	0.06
C7N	-	-	-	-	-	-	-
C8N	2.31	0.00	0.00	0.00	0.64	0.17	0.19
C9N	0.92	0.00	0.00	0.00	0.77	0.14	0.16
C6A	0.38	0.00	0.00	0.00	0.01	0.00	0.00
C7A	0.51	0.00	0.00	0.00	0.06	0.02	0.02
C8A	0.74	0.00	0.00	0.00	0.38	0.08	0.09
C9A	-	-	-	-	-	-	-
NBP[1]151*	2.61	0.00	0.00	0.00	3.34	0.45	0.54
NBP[1]162*	3.01	0.00	0.00	0.00	8.10	0.74	0.96
NBP[1]173*	2.63	0.00	0.00	0.00	14.16	0.92	1.32

NBP[1]185*	2.72	0.00	0.00	0.00	22.13	1.40	2.02
NBP[1]197*	2.76	0.00	0.00	0.00	23.83	2.13	2.78
NBP[1]208*	2.67	0.00	0.00	0.00	18.38	4.22	4.64
NBP[1]220*	2.56	0.00	0.00	0.00	5.25	8.97	8.86
NBP[1]231*	2.47	0.00	0.00	0.00	0.48	10.36	10.07
NBP[1]243*	2.54	0.00	0.00	0.00	0.03	10.66	10.34
NBP[1]254*	2.45	0.00	0.00	0.00	0.00	10.09	9.79
NBP[1]266*	1.88	0.00	0.00	0.00	0.00	7.53	7.30
NBP[1]278*	1.54	0.00	0.00	0.00	0.00	5.87	5.70
NBP[1]290*	1.57	0.00	0.00	0.00	0.00	5.63	5.46
NBP[1]301*	1.80	0.00	0.00	0.00	0.00	5.94	5.76
NBP[1]313*	2.03	0.00	0.00	0.00	0.00	5.99	5.81
NBP[1]324*	2.14	0.00	0.00	0.00	0.00	5.45	5.29
NBP[1]336*	2.10	0.00	0.00	0.00	0.00	4.32	4.19
NBP[1]348*	2.12	0.00	0.00	0.00	0.00	3.22	3.13
NBP[1]359*	2.39	0.00	0.00	0.00	0.00	2.40	2.33
NBP[1]367*	0.90	0.00	0.00	0.00	0.00	0.64	0.62
NBP[1]371*	0.91	0.00	0.00	0.00	0.00	0.53	0.51
NBP[1]375*	0.89	0.00	0.00	0.00	0.00	0.42	0.40
NBP[1]379*	0.82	0.00	0.00	0.00	0.00	0.30	0.29
NBP[1]383*	0.75	0.00	0.00	0.00	0.00	0.21	0.20
NBP[1]387*	0.72	0.00	0.00	0.00	0.00	0.15	0.14
NBP[1]391*	0.73	0.00	0.00	0.00	0.00	0.11	0.11

Stream Name	Feed	Desalter Water	Brine	Steam	Kerosene	LGO	LGO + EXCESS KERO
NBP[1]395*	0.71	0.00	0.00	0.00	0.00	0.07	0.07
NBP[1]399*	0.67	0.00	0.00	0.00	0.00	0.05	0.05
NBP[1]403*	0.64	0.00	0.00	0.00	0.00	0.03	0.03
NBP[1]407*	0.61	0.00	0.00	0.00	0.00	0.02	0.02
NBP[1]411*	0.56	0.00	0.00	0.00	0.00	0.01	0.01
NBP[1]415*	0.52	0.00	0.00	0.00	0.00	0.01	0.01
NBP[1]419*	0.52	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]423*	0.55	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]427*	0.66	0.00 NBP[1]530	0.00	0.00	0.00	0.00	0.00
NBP[1]431*	0.68	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]434*	0.66	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]438*	0.60	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]442*	0.62	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]447*	0.70	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]450*	0.80	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]454*	0.73	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]458*	0.60	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]462*	0.57	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]466*	0.58	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]470*	0.57	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]474*	0.55	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]478*	0.52	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]482*	0.48	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]486*	0.45	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]490*	0.42	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]494*	0.39	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]498*	0.37	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]502*	0.35	0.00	0.00	0.00	0.00	0.00	0.00

NBP[1]506*	0.33	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]510*	0.32	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]514*	0.30	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]518*	0.29	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]522*	0.28	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]526*	0.27	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]530*	0.26	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]534*	0.25	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]538*	0.25	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]542*	0.24	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]546*	0.23	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]550*	0.23	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]554*	0.22	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]558*	0.21	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]562*	0.21	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]566*	0.21	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]570*	0.21	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]574*	0.21	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]578*	0.21	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]582*	0.21	0.00	0.00	0.00	0.00	0.00	0.00
NBP[1]586*	0.22	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Annexe B: Stream Summary FOR CRUDE DISTILLATION UNIT

SKIKDA REFINERY REHABILITATION ADAPTATION PROJECT

STREAM ID	UNIT	1	2	3	4	5
NAME		CRUDE INLET	CRUDE TO E-107	CRUDE TO E-72	CRUDE FROM E72	CRUDE TO E-2
PHASE		LIQUID	LIQUID	LIQUID	Wet LIQUID	Wet LIQUID
TEMPERATURE	C	15	20	33	55	50
PRESSURE	KG/CM2G	0.3	15.5	14.8	14.1	10.7
* TOTAL STREAM *						
RATE	KG/HR	1130618	1200622	1200622	1200622	1127730
RATE	KG-MOL/HR	7844.5	11730.4	11730.4	11730.4	7684.2
ENTHALPY	M*KCAL/HR	-601.298	-864.620	-856.948	-843.120	-571.298
(BULK) DENSITY	KG/M3	803.1	810.8	800.7	783.0	776.1
MW	KG/KG MOLE	144.1	102.4	102.4	102.4	146.8
WT FRAC LIQUID		1.0	1.0	1.0	1.0	1.0
CRIT. TEMP	C	346.1	355.4	355.4	355.4	345.5
CRIT. PRES.	KG/CM2	33.4	96.7	96.7	96.7	29.5
RVP	PSIA	11.27	11.27	11.27	11.27	11.27

STREAM ID	UNIT	6	7	8	9	10
NAME		LGO FROM E-72	CRUDE FROM E2	VAPOR FROM V-1	PRETOPPED CRUDE	CRUDE FROM E82
PHASE		Wet LIQUID	Wet LIQUID	WET VAPOR	Wet LIQUID	Wet LIQUID
TEMPERATURE	C	153	148	140	140	151
PRESSURE	KG/CM2G	1.9	9.7	3.0	3.0	30.1
* TOTAL STREAM *						
RATE	KG/HR	251800	1127730	79574	1048156	1048156
RATE	KG-MOL/HR	1365.6	7684.2	1203.2	6481.0	6481.0
ENTHALPY	M*KCAL/HR	-114.917	-510.783	-38.973	-471.810	-464.482
(BULK) DENSITY	KG/M3	739.7	692.9	8.1	713.9	709.3
MW	KG/KG MOLE	184.4	146.8	66.1	161.7	161.7
WT FRAC LIQUID		1.0	1.0	0.0	1.0	1.0
CRIT. TEMP	C	442.3	345.5	211.7	370.4	370.4
CRIT. PRES.	KG/CM2	20.8	29.5	56.2	24.5	24.5
RVP	PSIA	---	11.27	47.81	5.43	5.43

STREAM ID	UNIT	11	12	13	14	15
NAME		CRUDE FROM E61	CRUDE FROM E83	LIQ_CRUD_91	LIQ_CRUD_90	LIQ_CRUD_62
PHASE		Wet LIQUID	Wet LIQUID	Wet LIQUID	Wet LIQUID	Wet LIQUID
TEMPERATURE	C	174	186	195	226	233
PRESSURE	KG/CM2G	28.9	27.5	26.5	25.8	24.9
* TOTAL STREAM *						
RATE	KG/HR	1048156	1048156	1048156	1048156	1048156
RATE	KG-MOL/HR	6481.0	6481.0	6481.0	6481.0	6481.0
ENTHALPY	M*KCAL/HR	-449.650	-441.922	-435.922	-414.736	-409.936
(BULK) DENSITY	KG/M3	688.4	677.2	668.3	637.0	629.3
MW	KG/KG MOLE	161.7	161.7	161.7	161.7	161.7
WT FRAC LIQUID		1.0	1.0	1.0	1.0	1.0
CRIT. TEMP	C	370.4	370.4	370.4	370.4	370.4
CRIT. PRES.	KG/CM2	24.5	24.5	24.5	24.5	24.5
RVP	PSIA	5.43	5.43	5.43	5.43	5.43

STREAM ID	UNIT	16	17	18	19	20
NAME		LIQ_CRUD_63	TOPPA_OUT_91	BOT_PA	TOP_PA	TOPPA_OUT_61
PHASE		Wet LIQUID	Wet LIQUID	Wet LIQUID	Wet LIQUID	Wet LIQUID
TEMPERATURE	C	260	203	292	219	163
PRESSURE	KG/CM2G	23.5	9.2	2.2	2.0	8.3
* TOTAL STREAM *						
RATE	KG/HR	1048156	590023	844990	590023	590023
RATE	KG-MOL/HR	6481.0	4129.3	3560.0	4129.3	4129.3
ENTHALPY	M*KCAL/HR	-390.471	-248.415	-304.341	-242.415	-263.247
(BULK) DENSITY	KG/M3	596.8	653.9	659.7	637.1	690.4
MW	KG/KG MOLE	161.7	142.9	237.4	142.9	142.9
WT FRAC LIQUID		1.0	1.0	1.0	1.0	1.0
CRIT. TEMP	C	370.4	385.4	492.0	385.4	385.4
CRIT. PRES.	KG/CM2	24.5	22.9	16.3	22.9	22.9
RVP	PSIA	5.43	0.61	0.49	0.61	0.61

STREAM ID	UNIT	21	22	23	24	25
NAME		BOTPA_OUT_62	BOTPA_OUT_90	RCO	RCO_OUT_63	RCO_OUT_83
PHASE		Wet LIQUID	Wet LIQUID	Wet LIQUID	Wet LIQUID	Wet LIQUID
TEMPERATURE	C	275	237	338	242	200
PRESSURE	KG/CM2G	9.3	8.6	2.3	17.1	15.6
* TOTAL STREAM *						
RATE	KG/HR	844990	844991	299001	299001	299001
RATE	KG-MOL/HR	3560.0	3560.0	857.2	857.2	857.2
ENTHALPY	M*KCAL/HR	-314.630	-335.817	-99.475	-118.719	-126.447
(BULK) DENSITY	KG/M3	676.7	708.0	691.1	765.3	794.8
MW	KG/KG MOLE	237.4	237.4	348.8	348.8	348.8
WT FRAC LIQUID		1.0	1.0	1.0	1.0	1.0
CRIT. TEMP	C	492.0	492.0	596.8	596.8	596.8
CRIT. PRES.	KG/CM2	16.3	16.3	13.7	13.7	13.7
RVP	PSIA	0.49	0.49	---	---	---

STREAM ID	UNIT	26	27	28	29	30
NAME		KERO_PDT	LGO_PDT	LGO_OUT_107	HGO_PDT	HGO_OUT_82
PHASE		Wet LIQUID	Wet LIQUID	Wet LIQUID	Wet LIQUID	Wet LIQUID
TEMPERATURE	C	230	241	97	284	155
PRESSURE	KG/CM2G	2.0	2.1	1.5	2.2	1.3
* TOTAL STREAM *						
RATE	KG/HR	101550	251800	251800	90629	90629
RATE	KG-MOL/HR	753.3	1365.6	1365.6	360.6	360.6
ENTHALPY	M*KCAL/HR	-40.981	-101.090	-122.589	-33.485	-40.811
(BULK) DENSITY	KG/M3	614.1	665.4	782.3	678.8	778.6
MW	KG/KG MOLE	134.8	184.4	184.4	251.3	251.3
WT FRAC LIQUID		1.0	1.0	1.0	1.0	1.0
CRIT. TEMP	C	374.5	442.3	442.3	512.3	512.3
CRIT. PRES.	KG/CM2	23.2	20.8	20.8	17.0	17.0
RVP	PSIA	---	---	---	---	---

STREAM ID	UNIT	31	32	33	34	35
NAME		HEATER_OUT	2ND_VAP	STM_RCO	REFLUX	VAP_KERO
PHASE		MIXED	WET VAPOR	WATER VAPOR	Wet LIQUID	WATER VAPOR
TEMPERATURE	C	356	172	330	135	215
PRESSURE	KG/CM2G	2.3	1.8	2.9	1.3	1.9
* TOTAL STREAM *						
RATE	KG/HR	1048156	980442	8498	581271	44295
RATE	KG-MOL/HR	6481.0	10254.8	471.7	5106.8	365.6
ENTHALPY	M*KCAL/HR	-278.675	-375.644	-26.078	-245.872	-14.656
(BULK) DENSITY	KG/M3	12.1	7.7	1.4	653.9	9.4
MW	KG/KG MOLE	161.7	95.6	18.0	113.8	121.2
WT FRAC LIQUID		0.1	0.0	0.0	1.0	0.0
CRIT. TEMP	C	370.4	294.4	374.1	318.4	339.5
CRIT. PRES.	KG/CM2	24.5	46.9	224.5	27.3	26.4
RVP	PSIA	5.43	9.86	---	2.04	1.90

STREAM ID	UNIT	36	37	38	39	40
NAME		KEROD	VAP_LGO	LGOD	VAP_HGO	HGOD
PHASE		Wet LIQUID	WATER VAPOR	WET LIQUID	WET VAPOR	WET LIQUID
TEMPERATURE	C	199	248	255	288	292
PRESSURE	KG/CM2G	1.9	2.1	2.1	2.2	2.2
* TOTAL STREAM *						
RATE	KG/HR	145845	49159	296563	12311	101413
RATE	KG-MOL/HR	1118.9	551.2	1672.8	151.4	427.3
ENTHALPY	M*KCAL/HR	-61.136	-27.413	-115.012	-7.727	-36.526
(BULK) DENSITY	KG/M3	635.8	6.6	642.4	5.6	659.7
MW	KG/KG MOLE	130.4	89.2	177.3	81.3	237.4
WT FRAC LIQUID		1.0	0.0	1.0	0.0	1.0
CRIT. TEMP	C	363.0	372.1	429.1	377.8	492.0
CRIT. PRES.	KG/CM2	24.3	108.7	20.1	131.3	16.3
RVP	PSIA	0.69	2.33	0.48	2.77	0.49

STREAM ID	UNIT	41	42	43	44	45
NAME		2nd VAPOR_2	CR OVHD	CR OVHD_92	GAS	UNSTAB_NAP
PHASE		MIXED	WET VAPOR	WET LIQUID	WET VAPOR	WET LIQUID
TEMPERATURE	C	135	135	40	39	39
PRESSURE	KG/CM2G	1.3	1.3	0.8	0.6	0.6
* TOTAL STREAM *						
RATE	KG/HR	980442	399170	399170	2375	380249
RATE	KG-MOL/HR	10254.8	5147.9	5147.9	45.4	4184.1
ENTHALPY	M*KCAL/HR	-436.159	-190.290	-248.264	-1.326	-184.344
(BULK) DENSITY	KG/M3	13.3	5.5	691.1	3.3	683.9
MW	KG/KG MOLE	95.6	77.5	77.5	52.4	90.9
WT FRAC LIQUID		0.5	0.0	1.0	0.0	1.0
CRIT. TEMP	C	294.4	270.6	270.6	140.7	249.3
CRIT. PRES.	KG/CM2	46.9	66.3	66.3	47.6	31.7
RVP	PSIA	9.86	19.54	19.54	126.49	18.60

STREAM ID	UNIT	46	47	48	49	50
NAME		UNSNAP_P	SOUR_WATER	UNSTAB_P	STM_HGO	STM_LGO
PHASE		WET LIQUID	WATER	WET LIQUID	WATER VAPOR	WATER VAPOR
TEMPERATURE	C	39	39	39	330	330
PRESSURE	KG/CM2G	13.4	0.6	13.4	2.9	2.9
* TOTAL STREAM *						
RATE	KG/HR	3710	16547	376539	1527	4396
RATE	KG-MOL/HR	40.8	918.5	4143.3	84.8	244.0
ENTHALPY	M*KCAL/HR	-1.797	-62.593	-182.380	-4.686	-13.490
(BULK) DENSITY	KG/M3	685.1	996.8	685.1	1.4	1.4
MW	KG/KG MOLE	90.9	18.0	90.9	18.0	18.0
WT FRAC LIQUID		1.0	1.0	1.0	0.0	0.0
CRIT. TEMP	C	249.3	374.1	249.3	374.1	374.1
CRIT. PRES.	KG/CM2	31.7	224.5	31.7	224.5	224.5
RVP	PSIA	18.60	---	18.60	---	---

STREAM ID	UNIT	51	52	53	54	55
NAME		LGO_RUN	HGO_RUN	STAB_FEED_P	KEROPDT_P	KERO_PDT_10
PHASE		WET LIQUID	WET LIQUID	WET LIQUID	WET LIQUID	WET LIQUID
TEMPERATURE	C	40	40	39	231	127
PRESSURE	KG/CM2G	4.0	4.0	13.4	9.4	8.2
* TOTAL STREAM *						
RATE	KG/HR	251800	90629	382417	101550	101550
RATE	KG-MOL/HR	1365.6	360.6	4223.7	753.3	753.3
ENTHALPY	M*KCAL/HR	-129.700	-46.139	-185.474	-40.943	-47.552
(BULK) DENSITY	KG/M3	824.6	859.5	684.3	615.6	712.6
MW	KG/KG MOLE	184.4	251.3	90.5	134.8	134.8
WT FRAC LIQUID		1.0	1.0	1.0	1.0	1.0
CRIT. TEMP	C	442.3	512.3	248.2	374.5	374.5
CRIT. PRES.	KG/CM2	20.8	17.0	31.8	23.2	23.2
RVP	PSIA	---	---	19.39	---	---

STREAM ID	UNIT	56	57	58	59	60
NAME		KERO_PDT_8	KERO_RUN	NAPC_9	C-62_COND3	RCO_OUT_8
PHASE		WET LIQUID	WET LIQUID	LIQUID	WATER	WET LIQUID
TEMPERATURE	C	50	40	132	43	119
PRESSURE	KG/CM2G	7.6	4.0	10.8	7.0	14.4
* TOTAL STREAM *						
RATE	KG/HR	101550	93751	128347	18	299001
RATE	KG-MOL/HR	753.3	695.4	1162.0	1.0	857.2
ENTHALPY	M*KCAL/HR	-51.624	-48.105	-53.017	-0.068	-140.007
(BULK) DENSITY	KG/M3	774.6	781.9	649.5	993.5	850.1
MW	KG/KG MOLE	134.8	134.8	110.5	18.0	348.8
WT FRAC LIQUID		1.0	1.0	1.0	1.0	1.0
CRIT. TEMP	C	374.5	374.5	308.8	374.1	596.8
CRIT. PRES.	KG/CM2	23.2	23.2	27.9	224.5	13.7
RVP	PSIA	---	---	1.28	---	---

Annexe C: TBP data

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TELECOPIE DE RESULTATS

I. Principales Caractéristiques du Pétrole :

Tableau I.1 : Caractéristiques physico-chimiques du pétrole alimentant la raffinerie de SKIKDA « RA1K »

Caractéristiques	Méthodes	Unité	Résultats
Masse volumique à 20°C	ASTM D5002-18	g/cm³	0,7975
Masse volumique à 15°C	ASTM D1250-Tables 53A	g/cm³	0,8012
Specific Gravity 60/60°F			0,8020
°API			44,9
Tension de vapeur Reid, (TVR) à 37,8°C (100 °F)	ASTM D323	KPa mm Hg psi	59,2 444 8,58
Viscosité cinématique à 20 °C	ASTM D445	cSt	3,225
Viscosité cinématique à 37,8 °C	ASTM D445	cSt	2,235
***Teneur en soufre par Ray X**	ASTM D4294-21	% Pds ppm	0,0647
Pouvoir Calorifique Supérieur	ASTM D240	Kcal/ Kg	11 010,7
Pouvoir Calorifique Inferieur	Calcul	Kcal/ Kg	10 259,2
Teneur en sels	ASTM D6470	% Pds ppm	< 0,0005 < 5

« Seuls les résultats d'essais repérés par le symbole * sont effectués sous le couvert de l'accréditation »

- *La conversion de la masse volumique de 20°C à 15°C du pétrole brut est effectuée selon la table 53A de l'ASTM D1250 après annulation de la correction incorporée dans ces tables pour représenter l'expansion thermique du verre de l'aéromètre. Le verre de la cellule du densimètre n'est pas soumis à la dilatation.*

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TELECOPIE DE RESULTATS

II. Distillation « True Boiling Point » TBP du Pétrole :

Tableau II.1 : Composition de la coupe $C5^-$ issue de la distillation TBP du pétrole alimentant la raffinerie de SKIKDA « RA1K »

Constituants	% Massique	% Volumique
Éthane	0,0	0,0
Propane	0,5	0,8
Iso- Butane	0,5	0,7
n-Butane	2,0	2,8
iso Pentane	0,1	0,1
n- Pentane	0,0	0
Total	**3,1**	**4,4**

TELECOPIE DE RESULTATS

Tableau II. 2 : Résultats de la distillation TBP du pétrole alimentant la raffinerie de SKIKDA « RA1K »

N° Fractions	Température en °C à 760 mm Hg	% Poids	% Poids cumulés	*Masse volumique à 20 °C, g/cm³	*Masse volumique à 15 °C, g/cm³	% Volume	% Volumes cumulés	Indice de réfraction à 20°C	KUOP
Légers C_5^-	<15	3,1	3,1	-	0,5623	4,4	4,4	-	-
1	15 - 65	6,3	9,4	0,6452	0,6501	7,6	12,0	-	-
2	65 - 70	0,9	10,3	0,6832	0,6879	1,0	13,0	1,3861	12,34
3	70 - 75	0,8	11,1	0,6933	0,6980	0,9	13,9	1,3904	12,22
4	75 - 80	0,7	11,8	0,7012	0,7059	0,8	14,7	1,3942	12,14
5	80 – 85	0,7	12,5	0,7067	0,7114	0,8	15,5	1,3967	12,10
6	85 - 90	1,0	13,5	0,7106	0,7152	1,1	16,6	1,3985	12,10
7	90 - 95	1,4	14,9	0,7146	0,7192	1,5	18,1	1,4008	12,08
8	95 - 100	1,6	16,5	0,7203	0,7249	1,8	19,9	1,4039	12,04
9	100 - 105	1,3	17,8	0,7257	0,7303	1,4	21,3	1,4066	12,01
10	105 - 110	1,2	19,0	0,7289	0,7335	1,3	22,6	1,4084	12,01
11	110 - 115	1,2	20,2	0,7305	0,7351	1,3	23,9	1,4094	12,03
12	115 - 120	1,3	21,5	0,7324	0,7370	1,4	25,3	1,4107	12,05
13	120 - 125	1,4	22,9	0,7364	0,7410	1,5	26,8	1,4132	12,04
14	125 - 130	1,2	24,1	0,7426	0,7471	1,3	28,1	1,4167	11,99
15	130 - 135	1,2	25,3	0,7484	0,7530	1,3	29,4	1,4202	11,95
16	135 - 140	1,2	26,5	0,7523	0,7568	1,2	30,6	1,4222	11,94
17	140 - 145	1,2	27,7	0,7545	0,7590	1,3	31,9	1,4231	11,95
18	145 - 150	1,2	28,9	0,7570	0,7615	1,3	33,2	1,4246	11,96
19	150 - 155	1,2	30,1	0,7610	0,7655	1,3	34,5	1,4268	11,94
20	155 - 160	1,2	31,3	0,7655	0,7700	1,3	35,8	1,4293	11,92
21	160 - 165	1,3	32,6	0,7695	0,7738	1,4	37,2	1,4317	11,91
22	165 - 170	1,4	34,0	0,7724	0,7766	1,4	38,6	1,4334	11,91
23	170 - 175	1,1	35,1	0,7740	0,7782	1,1	39,7	1,4342	11,93
24	175 - 180	1,0	36,1	0,7763	0,7804	1,1	40,8	1,4355	11,94
25	180 - 185	1,0	37,1	0,7788	0,7828	1,1	41,9	1,4364	11,95
26	185 - 190	1,2	38,3	0,7814	0,7853	1,2	43,1	1,4380	11,95
27	190 - 195	1,1	39,4	0,7844	0,7882	1,1	44,2	1,4398	11,95
28	195 - 200	1,0	40,4	0,7872	0,7910	1,0	45,2	1,4409	11,95
29	200 - 205	1,0	41,4	0,7895	0,7933	1,0	46,2	1,4420	11,96
30	205 - 210	1,1	42,5	0,7911	0,7949	1,1	47,3	1,4427	11,98
31	210 - 215	1,1	43,6	0,7928	0,7965	1,1	48,4	1,4435	11,99
32	215 - 220	1,0	44,6	0,7957	0,7994	1,0	49,4	1,4450	11,99

TELECOPIE DE RESULTATS

Tableau II.2: Résultats de la distillation TBP du pétrole alimentant la raffinerie de SKIKDA « RA1K » (suite)

N° Fractions	Température en °C à 760 mm Hg	% Poids	% Poids cumulés	*Masse volumique à 20 °C, g/cm³	*Masse volumique à 15 °C, g/cm³	% Volume	% Volumes cumulés	Indice de réfraction à 20°C	KUOP
33	220 - 230	2,3	46,9	0,8052	0,8089	2,2	51,6	1,4498	11,91
34	230 - 240	2,2	49,1	0,8084	0,8121	2,1	53,7	1,4522	11,94
35	240 - 250	2,1	51,2	0,8151	0,8187	2,1	55,8	1,4562	11,92
36	250 - 260	2,1	53,3	0,8203	0,8239	2,0	57,8	1,4594	11,92
37	260 - 270	2,0	55,3	0,8249	0,8285	1,9	59,7	1,4618	11,93
38	270 - 280	2,0	57,3	0,8298	0,8334	1,9	61,6	1,4647	11,93
39	280 - 290	1,9	59,2	0,8316	0,8352	1,8	63,4	1,4654	11,98
40	290 - 300	1,7	60,9	0,8345	0,8381	1,6	65,0	1,4676	12,01
41	300 - 310	1,7	62,6	0,8374	0,8410	1,6	66,6	1,4679	12,04
42	310 - 320	2,4	65,0	0,8417	0,8452	2,2	68,8	1,4702	12,05
43	320 - 330	1,6	66,6	0,8472	0,8507	1,5	70,3	1,4734	12,04
44	330 - 340	1,6	68,2	0,8524	0,8559	1,5	71,8	1,4765	12,03
45	340 - 350	1,6	69,8	0,8566	0,8601	1,5	73,3	1,4790	12,04
46	350 - 360	1,7	71,5	0,8596	0,8631	1,6	74,9	1,4808	12,06
47	360 - 370	1,4	72,9	0,8621	0,8656	1,3	76,2	1,4819	12,09
48	370 - 380	1,6	74,5	0,8641	0,8676	1,4	77,6	1,4829	12,12
Résidu	380+	25,5	100,0	-	0,9119	22,4	100,0	-	-

« Seuls les résultats d'essais repérés par le symbole * sont effectués sous le couvert de l'accréditation »

N.B :

- *Le point initial ''PI'' de la distillation TBP de ce pétrole est égale à 15 °C.*
- *La masse volumique de la coupe $C5^-$ est calculée à partir de la composition chromatographique.*
- *La masse volumique de Résidu atmosphérique a été mesurée à une température égale à 70°C et elle est égale à 0,8734 g/cm³.*
- *La détermination de la masse volumique de Résidu atmosphérique n'est pas couverte par l'accréditation.*
- *La conversion des masses volumiques de 20°C à 15 °C des différentes fractions pétrolières, est effectuée selon les tables 53B de l'ASTM D1250, après annulation de la correction incorporée dans ces tables pour représenter l'expansion thermique du verre de l'aéromètre. Le verre de la cellule du densimètre n'est pas soumis à la dilatation.*

Annexe D: stream summery

TIME	CHARGE AND PREHEATRAIN					
	FLOW		TEMP			
	10FI4	10FIC2	10TI1161	10TI1454	10TI1152	10TI171
	PV	PV	PV	PV	PV	PV
	P-71A/B DISCHARGE	P-72A/B/C DISCHARGE	CRUDE AT B/L	10-E-107-5A/B SHELL OUTLET	10-E-72A/B OUTLET	10-V-51 INLET
	m3/hr	m3/hr	DegC	DegC	DegC	DegC
00:00	1268	1347,9	26,51	48,79	77,9	78,0
01:00	1262	1345,6	26,43	48,78	77,9	78,1
02:00	1256	1347,7	26,35	48,76	78,0	78,1
03:00	1250	1346,8	26,31	48,94	78,4	78,5
04:00	1262	1347,7	26,30	48,58	77,8	77,9
05:00	1261	1346,9	26,29	48,55	77,7	77,9
06:00	1263	1346,4	26,24	48,59	77,8	77,9
07:00	1266	1347,2	26,20	48,54	77,7	77,9
08:00	1257	1346,5	26,46	49,02	78,3	78,5
09:00	1260	1348,0	26,72	49,12	78,3	78,4
10:00	1285	1347,5	26,95	48,98	77,7	77,9
11:00	1251	1348,5	27,04	49,90	79,2	79,3
12:00	1258	1348,4	27,17	49,65	78,7	78,8
13:00	1266	1346,9	27,25	49,89	78,8	79,0
14:00	1272	1347,4	27,19	49,75	78,7	78,8
15:00	1265	1346,8	27,18	49,60	78,5	78,6
16:00	1257	1346,9	27,14	49,73	78,8	78,9
17:00	1270	1346,6	27,15	49,59	78,5	78,6
18:00	1268	1346,6	27,01	49,45	78,4	78,5
19:00	1267	1348,8	27,00	49,43	78,4	78,6
20:00	1257	1346,3	27,04	49,53	78,6	78,7
21:00	1267	1346,6	27,06	49,31	78,2	78,4
22:00	1264	1346,8	27,04	49,38	78,4	78,5
23:00	1260	1347,0	27,03	49,40	78,4	78,6
Average						
Total						
Maximum						
Minimum						

TIME	CHARGE AND PREHEATRAIN					
	TEMP					
	10TI170	10TI1153	10TI1	10TI1159	10TI7	10TI1456
	PV	PV	PV	PV	PV	PV
	10-V-51 HDR OUTLET	E-93A-H OUTLET	V-1 PREFLASH DRUM LIQUID OUTLET	E-82A OULET	E-82B OUTLET	E-61A-D OUTLET

	DegC	DegC	DegC	DegC	DegC	DegC
00:00	78,3	148,8	144,2	147,6	154,0	174,1
01:00	78,1	148,6	143,9	147,3	153,8	174,0
02:00	78,4	148,8	144,1	147,5	154,0	174,1
03:00	78,6	149,2	144,4	147,7	154,1	174,2
04:00	78,2	149,1	144,4	147,8	154,3	174,4
05:00	78,1	149,0	144,3	147,7	154,1	174,3
06:00	78,1	148,5	143,9	147,2	153,7	173,8
07:00	78,0	148,5	143,8	147,1	153,6	173,9
08:00	78,4	149,0	144,1	147,4	153,8	174,1
09:00	78,8	149,5	144,7	148,0	154,4	174,6
10:00	78,1	148,4	143,8	147,2	153,5	173,9
11:00	79,0	149,0	144,1	147,4	153,8	174,0
12:00	79,3	151,4	146,2	149,4	155,7	175,5
13:00	79,0	150,9	146,0	149,3	155,6	175,5
14:00	79,1	150,7	145,9	149,2	155,5	175,4
15:00	78,9	151,0	146,0	149,3	155,5	175,3
16:00	79,0	150,8	145,9	149,2	155,5	175,4
17:00	78,9	150,2	145,3	148,7	155,0	175,0
18:00	78,7	150,3	145,3	148,7	154,9	174,9
19:00	78,7	150,3	145,3	148,6	154,9	174,9
20:00	78,9	150,6	145,6	148,9	155,1	175,0
21:00	78,7	150,5	145,5	148,8	155,0	175,0
22:00	78,6	150,3	145,4	148,7	154,9	174,9
23:00	78,8	150,5	145,5	148,7	154,9	174,9
Average						
Total						
Maximum						
Minimum						

TIME	CHARGE AND PREHEATRAIN					
	TEMP					
	10TI1160	10TI8	10TI10	10TI12	10TI1460	10TI1461
	PV	PV	PV	PV	PV	PV
	E-83A OUTLET	E-83B OUTLET	E-91 OUTLET	E-90A/B OUTLET	E-62 OUTLET	E-63A/B OUTLET
	DegC	DegC	DegC	DegC	DegC	DegC
00:00	178,9	187,2	196,1	220,7	232,6	240,3
01:00	178,7	187,0	195,9	220,6	232,4	240,2
02:00	178,8	187,1	196,0	220,7	232,5	240,3
03:00	178,9	187,2	196,1	220,7	232,5	240,3
04:00	179,3	187,6	196,4	221,0	232,8	240,6
05:00	179,1	187,4	196,3	221,0	232,8	240,6
06:00	178,6	186,8	195,9	220,5	232,4	240,1

07:00	178,6	186,9	196,0	220,7	232,6	240,2
08:00	178,8	187,0	196,2	220,8	232,6	240,3
09:00	179,5	187,8	196,8	221,3	233,0	240,8
10:00	178,7	186,9	196,1	220,6	232,4	240,2
11:00	178,7	186,8	196,0	220,5	232,4	239,9
12:00	179,9	187,8	197,0	221,6	233,4	240,6
13:00	180,0	188,0	197,1	221,9	233,5	240,8
14:00	180,0	187,9	197,0	221,9	233,6	240,9
15:00	179,9	187,8	196,9	221,6	233,3	240,5
16:00	179,9	187,8	197,0	221,7	233,5	240,6
17:00	179,7	187,7	196,8	221,6	233,4	240,7
18:00	179,6	187,6	196,7	221,3	233,1	240,5
19:00	179,5	187,5	196,6	221,3	233,1	240,5
20:00	179,7	187,8	196,8	221,2	232,9	240,4
21:00	179,7	187,7	196,8	221,1	232,9	240,4
22:00	179,5	187,6	196,6	220,9	232,7	240,2
23:00	179,5	187,5	196,6	220,9	232,7	240,1
Average						
Total						
Maximum						
Minimum						

TIME	CHARGE AND PREHEATRAIN				
	PRESS				
	10PI1152	10PDI213	10PI40	10PIC1351	10PIC1
	PV	PV	PV	PV	PV
	CRUDE AT B/L	DESALTER MIXING VALVE DEL. P	V-51 DESALTER OUTLET	LV-2 INLET PRESSURE	V-1 PREFLASH DRUM VAPOR OUTLET
	kg/cm2	kg/cm2	kg/cm2	kg/cm2	kg/cm2
00:00	0,630	0,601	8,31	5,58	3,000
01:00	0,630	0,595	8,29	5,57	3,000
02:00	0,630	0,590	8,27	5,55	3,001
03:00	0,627	0,584	8,32	5,58	3,001
04:00	0,577	0,592	8,31	5,57	3,001
05:00	0,520	0,590	8,31	5,58	2,999
06:00	0,468	0,591	8,28	5,55	3,001
07:00	0,630	0,594	8,34	5,59	3,001
08:00	0,630	0,587	8,33	5,59	3,001
09:00	0,630	0,589	8,35	5,61	3,001
10:00	0,630	0,609	8,34	5,60	2,999
11:00	0,630	0,510	8,35	5,60	3,000
12:00	0,621	0,442	8,35	5,61	3,003
13:00	0,571	0,522	8,36	5,62	3,000
14:00	0,508	0,322	8,34	5,60	3,000

15:00	0,451	0,217	8,30	5,58	3,000
16:00	0,499	0,525	8,34	5,60	3,001
17:00	0,630	0,602	8,36	5,62	3,001
18:00	0,630	0,601	8,35	5,61	3,000
19:00	0,630	0,601	8,35	5,62	3,002
20:00	0,630	0,564	8,35	5,61	3,000
21:00	0,630	0,538	8,35	5,61	3,001
22:00	0,630	0,575	8,34	5,61	3,001
23:00	0,630	0,581	8,35	5,61	3,000
Average					
Total					
Maximum					
Minimum					

TIME	DESALTER	DESALTER			C-1 ATMOSPHERIC COLUMN	
	TEMP	TEMP	PRESS		FLOW	
	10TI171	10TI170	10PDI213	10PI40	10FIC5	10FIC43
	PV	PV	PV	PV	PV	PV
	V-51 DESALTER INLET	V-51 DESALTER OUTLET	DESALTER MIXING VALVE DEL. P	V-51 DESALTER OUTLET	RESIDUE TO STORAGE	BOTTOM PUMP AROUND RETURN
	DegC	DegC	kg/cm2	kg/cm2	m3/hr	m3/hr
00:00	78,0	78,3	0,601	8,31	306,3	957
01:00	78,1	78,1	0,595	8,29	300,5	959
02:00	78,1	78,4	0,590	8,27	298,4	958
03:00	78,5	78,6	0,584	8,32	303,8	956
04:00	77,9	78,2	0,592	8,31	313,4	956
05:00	77,9	78,1	0,590	8,31	311,1	956
06:00	77,9	78,1	0,591	8,28	299,7	958
07:00	77,9	78,0	0,594	8,34	304,6	954
08:00	78,5	78,4	0,587	8,33	307,8	954
09:00	78,4	78,8	0,589	8,35	317,3	950
10:00	77,9	78,1	0,609	8,34	310,1	953
11:00	79,3	79,0	0,510	8,35	304,2	954
12:00	78,8	79,3	0,442	8,35	293,5	955
13:00	79,0	79,0	0,522	8,36	295,9	958
14:00	78,8	79,1	0,322	8,34	297,5	954
15:00	78,6	78,9	0,217	8,30	292,4	954
16:00	78,9	79,0	0,525	8,34	291,5	956
17:00	78,6	78,9	0,602	8,36	295,1	956
18:00	78,5	78,7	0,601	8,35	297,1	957
19:00	78,6	78,7	0,601	8,35	297,4	956
20:00	78,7	78,9	0,564	8,35	300,7	955

21:00	78,4	78,7	0,538	8,35	301,4	960
22:00	78,5	78,6	0,575	8,34	300,7	953
23:00	78,6	78,8	0,581	8,35	298,9	956
Average						
Total						
Maximum						
Minimum						

TIME	C-1 ATMOSPHERIC COLUMN						C-1 ATMOSPHERIC COLUMN
	FLOW						TEMP
	10FIC1751	10FIC40	10FI42	10FIC1752	10FI80	10FI81	10TI2055
	PV	PV	PV	PV	PV	PV	PV
	TOP PUMP AROUND RETURN	REFLUX	SUPERHEATED LP STEAM TO C-1	BACK UP MS TO C-1	FUEL GAS TO V-3	OFF GAS FROM V-3 TO BD	RESIDUE TO STORAGE
	m3/hr	m3/hr	kg/hr	kg/hr	Nm3/hr	Nm3/hr	DegC
00:00	848	645	7898	1	0,0	3	71,2
01:00	849	645	7952	1	0,0	3	70,8
02:00	849	646	7922	1	0,0	3	70,8
03:00	848	644	7921	1	0,0	3	71,2
04:00	848	644	7828	1	0,0	3	72,2
05:00	847	644	7865	1	0,0	3	72,6
06:00	848	644	7979	1	10,7	3	71,2
07:00	847	644	7968	1	0,0	3	70,8
08:00	847	643	7933	1	0,0	3	71,5
09:00	846	643	7767	1	0,0	138	74,1
10:00	846	642	7880	1	0,0	3	74,0
11:00	846	642	7965	1	0,0	3	73,1
12:00	846	645	7906	1	0,0	3	71,6
13:00	848	656	7873	1	0,0	4	72,5
14:00	848	657	7823	1	0,0	3	72,6
15:00	847	649	7866	1	0,0	4	72,8
16:00	848	654	7900	2	0,0	3	71,8
17:00	847	656	7847	2	0,0	3	72,9
18:00	848	656	7804	1	0,0	3	73,5
19:00	848	657	7783	1	0,0	3	73,2
20:00	847	657	7742	2	0,0	6	74,7
21:00	847	656	7728	2	0,0	6	74,7
22:00	847	657	7714	2	0,0	6	74,3
23:00	848	657	7745	2	0,0	3	73,6
Average							
Total							
Maximum							

Minimum							

TIME	C-1 ATMOSPHERIC COLUMN					
	TEMP					
	10TI90	10TI89	10TI86	10TI87	10TI85	10TI83
	PV	PV	PV	PV	PV	PV
	RESIDUE AT C-1 BOTTOM	FLASH ZONE	BPA DRAW TEMP	BPA RETURN TEMP	TPA DRAW TEMP	TPA RETURN TEMP
	DegC	DegC	DegC	DegC	DegC	DegC
00:00	329,9	337,0	295,0	240,8	216,1	170,0
01:00	329,6	336,6	295,6	240,7	216,2	169,8
02:00	329,8	337,0	296,1	240,8	216,2	169,9
03:00	329,6	336,8	296,3	240,8	216,1	170,0
04:00	329,7	336,8	296,3	240,8	216,3	170,3
05:00	329,8	336,8	296,5	240,8	216,0	170,1
06:00	329,7	336,8	296,0	240,7	216,2	169,7
07:00	329,9	336,9	296,7	240,8	216,2	169,7
08:00	329,8	336,8	296,0	240,8	216,3	169,9
09:00	329,7	336,9	295,9	240,9	216,5	170,4
10:00	329,6	336,7	296,2	240,5	216,5	169,7
11:00	329,8	336,9	296,2	240,8	216,4	169,8
12:00	330,2	337,0	296,5	241,1	216,4	171,3
13:00	329,8	336,7	296,2	240,8	216,2	171,4
14:00	330,1	336,8	296,4	240,8	216,1	171,3
15:00	329,7	336,5	296,1	240,6	216,2	171,3
16:00	330,1	337,0	296,8	240,9	216,2	171,3
17:00	330,1	336,9	296,8	240,7	216,3	170,9
18:00	329,9	336,7	296,3	240,6	216,1	170,8
19:00	330,3	337,2	296,0	240,8	216,1	170,7
20:00	329,6	336,7	296,6	240,6	216,5	170,9
21:00	329,7	336,9	297,0	240,8	216,3	170,8
22:00	329,6	336,8	296,8	240,7	216,1	170,7
23:00	329,9	337,0	296,0	240,8	216,2	170,7
Average						
Total						
Maximum						
Minimum						

TIME	C-1 ATMOSPHERIC COLUMN					
	TEMP					
	10TI81	10TIC1180	10TI1955	10TI82	10TI84	10TI86
	PV	PV	PV	PV	PV	PV
	ATM COLUMN TOP	V-2	V-3	KEROSENE DRAW	LGO DRAW	HGO DRAW

	DegC	DegC	DegC	DegC	DegC	DegC
00:00	166,2	131,7	46,54	200,2	257,5	297,3
01:00	166,3	131,5	45,47	199,9	257,2	297,0
02:00	167,0	131,7	46,96	199,5	256,7	297,1
03:00	166,1	132,2	46,22	200,3	257,7	297,1
04:00	166,5	132,0	48,13	200,1	257,1	297,1
05:00	165,9	131,9	47,17	200,5	257,8	297,1
06:00	165,8	131,4	45,99	200,0	257,6	297,3
07:00	165,9	131,3	45,73	200,2	257,8	297,4
08:00	166,0	131,9	46,46	200,5	258,0	297,4
09:00	166,1	132,5	49,43	200,7	257,8	297,3
10:00	166,2	131,3	47,23	200,7	258,1	297,1
11:00	166,5	132,1	45,65	200,8	258,5	297,5
12:00	166,3	134,3	47,27	202,7	259,7	298,2
13:00	166,3	133,9	47,73	200,4	257,6	297,6
14:00	166,1	133,9	48,89	200,2	257,3	297,6
15:00	166,4	134,0	47,49	201,5	258,9	297,6
16:00	166,8	133,8	46,67	200,8	257,9	297,8
17:00	166,1	133,4	47,48	200,0	257,4	297,5
18:00	165,8	133,4	48,04	200,0	257,5	297,4
19:00	165,9	133,4	48,44	199,9	257,5	297,6
20:00	166,0	133,8	49,46	200,2	257,6	297,2
21:00	166,1	133,7	49,83	200,4	257,7	297,4
22:00	166,2	133,6	49,58	200,3	257,7	297,3
23:00	166,1	133,7	49,24	200,4	257,9	297,6
Average						
Total						
Maximum						
Minimum						

TIME	C-1 ATMOSPHERIC COLUMN				SIDE STRIPPERS	
	PRESS				FLOW	
	10PI14	10PI13	10PIC15	10PI2056	10FIC3	10FIC2051
	PV	PV	PV	PV	PV	PV
	FLASH ZONE	ATM COLUMN TOP	V-3	RESIDUE TO STORAGE (B/L)	KERO TO STORAGE OR U-20	EXCESS KERO TO LGO
	kg/cm2	kg/cm2	kg/cm2	kg/cm2	m3/hr	m3/hr
00:00	1,723	1,290	0,471	2,39	133,1	0,02
01:00	1,698	1,263	0,433	2,42	133,1	0,02
02:00	1,724	1,292	0,479	2,46	133,3	0,02
03:00	1,717	1,282	0,452	2,45	133,3	0,02
04:00	1,764	1,334	0,538	2,50	133,3	0,02
05:00	1,739	1,307	0,508	2,49	134,5	0,03
06:00	1,700	1,267	0,449	2,49	137,5	0,03

07:00	1,703	1,269	0,448	2,51	137,6	0,03
08:00	1,722	1,291	0,473	2,52	138,4	0,03
09:00	1,799	1,374	0,623	2,56	138,0	0,03
10:00	1,744	1,314	0,541	2,53	138,5	0,03
11:00	1,705	1,270	0,448	2,53	138,4	0,03
12:00	1,732	1,294	0,446	2,44	139,7	0,03
13:00	1,748	1,308	0,473	2,49	136,9	0,03
14:00	1,777	1,340	0,519	2,54	137,2	0,03
15:00	1,743	1,303	0,467	2,47	137,9	0,03
16:00	1,741	1,302	0,506	2,51	138,0	0,03
17:00	1,762	1,323	0,566	2,59	137,1	0,03
18:00	1,778	1,342	0,597	2,60	137,3	0,03
19:00	1,788	1,351	0,615	2,63	137,5	0,03
20:00	1,806	1,372	0,642	2,65	137,8	0,03
21:00	1,819	1,385	0,667	2,66	137,7	0,03
22:00	1,812	1,377	0,654	2,66	138,3	0,03
23:00	1,803	1,368	0,637	2,69	138,3	0,03
Average						
Total						
Maximum						

TIME	SIDE STRIPPERS					
	FLOW				TEMP	
	10FIC47	10FIC46	10FIC1851	10FIC1852	10TI2	10TI1855
	PV	PV	PV	PV	PV	PV
	LGO TO STORAGE	HGO TO STORAGE	MP STEAM TO C-3	MP STEAM TO C-4	KERO TO STORAGE	LGO TO STORAGE
	m3/hr	m3/hr	kg/hr	kg/hr	DegC	DegC
00:00	315,5	62,1	1401	749	53,12	26,12
01:00	315,5	62,4	1399	750	53,19	26,14
02:00	315,9	63,0	1400	748	52,95	26,18
03:00	315,9	60,9	1399	752	53,30	26,42
04:00	315,0	63,2	1400	749	53,70	26,50
05:00	313,8	62,5	1399	751	55,33	26,96
06:00	314,6	61,8	1400	750	56,24	26,93
07:00	315,0	60,9	1401	751	55,60	26,92
08:00	315,0	60,4	1400	749	56,58	27,25
09:00	313,7	61,6	1400	749	58,74	27,94
10:00	313,5	60,9	1400	749	59,87	28,55
11:00	314,3	61,7	1400	748	59,75	29,56
12:00	308,8	59,7	1400	747	60,48	29,75
13:00	314,6	60,6	1400	750	59,35	30,11
14:00	315,3	61,3	1400	751	59,60	30,33
15:00	310,0	59,8	1400	750	60,62	30,34

16:00	312,1	60,2	1400	749	60,22	30,18
17:00	314,1	61,4	1400	748	59,98	30,27
18:00	314,1	60,4	1399	750	60,15	30,31
19:00	314,8	60,6	1401	750	60,33	30,45
20:00	313,2	59,8	1399	749	61,67	30,59
21:00	312,6	60,2	1400	749	61,77	30,37
22:00	312,8	59,9	1399	750	61,68	30,18
23:00	312,4	59,8	1401	749	61,29	30,01
Average						
Total						
Maximum						

TIME	SIDE STRIPPERS						
	TEMP					PRESS	
	10TI1856	10TI92	10TIC19	10TI98	10TI95	10PI1858	10PI1857
	PV	PV	PV	PV	PV	PV	PV
	HGO TO STORAGE	C-2 BOTTOM LIQUID	C-2 REBOILER RETURN	C-3 BOTTOM LIQUID	C-4 BOTTOM LIQUID	LGO TO STORAGE (B/L)	HGO TO STORAGE (B/L)
	DegC	DegC	DegC	DegC	DegC	kg/cm2	kg/cm2
00:00	25,41	226,7	234,8	242,8	269,9	0,436	0,408
01:00	25,64	226,4	234,5	242,6	269,9	0,467	0,435
02:00	25,71	226,3	234,4	242,1	269,7	0,499	0,462
03:00	25,65	226,6	234,7	243,2	269,5	0,527	0,488
04:00	26,13	226,6	234,7	242,5	269,2	0,559	0,520
05:00	26,42	226,8	235,0	243,0	269,5	0,588	0,548
06:00	26,39	226,2	234,7	242,9	268,5	0,621	0,579
07:00	26,18	226,5	235,0	243,3	268,8	0,650	0,609
08:00	26,25	226,7	235,1	243,4	268,9	0,680	0,639
09:00	27,11	226,7	235,2	242,9	269,1	0,709	0,668
10:00	27,70	226,7	235,2	243,3	269,2	0,739	0,698
11:00	28,72	226,7	235,1	243,6	269,0	0,773	0,732
12:00	29,13	228,2	236,9	244,4	269,4	0,809	0,769
13:00	29,64	226,1	234,4	242,6	269,9	0,853	0,812
14:00	30,01	225,9	234,1	242,4	269,3	0,891	0,850
15:00	30,09	226,8	235,1	243,6	269,1	0,921	0,879
16:00	30,02	226,7	235,2	242,8	268,5	0,973	0,932
17:00	29,97	225,7	234,0	242,4	268,3	1,016	0,976
18:00	29,97	225,8	234,1	242,5	268,8	1,057	1,017
19:00	30,09	225,8	234,1	242,5	269,1	1,103	1,062
20:00	30,10	225,8	234,1	242,5	269,3	1,142	1,101
21:00	29,92	226,0	234,3	242,4	269,1	1,185	1,146
22:00	29,54	225,9	234,2	242,6	269,1	1,227	1,187
23:00	29,31	226,0	234,4	242,8	268,7	1,271	1,231

Annexe E : LAB project presentation

Consultant

ACHOUR Bachir

DAO FEED PROJET LAB

PRESENTATION DU PROJET LAB ETPRESTATIONS A REALISER PAR ENG SUR LE DAO DU FEED

4.CHARGES

Les charges pour la production du LAB sont constituées de Kérosène et de benzène. Ces charges proviennent de la raffinerie RAI K.

Les n-paraffines sont les seules à être utilisées pour la production du LAB à partir d'une coupe d'hydrocarbures constituée essentiellement d'hydrocarbures CIO à C 13 provenant du Kérosène les autres coupes de kérosène sont soit retournées au raffinage ou bien vendues en tant que sous-produit.

Les iso paraffines de la coupe CIO à C 13, après extraction des n-paraffines, sont retournées à RA 1K cette coupe de kérosène est commercialisée en tant que Jet Al.

Quantités pour la production de 100 000 tonnes de LAB

Coupe C10 à C 13 du kérosène utilisé hors Kérosène légers et lourds séparés:
4,5095 t par tonne de LAB soit pour 100 000 tonnes de LAB : 450 950 tonnes
Benzène : 0,3588 t par tonne de LAB soit pour 100 000 tonnes de LAB : 35 880 tonnes.

La quantité totale de Kérosène à fournir par RA 1K est supérieur à 450 050 tonnes il faudra ajouter à cette quantité les Kérosènes léger et lourds extraits à déterminer en fonction de la composition exact du kérosène fourni par RA1K.

Spécification du kérosène

La spécification du Kérosène est importante pour les deux paramètres suivants afin d'être utilisé pour la production du LAB:

- Teneur minimale en n-paraffines de 18 % poids.
- Courbe de distillation ASTM:
  5 % de distillat entre 175 et 180 ° C

  95 % de distillat entre 230 et 240 ° C

Interface avec la Zone Industrielle ZIK

Localisation du Complexe LAB

Le Pôle Pétrochimie doit évaluer correctement le choix de la localisation du Complexe parmi les zones possibles suivantes:

- DEV 1:

Nous pensons que ce site doit être réservé pour l'implantation d'installation liées à la mer tel que nouvelle usine de dessalement d'eau de mer, pomperie d'eau de mer pour les nouvelles usines de pétrochimie à installer dans la zone industrielle et nécessitant un grand volume d'eau de refroidissement.

Cette zone peut aussi servir d'assiette pour l'extension du port de Skikda pour les besoins de la pétrochimie dans le cas où cette extension ce fait sur l'est de l'actuel port.

- DEV 2

Cette zone peut recevoir le complexe LAB mais elle va présenter un problème temporaire très important.
Les installations temporaires de réalisation de la rénovation de RA 1K ainsi que de stockage des rebuts actuels issus de la rénovation sont installés dans cette zone. Il faut aussi prendre en considération que RA 1K n'a pas fini son programme d'extension elle doit réaliser avant 2020 des unités HDS selon ARH pour rendre le gasoil et exportable après le démarrage des nouvelles raffineries de Biskra, Hassi Messaoud et Tiaret.
Nous recommandons de ne pas implanter le Complexe LAB sur DEV 2 et laisser cette zone pour les projetsui viendraient après le projet HDS et le LAB.

DEV 5

Cette zone est réservée pour les extensions de RAI K.

DEV 4

Cette zone pourra être utilisée pour l'implantation du Complexe LAB et du projet PTA/PET inscrit dans le dernier plan de développement de la pétrochimie de LRP.

Il faut aussi avoir à l'esprit que le projet CP3K a été annulé et qu'il n'y aura plus probablement de grand complexe intégré nécessitant une grande surface. Il n'y aura plus que petites unités ou de petits complexe pétrochimiques à installer à Skikda qui pourront facilement implanter séparément sur le DEV 4 résiduel, le DEV 2 et les parties de CP 1K libres ou bien à démolir pour implanter de nouvelles unités.

Cette analyse doit être affinée par le Pôle Pétrochimie avec les structures suivantes ZIK, Pôle Raffinage et soumise à l'accord du Vice-Président LRP avant l'octroi du contrat du FEED. L'implantation exact et judicieux du Complexe LAB au sein de de la zone retenue sera effectuée par le consultant du FEED selon les principes à déterminer par Sonatrach.

Le plan de localisation des zones figure dans l'annexe A du présent rapport. PEC doit récupérer dans les des zones à partir des originaux élaborés par ZIK et mis à jour pour inclure un plan de bonne

Annexe F: Calculation of kerosene's molecular weight produced by RA1K

This calculation aims to define the molecular weight (Mw) of the kerosene produced by RA1K ,taking intoaccount various corrections .

- The molecular weight is determined from the characterization factor K_{UOP} using specific gravity and the average boiling temperature of the fraction.

  VOINOV formula :

  $$M=a+bT_m+cT_m^2 \quad (1)$$

- (T_m) is the averge boiling temperature of the fraction in °C
  T_m is calculated as the arithmetic mean of the initial boiling point (PI) and final boiling point(PF) of the fraction:

  $$T_m=\frac{PI+PF}{2} \quad (2)$$

- Contants (a),(b) and (c) depend on the chemical nature of the fraction and are related to K_{UOP} , given by:

  $$K_{UOP}=\frac{\sqrt[3]{Tm}}{SP\ gr60/60} \quad (3)$$

- T_m: average boiling temoerature in Rankine (°R)
- SP gr 60/60 : specific gravity at 60°F.
  Constants for the VOINOV formula :
  The value of constants(a) ,(b)and(c) are provided in a table based on K_{UOP}:

Tab (a),(b) and(c) values.

K_{UOP}	10	10,5	11	11.5	12
a	56	57	59	63	69
b	0,23	0,24	0,24	0,225	0,18
c	0,0008	0,0009	0,0010	0,00115	0,0014

The results

	Unites	Values
PI	°C	160
PF	°C	219
T_m	°R	832,77

SP gr 60/60		0,7891
K_{UOP}		11,92
a		96
b		0,18
c		0,0014
M	g/mol	153,38

Annexe G: Kerosene composition

Activité LRP **Pôle Raffinage** **Raffinerie de Skikda (RA1K)** **Département : Laboratoire**	**bulletuin d'analyse**

V.F.3.3.1 KEROSENE

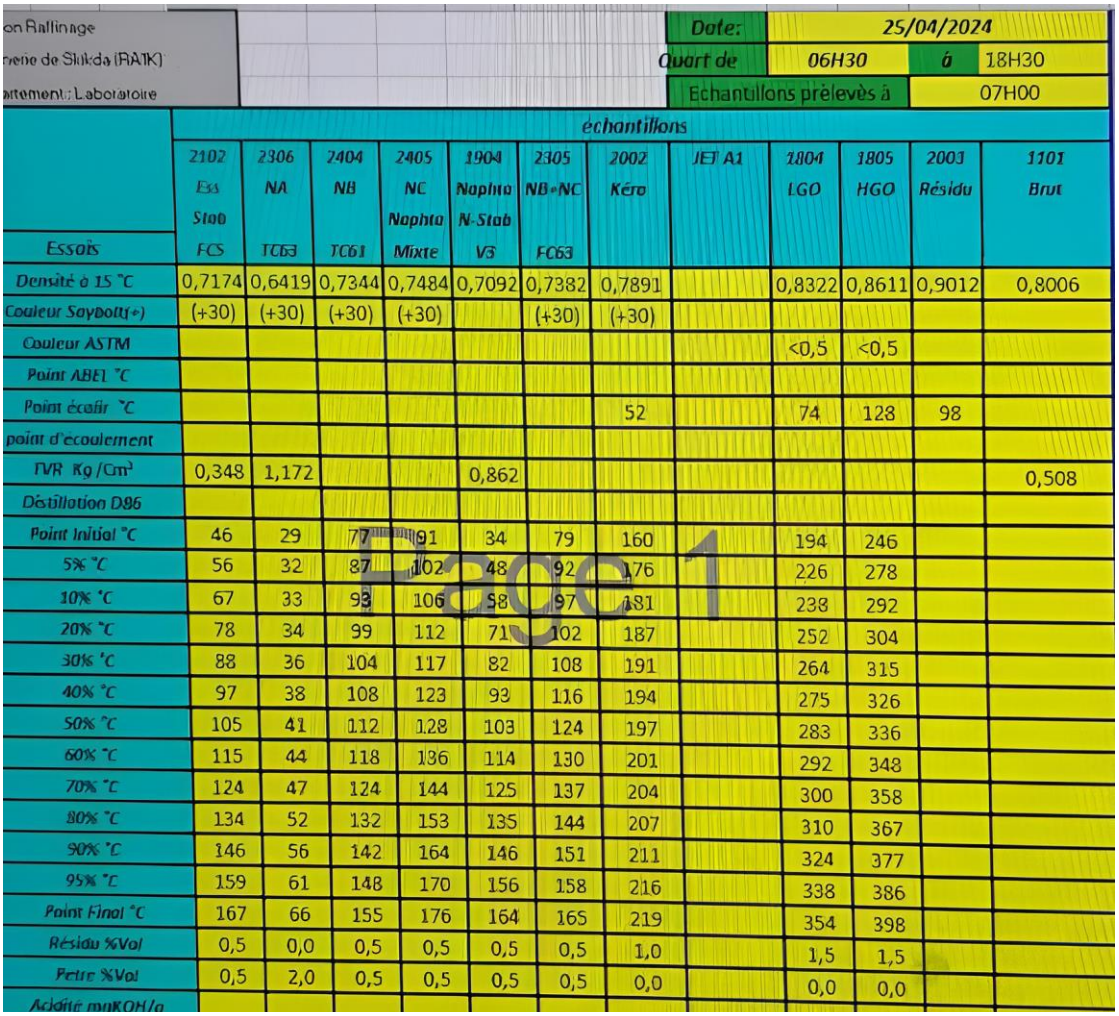
ECHANTILLONS : **UNITE 10**

DATE D'ECHANTILLONAGE : **24/01/2017**

HEURE D'ECHANTILLONS : **13h15**

COPOSISTION (%PDS)	***ISO.PARAFFINES***	***N.PARAFFINES***	**NAPHTENES**	**OLÉFINES**	**AROMATIQUES**	
C4	/	/	/	/	/	
C5	/	/	/	/	/	
C6	/	/	/	/	/	
C7	*0.03*	*0.07*	0.13	/	0.07	
C8	*0.30*	*0.38*	0.55	/	0.52	
C9	*0.98*	*1.19*	1.42	0.1	2.93	
C10	*2.85*	*3.74*	3.40	0.05	7.31	
C11	*6.61*	*8.24*	4.48	0.46	HEAVY AROMATICS	7.84
C12	*6.09*	*7.34*	0.55	/		
C13	*4.02*	*4.72*	0.34			
TOTAL	*20.88*	*25.68*	10.87	0.52	18.67	
C14+	23.38					

Annexe H: Petroleum fractions specifications



on Raffinage
rene de Skikda (RA1K)
irtement: Laboratoire

Date: 25/04/2024
Quart de 06H30 à 18H30
Echantillons prélevés à 07H00

Essais	échantillons											
	2102 Ess Stab FCS	2306 NA TC63	2404 NB TC61	2405 NC Naphta Mixte	1904 Naphta N-Stab V3	2305 NB+NC FC63	2002 Kéro	JET A1	1804 LGO	1805 HGO	2003 Résidu	1101 Brut
Densité à 15 °C	0,7174	0,6419	0,7344	0,7484	0,7092	0,7382	0,7891		0,8322	0,8611	0,9012	0,8006
Couleur Saybolt(+)	(+30)	(+30)	(+30)	(+30)		(+30)	(+30)					
Couleur ASTM									<0,5	<0,5		
Point ABEL °C												
Point éclair °C							52		74	128	98	
point d'écoulement												
TVR Kg/Cm³	0,348	1,172			0,862							0,508
Distillation D86												
Point Initial °C	46	29	77	91	34	79	160		194	246		
5% °C	56	32	87	102	48	92	176		226	278		
10% °C	67	33	93	106	58	97	181		238	292		
20% °C	78	34	99	112	71	102	187		252	304		
30% °C	88	36	104	117	82	108	191		264	315		
40% °C	97	38	108	123	93	116	194		275	326		
50% °C	105	41	112	128	103	124	197		283	336		
60% °C	115	44	118	136	114	130	201		292	348		
70% °C	124	47	124	144	125	137	204		300	358		
80% °C	134	52	132	153	135	144	207		310	367		
90% °C	146	56	142	164	146	151	211		324	377		
95% °C	159	61	148	170	156	158	216		338	386		
Point Final °C	167	66	155	176	164	165	219		354	398		
Résidu %Vol	0,5	0,0	0,5	0,5	0,5	0,5	1,0		1,5	1,5		
Perte %Vol	0,5	2,0	0,5	0,5	0,5	0,5	0,0		0,0	0,0		
Acidité mgKOH/g												

Annexe I: OPERATING MANUAL for crude distillation unit-10

	SKIKDA REFINERY REHABILITATION & ADAPTATION PROJECT	SAMSUNG ENGINEERI

Description	Tag No	Unit	Norm	Max
Crude to Atmospheric column total flow	10-FIC-2	m^3 / h	1468.0	1615.0
MP steam to 10-C-1	10-FIC-1752	Kg/hr	774.0	9347.8
MP steam to 10-C-1	10-FI-42	Kg/hr	7725.0	8497.5
Reflux to column	10-FIC-40	m^3 / h	889.0	977.9
Kero Draw from column	10-LV-5	m^3 / h	229.4	252.3
Top PA to column	10-FIC-1751	m^3 / h	854.6	940.1
LGO Draw from column	10-LV-10	m^3 / h	153.7	169.1
HGO Draw from Column	10-LV-12	m^3 / h	461.6	507.8
Bottom PA to Column	10-FV-43	m^3 / h	1193.6	1313.0
Residue Pump Turbine - MP Steam Flow	10-FI-1755	Kg/hr	7740.0	8800.0
Reflux Pump (10-P-73 A/B) MP Steam Flow	10-FI-1953	Kg/hr	7460.0	9480.0
RCO from Column Bottom	10-FIC-5	m^3 / h	338.6	372.5
Reflux Flow cycled to Recycle Drum	10-LV-6	m^3 / h	181.8	200.0
Unstabilized Naphtha Recycle flow to Reflux Drum	10-LV-1951	m^3 / h	63.6	70.0
Flare Gas flow from 10-V-3 Overhead	10-FI-81	Nm^3 / h	1015.0	1116.0
Column Top Temp	10-TI-81	°C	172.0	245.0
	10-TIC-16	°C	172.0	245.0
Kero Draw Temp	10-TI-82	°C	199.0	278.0
Reflux Temp to column	10-TIC-1180	°C	135.0	166.0
TPA from column temp	10-TI-85	°C	219.0	235.0
T PA return to column	10-TI-83	°C	163.0	221.0
	10-TIC-17	°C	163.0	221.0
LGO Draw from column temp	10-TI-84	°C	255.0	282.0
HGO Draw from Column temp	10-TI-86	°C	292.0	311.0
Bottom PA from Column	10-TI-87	°C	237.0	290.0

Temp	10-TIC-18	°C	237.0	290.0
Column Bottom Temp	10-TI-90	°C	338.0	365.0
Preflash vapor to column	10-TI-1352	°C	226.3	256.0

Description	Tag No	Unit	Norm	Max
Feed Crude to Column	10-TI-80	°C	356.0	425.0
Feed Crude to Column	10-TI-48	°C	356.0	425.0
Overhead Condensate to	10-TI-1955	°C	40.0	70.0
Unstable Naphtha Temp from 10-V-3	10-TI-1956	°C	310.0	365.0
Temperature above the crude feed tray	10-TI-89	°C	338.0	395.0
Residue Pump Turbine - MP Steam Inlet Temp	10-TI-1755	°C	310.0	365.0
Residue Pump Turbine - Steam Outlet Temp	10-TI-1753	°C	206.0	255.0
	10-TI-1958 (L)	°C	226.0	255.0
Reflux Pump Turbine MP Steam Inlet Temp	10-TI-1956	°C	310.0	365.0
Reflux Pump Turbine Steam Outlet Temp	10-TI-1957	°C	226.0	255.0
	10-TI-1958 (L)	°C	226.0	255.0
OVHD Press of 10-C-1	10-PI-13	Kg/ cm²g	1.8	4.0
	10-PI-1755 A/B/C	Kg/ cm²g	1.8	4.0
Pressure above the crude feed tray	10-PI-14	Kg/ cm²g	2.5	4.0
Column Bottom Press	10-PI-54 (L)	Kg/ cm²g	2.3	4.0
Pressure at 10-V-3 (ATM OVHD PDT Drum)	10-PIC-15	Kg/ cm²g	0.6	4.0
	10-PI-57 (L)	Kg/ cm²g	0.6	4.0
Pressure at inlet line to ATM OVHD PDT Drum	10-PI-1955 (L)	Kg/ cm²g	0.8	4.0
Press at 10-V-2 Overhead	10-PI-56 (L)	Kg/ cm²g	1.3	4.0
Reflux Pump suction Press (10-P-73 A/B)	10-PI-76 /78 (L)	Kg/ cm²g	1.3	9.4
Reflux Pump discharge Press (10-P-73 A/B)	10-PI-75 / 77 (L)	Kg/ cm²g	8.3	9.4
Stabilizer Feed Pump suc press (10-P-92 A/B)	10-PI-81 / 83 (L)	Kg/ cm²g	0.6	17.8
Stabilizer Feed Pump Disc press (10-P-92 A/B)	10-PI-80 / 82 (L)	Kg/ cm²g	15.5	17.8
Acid Water Pump (10-P-70 A/B) suction press	10-PI-110/112 (L)	Kg/ cm²g	0.6	6.2
Acid Water Pump (10-P-70 A/B) disch press	10-PI-109 / 111 (L)	Kg/ cm²g	3.5	6.2

Description	Tag No	Unit	Norm	Max
Top PA Pump (10-P-75 A/B) Suct Press	10-PI-59 / 1751 (L)	Kg/ cm²g	2.0	11.6
Top PA Pump (10-P-75 A/B) Disch Press	10-PI-58 / 1752 (L)	Kg/ cm²g	9.9	11.6
Bottom PA Pump (10-P-15 A/B) Suct Press	10-PI-61/63/65 (L)	Kg/ cm²g	2.2	4.0
Bottom PA Pump (10-P-15 A/B) Disch Press	10-PI-60/62/64 (L)	Kg/ cm²g	8.7	9.5
Residue Pump (10-PI-76 A/B) suct press	10-PI-67/69 (L)	Kg/ cm²g	2.3	22.4
Residue Pump (10-PI-76 A/B) disch press	10-PI-66/68 (L)	Kg/ cm²g	18.6	22.4
Residue Pump Turbine - MP Steam Inlet Press	10-PI-1758	Kg/ cm²g	30.0	35.0
	10-PI-1761 (L)	Kg/ cm²g		
Residue Pump Turbine - Steam Outlet Press	10-PI-1760	Kg/ cm²g	3.5	6.0
	10-PI-1759 (L)	Kg/ cm²g	3.5	6.0
Reflux Pump (10-P-73 A/B) MP Steam Inlet Press	10-PI-1961	Kg/ cm²g	30.0	35.0
	10-PI-1964 (L)	Kg/ cm²g		
Reflux Pump (10-P-73 A/B) Steam Outlet Press	10-PI-1963	Kg/ cm²g	3.5	6.0
	10-PI-1962 (L)	Kg/ cm²g	3.5	6.0
Column Bottom level	10-LI-1751	Mm	780 (Low)	
	10-LIC-4	Mm	1182.0 (Low)	2388.0 (High)
	10-LG-6 A~C	Mm		
Reflux Drum liquid Level	10-LIC-6	Mm	675.0 (Low)	1360.0 (High)
	10-LG-8	mm		
Reflux Drum boot liquid interface Level	10-LIC-7	mm	493.0 (Low)	707.0 (High)
	10-LG-9	mm		
OVHD PDT Drum liquid Level	10-LIC-8	mm	2050.0 (Low)	2675.0 (High)
	10-LI-1951 (High-High)	mm		2900.0 (High-High)
	10-LG-10	mm		

Description	Tag No	Unit	Norm	Max
ATM Column OVHD PDT boot liquid interface Level	10-LIC-9	mm	493.0 (Low)	707.0 (High)
	10-LG-11	mm		

Table 3.4 Kero Stripper

Description	Tag No	Unit	Norm	Max
Feed to Kero stripper	10-LV-5	m^3 / h	229.4	252.3
Kero Stripper Bottom Product Flow	10-FV-3	m^3 / h	129.8	142.8
Kero Stripper Feed Temp	10-TI-82	°C	199.0	278.0
Kero Stripper Bottom Temp	10-TI-92	°C	230.0	278.0
Kero Stripper Reboiler Outlet Temp	10-TI-19	°C	232.0	278.0
Kero Stripper Bottom Press	10-PI-55 (L)	Kg/ cm^2g	2.0	4.0
Kero Pump suction press	10-PI-72/74 (L)	Kg/ cm^2g	2.0	11.2
Kero Pump disch press	10-PI-71/73 (L)	Kg/ cm^2g	9.4	11.2
Level in Kero stripper	10-LI-1752 (Low-Low)	mm	700.0 (Low)	
	10-LIC-5	mm	970.0 (Low)	1780.0 (High)
	10-LG-7	mm		

Table 3.5 LGO Stripper

Description	Tag No	Unit	Norm	Max
Feed flow to LGO Stripper	10-LV-12	m^3 / h	461.6	507.8
MP Steam Flow to Stripper	10-FV-1851	Kg/hr	4396.0	4835.6
LGO Stripper Feed Temp	10-TI-84	°C	255.0	282.0
LGO Stripper Bottom Temp	10-TI-98	°C	241.0	282.0
LGO Stripper Bottom Press	10-PI-86 (L)	Kg/ cm^2g	2.1	4.0
LGO Product Pump (10-P-74 A/B) Suct Press	10-PI-93/1859 (L)	Kg/ cm^2g	1.5	13.3
LGO Product Pump (10-P-74 A/B) Disch Press	10-PI-92/1860 (L)	Kg/ cm^2g	10.7	13.3
Level in in LGO Stripper Bottom	10-LIC-12	mm	690.0 (Low)	2210.0 (High)

Table 3.6 HGO Stripper

Description	Tag No	Unit	Norm	Max
Feed flow to HGO Stripper	10-LV-10	m^3 / h	153.7	169.1

MP Steam Flow to Stripper	10-FV-1852	m^3 / h	1527.0	1679.9
HGO Stripper Feed Temp	10-TI-86	°C	292.0	311.0
HGO Stripper Bottom Temp	10-TI-95	°C	284.0	311.0
HGO Stripper Bottom Press	10-PI-84(L)	Kg/ cm^2g	2.2	4.0
HGO Product Pump (10-P-95 A/B) Suct Press	10-PI-89/91 (L)	Kg/ cm^2g	1.3	13.0
HGO Product Pump (10-P-95 A/B) Disch Press	10-PI-88/90 (L)	Kg/ cm^2g	9.1	13.0
Level in HGO Stripper Bottom	10-LIC-10	mm	1020.0 (Low)	2300.0 (High)
	10-LG-12 A~C	mm		

Table 3.7 Stabilizer A (10-C-5)

Description	Tag No	Unit	Norm	Max
10-C-5 Feed Flow	10-FIC-52	m^3 / h	428.8	471.6
10-C-5 Reflux Flow	10-FIC-53	m^3 / h	188.6	207.5
10-C-5 Bottom Flow	10-FIC-54	m^3 / h	394.0	433.4
10-C-5 OVHD Flow Rate	10-PV-2151	m^3 / h	241.3	265.4
10-C-5 OVHD Product Rate	10-FIC-55	m^3 / h	52.6	57.9
10-C-5 reflux drum overhead fuel gas flow rate	10-FI-82	Nm^3 / h		1042.0
	10-PV-21	Nm^3 / h	947.3	1042.0
10-C-5 Feed Temp	10-TI-108	°C	140.0	182.0
10-C-5 OVHD Temp	10-TI-107	°C	60.0	87.0
OVHD liq to Reflux Drum (10-V-8)	10-TI-2157	°C	43.0	70.0
10-C-5 OVHD product temp	10-TI-2193	°C	38.0	65.0
	10-TI-2192 (L)	°C	38.0	65.0
10-C-5 Bottom Temp	10-TI-111	°C	179.0	223.0
Reboiler (10-E-69 A/B) Outlet Temp	10-TIC-2151	°C	189.6	210.0
	10-TIC-2168	°C	189.6	210.0
10-C-5 Reflux Temp	10-TI-112	°C	43.0	70.0
10-C-5 OVHD Press	10-PI-2168 A/B/C	Kg/ cm^2g	7.7	9.8
	10-PI-121	Kg/ cm^2g	7.7	9.8
	10-PIC-2151	Kg/ cm^2g	7.7	9.8
10-C-5 Reflux Pump (10-	10-PI-2170/2171	Kg/ cm^2g	7.0	12.5