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Optimizing of the operating conditions of the atmospheric distillation column T103 of the RA2K topping unit to improve kerosene yield

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DEDICATION

*To my beloved **father and mother**, whose love, patience, and sacrifices have been the foundation of everything I've achieved.*

*To **my dear sister and brother**, for their unwavering support and presence through every step of the journey.*

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CEDRATI Mohamed Elhadi

SCAN ME

DEDICATION

First and foremost, I dedicate this work to ***my father*** *— for every sacrifice he made, every hardship he endured, and every silent burden he carried just to see me become who I am today. Your strength and resilience have always been my greatest motivation.*

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SIFOUR ZIAD

DEDICATION

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And finally, I dedicate this work to my ***younger self***
Okay, to the ***next chapter !***

Bouhaouche Noureddine

Abstract:

This study, conducted as part of a graduation thesis following a practical internship at the RA2K TOPPING complex of the Skikda refinery, focuses on analyzing and improving the performance of the atmospheric distillation column T103 to increase kerosene yield. The theoretical part covers distillation principles, the characteristics of Algerian condensate, and key operational parameters. The practical section relies on realistic simulation using Aspen HYSYS software. The results confirmed the effectiveness of the optimized conditions in boosting kerosene recovery without compromising the quality of other products. The study concludes with technical recommendations suitable for industrial application.

Keywords: Atmospheric distillation, RA2K, T103 column, kerosene, Aspen HYSYS, optimization, yield, condensate, simulation.

Résumé

Cette étude, réalisée dans le cadre d’un mémoire de fin d’études suite à un stage pratique au sein du complexe RA2K TOPPING de la raffinerie de Skikda, porte sur l’analyse et l’optimisation des performances de la colonne de distillation atmosphérique T103 dans le but d’augmenter le rendement en kérosène. La partie théorique couvre les principes de la distillation, les caractéristiques du condensat algérien, ainsi que les paramètres opérationnels influents. La partie pratique s’appuie sur une simulation réaliste via le logiciel Aspen HYSYS. Les résultats ont confirmé l’efficacité des conditions optimisées pour améliorer la récupération de kérosène sans nuire à la qualité des autres fractions. L’étude se conclut par des recommandations techniques applicables à l’échelle industrielle.

Mots clés : Distillation atmosphérique, RA2K, Colonne T103, kérosène, Aspen HYSYS, optimisation, rendement, condensat, simulation.

الملخص

بمصفاة RA2K TOPPING تلخص هذه الدراسة، المنجزة في إطار مذكرة تخرج بعد تدريب تطبيقي بمجمع شملت الدراسة .بهدف رفع مردودية الكيروسين T103 سكيكدة، في تحليل وتحسين أداء عمود التقطير الجوي جانباً نظرياً تناول مبادئ التقطير وخصائص المكثف الجزائري والعوامل التشغيلية المؤثرة، إضافة إلى جانب أظهرت النتائج فعالية التحسينات .Aspen HYSYS تطبيقي اعتمد على محاكاة واقعية باستخدام برنامج المقترحة في زيادة إنتاجية الكيروسين دون التأثير على باقي المشتقات، واختُتمت الدراسة بتوصيات تقنية قابلة للتطبيقالصناعي

الكلمات المفتاحية :التقطير الجوي، RA2K، العمود T103، الكيروسين، Aspen HYSYS، التحسين، المردودية، المكثف، المحاكاة.

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Abbreviations, Acronyms, and Indexes

ADU: Atmospheric Distillation Unit

BTX: Benzene, Toluene, Xylene

CTU: Condensate Topping Unit

DCS: Distributed Control System

DHP: Distillation High Pressure

EOS: Equation of State

ESD: Emergency Shutdown System

FBP: Final Boiling Point

F101 / F102 / F103: Furnace codes

GTP: Gas Treatment Plant

HGO: Heavy Gas Oil

HP/LP: High Pressure / Low Pressure

HYSYS: Hyprotech Systems (Aspen Simulation Software)

IBP: Initial Boiling Point

Jet A1: Type of aviation kerosene

LGO: Light Gas Oil

LPG: Liquefied Petroleum Gas

PA110 / PA112: Pump-Around loops

PFD: Process Flow Diagram

P/V/T: Pressure / Volume / Temperature

RA2K: Skikda Condensate Topping Refinery

SSC: Corrosion Monitoring System

TBP: True Boiling Point

T101 / T102 / T103 / T104 / T105: Column identifiers

U-100: Unit 100 (Main Topping Unit at RA2K)

VLE: Vapor–Liquid Equilibrium

API : American petroleum institute

ASTM : American Society for Testing Materials.

°C : degree Celsius.

D: is the mass flow rate (in mol/h) of the distillate

P: pressure

Pi: partial pressure of component I

Pi°: saturated vapor pressure of component i

PT: total pressure

ppm: Parts Per Million

WT: Weight percent (wt%)

α: Relative volatility

x_i : Mole fraction of component i in liquid phase

y_i : Mole fraction of component i in vapor phase

R : Reflux ratio

F: Feed flow rate

W:Bottoms flow rate

z_i : Mole fraction of component i in feed

v : Molar volume

a, b : Parameters in Peng–Robinson Equation of State

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General Introduction

General Introduction

In a global energy context marked by increasing hydrocarbon needs, oil remains a strategic commodity for many countries, including Algeria. Indeed, the national economy is heavily reliant on this vital sector, which accounts for approximately 90% of exports and is the main source of budgetary income. Due to massive crude oil, natural gas, and condensates reserves, Algeria is a key actor in the global energy context. But this overdependence on fossil resources, while being economically rewarding, leaves the nation exposed to the volatility of oil prices and underscores the need for rationalization and optimization of the explotation of its energy resources **[1]**.

In this case, the national company Sonatrach plays a central role in hydrocarbons exploration, production, transport, and processing. The national oil plant consists of several refineries situated strategically at Skikda, Arzew, Hassi Messaoud, and Algiers which convert raw materials to very value-added finished products **[2]**.

Among these strategic plants, Skikda Condensate Topping (RA2K), commissioned in 2009, merits special mention. This innovation project enabled valorization of Algerian condensate, which had previously been under-exploited — often reinjected, blended, or merely flared. With a production capacity of 5 million tons per year, RA2K is typical of Sonatrach's efforts to optimize the exploitation of resources and improve the quality of distillates, particularly kerosene **[3]**.

Kerosene, an intermediate cut product of atmospheric distillation of condensate or oil,is now best known for its critical role in the aviation sector , powering jet engines and turbines. It is also used for home heating and industrial applications as well. Kerosene is valued for its clean combustion, energy efficiency, and ability to operate at extremely low temperatures, making it an ideal choice for hostile climates and high-altitude conditions .Thus,optimizing its production has become a strategic issue for refineries.

In topping units, where condensate is fractionated into various petroleum cuts,problems of yield are common: feedstock that does not comply with design specifications, variations in crude composition, and equipment constraints can affect light fraction separation efficiency such as kerosene.

To address this issue, the present work is aimed at exploring the possibility of optimizing the operation parameters of the T103 atmospheric distillation column of the RA2K complex.The objective is to achieve the maximum kerosene yield irrespective of the feed variations.This will be carried out using a numerical simulation method based on Aspen HYSYS software and enabling analysis of the actual process performance and the proposal of relevant adjustments.

This thesis is divided into five chapters:

Chapter 1: covers generalities of atmospheric distillation, introducing the thermodynamic foundation of the process, the most important operating parameters, and the properties of the produced products, specifically kerosene and. It also outlines yield and separation efficiency ideas.

Chapter 2: summarizes the general properties of condensate, focusing especially on its behavior in distillation and industrial use.

Chapter 3: describes the presentation and functioning of the RA2K topping unit, including the process design, primary processing units, and strategic position of the T103 atmospheric column for fraction separation.

Chapter 4: presents a practical study of the T103 column using real data and Aspen HYSYS simulator, focusing on the outcomes of the simulation process, including validation, optimization, and the resulting improvements in kerosene production.

The work concludes with a general conclusion and proper recommendations.

Chapter I

General overview of atmospheric distillation

I.1 Introduction

Atmospheric distillation is the fundamental unit in crude oil refining, historically introduced at the end of the last century. Positioned at the front end of all downstream processing units, it handles the largest volume of crude and plays a pivotal role in the overall operation of the refinery.

In general, this unit separates crude oil into several key product streams: a top product consisting of non-condensable gases, LPG, and total naphtha; three side cuts, namely kerosene, light gas oil, and heavy gas oil; and a bottom product known as atmospheric residue, which serves as the feedstock for the vacuum distillation unit.

I.2 Description of the Atmospheric Distillation Process

Crude oil enters the system at high pressure, while the distillation column operates at atmospheric pressure. This significant pressure drop causes a sudden expansion of the crude, leading to the formation of two phases: a vapor phase (comprising light fractions) and a liquid phase (comprising heavier fractions).

The lighter vapor phase rises to the top section of the column, known as the rectification section. Meanwhile, heavier components condense into a liquid that descends to the lower part of the column, referred to as the stripping section, located at the bottom.

To achieve the mass transfer required for effective fractionation, ascending vapors must interact with the descending liquid that flows in a counter-current manner through the column. To facilitate this interaction, a portion of the condensed vapor collected at the top of the column is reintroduced as reflux. As this reflux liquid gradually vaporizes, it causes an equivalent condensation of heavier molecules, which then flow back down to the trays below.

This counter-current contact between rising vapors and descending liquids enables simultaneous heat and mass transfer, enriching the downward liquid stream with heavier components. Conversely, the vapor phase becomes progressively richer in lighter components as it ascends. This results in a vertical temperature gradient within the column, increasing from approximately 110°C at the top to about 350°C at the bottom **[4]**.

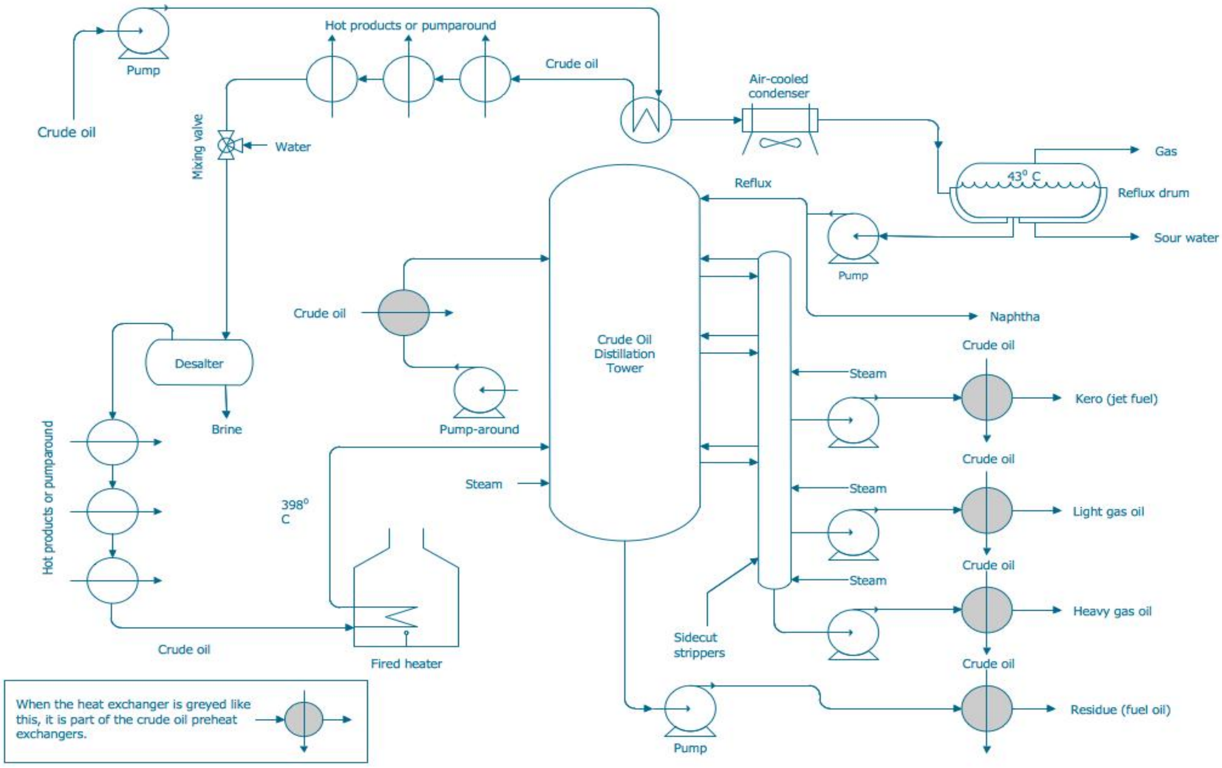


Figure I-1 *Crude Oil Atmospheric Distillation Process Flow Diagram* ***[5]***

I.3 Thermodynamic Principles of Distillation

Distillation separates a liquid mixture into products of different volatility by exploiting vapor–liquid equilibrium (VLE). In an atmospheric crude column, rising vapor and descending liquid achieve countercurrent contact on trays or packing, tending toward equilibrium compositions at each stage. The fundamental equilibrium relation in an ideal liquid mixture is Raoult's law, which states $P_i = x_i P_i^{\circ}$ for each component i (where P_i° is the pure-component vapor pressure and x_i is its liquid mole fraction). Combined with Dalton's Law of partial pressures $P = \sum_i \; P_i$, Raoult's law implies the phase-equilibrium condition

$$y_i P = x_i \, P_i^{\mathrm{sat}}(T) \quad \textbf{Eq I.1}$$

for component i (with y_i the vapor mole fraction and P the system pressure). This equation defines the bubble-point and dew-point curves (T-x-y and P-x-y diagrams) for the multicomponent mixture. The relative volatility α_{AB} between components A and B is defined as

$$\alpha_{AB} \;=\; \frac{(y_A/x_A)}{(y_B/x_B)}\;, \quad \textbf{Eq I.2}$$

which for ideal low-pressure mixtures reduces approximately to $\alpha_{AB} \approx P_A^{\mathrm{sat}}/P_B^{\mathrm{sat}}$. A large α means A is much more volatile than B, making separation of A from B easier. In practice, non-ideal behavior (deviations from Raoult's Law) can occur, but crude oil fractions are largely treated as near-ideal on each tray **[6]**.

In a fractionation column at steady state, each tray enforces the VLE relation, and heat and mass transfer drive the vapor composition toward the bubble point of the liquid. Under total reflux (no withdrawal of product), an infinite-column ideal distillation of a binary A–B mixture would exhibit a distillation curve that remains at $T = T_A$ until A is completely distilled, then jumps to $T = T_B$ (the boiling point of B), as shown in schematic Figure 2. In reality, finite reflux and trays produce a continuous distillation curve, and some overlap in volatility ranges. The minimum number of ideal stages required for a given separation (binary case) can be estimated by the Fenske equation **[6].**

$$N_{\min} = \frac{\log \frac{x_{D,A}/x_{D,B}}{x_{B,A}/x_{B,B}}}{\log \alpha_{AB}}, \quad \textbf{Eq I.3}$$

where $x_{D,i}$ and $x_{B,i}$ are the mol fractions of component i in the distillate and bottoms. In multi-component mixtures (crude oil), concepts like the Multicomponent Fenske or McCabe-Thiele methods are extended graphically or by simulation, but all rely on the underlying Raoult-Dalton framework .

Finally, distillation must obey mass and energy balances. For an input feed flow F splitting into distillate D and bottoms B, the overall mass balance is

$$F = D + B, \quad \textbf{Eq I.4}$$

and for each component i:

$$F z_i = D x_{D,i} + B x_{B,i}, \quad \textbf{Eq I.5}$$

where z_i is the mole fraction in the feed, and $x_{D,i}, x_{B,i}$ are in the distillate and bottoms. A portion of condensed vapor is returned as reflux to enhance separation: defining the liquid reflux flow rate L, the *reflux ratio* is $R = L/D$. Higher R increases product purity but reduces net output. In summary, the thermodynamic limits of separation in an atmospheric column are set by VLE (Raoult's and Dalton's laws), relative volatilities, and the imposed reflux/stage configuration.

At the core of distillation is vapor–liquid equilibrium. Each tray enforces that the liquid composition and vapor composition satisfy Raoult's Law (modified for non-ideality if needed). Specifically, at steady state and pressure P **[7]**.

$$y_i P = x_i P_i^{\text{sat}}(T), \quad \textbf{Eq I.5}$$

where $P_i^{\text{sat}}(T)$ is the saturation pressure of i at temperature T. For an ideal solution, P_i^{sat} can be obtained from the Antoine or Clausius–Clapeyron relation:

$$\ln P_i^{\text{sat}} = -\frac{\Delta H_{\text{vap},i}}{RT} + C_i. \quad \textbf{Eq I.6}$$

Thus vapor pressure (and hence boiling point) is exponentially sensitive to temperature. In an atmospheric column, the pressure drop along the height is small, so each stage can be treated as nearly isobaric. A distillation run can be visualized on a T–x–y diagram or T–fraction distilled curve, where temperature increases from top to bottom. Under ideal total-reflux conditions, the distillation curve of a binary mixture would have two plateau regions at the pure-component boiling points (Figure 2). In real operation (finite reflux and trays), the temperature gradient on the column is smooth but the top and bottom temperatures still correspond approximately to the light and heavy ends. Non-idealities (e.g. partial miscibility or strong interactions) are uncommon for middle-distillate fractions. (Azeotropes and residual non-ideal behavior are more relevant in lighter fuel-grade distillations.) In summary, Raoult's law and phase equilibrium charts dictate how each component partitions between vapor and liquid; these relations are the thermodynamic basis of distillation separation **[8]**.

I.3.1 Relative Volatility and Ideal Separation:

The relative volatility α_{AB} quantitatively measures how easily two components can be separated by distillation. It is defined for components A and B as

$$\alpha_{AB} = \frac{K_A}{K_B} = \frac{y_A/x_A}{y_B/x_B}, \textbf{ Eq I.7}$$

where $K_i = y_i/x_i$ is the equilibrium ratio (K-value) of component i. For ideal behavior, $K_i = P_i^{\text{sat}}/P$, so $\alpha_{AB} \approx P_A^{\text{sat}}/P_B^{\text{sat}}$. If $\alpha_{AB} > 1$, component A is more volatile than B. Typically, relative volatilities in crude fractions are modest (1.1–2 for adjacent n-paraffins) but large contrasts occur between far-apart boiling species. The design of the column (number of stages, reflux) directly depends on α. A large α means fewer theoretical stages are needed to achieve a given separation, whereas α approaching 1 means very high reflux or many stages are required. In extreme (ideal) cases with $\alpha \to \infty$, a sharp (nearly pure) cut is possible – this is the TBP (true boiling point) idealization mentioned above. In practice, one often linearizes α by plotting effective constant-volatility curves for design. The Fenske–Underwood–Gilliland (FUG) shortcut method for minimum reflux and minimum stages uses relative volatilities to estimate column requirements. In short, relative volatility embeds the thermodynamic ‘cleanliness’ of separation between key components. When α_{AB} is low (closer boiling points), distillation becomes less efficient, and one may resort to additives or alternate separation means (e.g. alkylation, hydrocracking for certain cuts) **[9]**.

I.3.2 Column Balances and Reflux:

In addition to equilibrium, material and energy balances around the column set performance constraints. Let the feed flow be F (mole or mass basis) with overall composition z_i . Let D and B denote the distillate and bottom flowrates, with compositions $x_{D,i}$, $x_{B,i}$. Then overall and component balances give

$$F = D + B, \qquad F\,z_i = D\,x_{D,i} + B\,x_{B,i} \quad \text{(for each} i\text{).}$$ **Eq I.8**

These balances allow calculation of yields once product cut-point compositions are specified. For example, if the kerosene cut is defined from T_a to T_b , then its volumetric yield equals the fraction of feed distilled between T_a and T_b . The reflux ratio $R = L/D$ (liquid reflux L returned per unit distillate) appears in the enthalpy balance of the rectifying section. In practice, the overhead vapor is partially condensed; a fraction is withdrawn as product (light naphtha) and the rest is refluxed. This liquid reflux washes down the column, enriching lighter components toward the top. Higher R yields sharper separations but reduces net product and increases heat duty. In a conventional crude tower, reflux mainly consists of condensed naphtha; additional downflow is provided by pump-around loops and side-stripping steam to improve separation of kerosene and gas oil (Figure 1). Energy balances determine required reboiler heat. In summary, Raoult’s/Dalton’s laws set the equilibrium composition for given T, P, while mass balances and reflux determine the actual flows and cut yields in the column **[10]**.

I.4 Operating Variables and Their Influence

The performance of an atmospheric distillation column is sensitive to several key operating parameters. Important variables include pressure, temperature (heat input), reflux ratio, and feed conditions. In broad terms, one can summarize the influences as follows:

I.4.1 Furnace Outlet Temperature :

The thermal energy required for atmospheric distillation is supplied by preheating the crude oil feed in a furnace. As a result, the feed is partially vaporized before entering the column.

At constant pressure, the degree of vaporization depends directly on the furnace outlet temperature. Typically, the crude feed is vaporized to a level between 67% and 82% before entering the atmospheric column. An increase in furnace outlet temperature leads to a higher vapor fraction entering the column, which enhances the internal reflux at the top. This promotes more effective liquid–vapor contact on the trays, improving the fractionation process and leading to sharper separation between products.

However, the transfer line temperature must be carefully controlled. If it exceeds safe limits, thermal cracking may occur, potentially causing coke formation on the inner walls of the furnace tubes. This not only reduces heat transfer efficiency but also increases maintenance requirements **[11]**.

I.4.2 Column Pressure:

The operating pressure of the atmospheric column is typically maintained at or slightly above atmospheric conditions. Although it is generally kept constant, pressure variations have direct implications for separation.

An increase in pressure, assuming a constant transfer temperature, leads to a reduction in the vaporization rate of the feed. This results in lower vapor traffic within the column and poorer separation efficiency due to reduced relative volatility between components **[12]** .

I.4.3 Overhead Temperature:

The top temperature of the distillation column must be precisely regulated to ensure that the overhead product (usually a mixture of gases and light naphtha) exits the column entirely in vapor form, corresponding to its designed boiling range.

If operating conditions remain unchanged, an increase in the top temperature reduces the amount of internal reflux. This in turn elevates tray temperatures and can cause heavier components to rise, altering product quality.

A change in reflux temperature also affects reflux flow rate, which subsequently impacts the sharpness of the separation between the top and side products **[11]**.

I.4.4 Product Draw-Off Rates:

The rate at which side products (e.g., kerosene, diesel, heavy gas oil) are withdrawn from the column significantly influences the internal reflux balance and the boiling range of each product cut.

Adjusting the draw-off rates allows operators to manipulate product properties such as end point temperature and density. For instance, to increase the final boiling point of a particular product, a higher withdrawal rate is applied. This may, however, affect the cuts immediately below by shifting their boiling ranges upward.

To correct this shift, the draw-off rate of the next lower product must be decreased. The opposite applies when a lower final boiling point is desired **[13]**.

I.4.5 Superheated Steam Injection at the Column Base:

Injecting superheated steam at the base of the column serves to strip lighter components from the bottom product (atmospheric residue). Steam reduces the partial pressure of hydrocarbons, effectively lowering their boiling points.

This promotes the removal of volatile contaminants, thereby improving bottom product quality by increasing its flash point and altering viscosity. Steam injection also helps limit entrainment and coke formation **[14]**.

I.4.6 Pump-Around Circulation (Intermediate Reflux):

Pump-arounds play a dual role in the column operation: they remove heat from specific sections of the column and condense side products to maintain thermal and phase balance.

The extracted heat is recovered via heat exchangers to preheat the incoming crude feed, improving overall energy efficiency.

Since pump-arounds regulate both the liquid-vapor equilibrium and the thermal profile within the column, the flow rate of pump-around streams must closely match the design specifications. Deviations can lead to inefficiencies in product separation and thermal imbalance **[15]**.

I.5 Fractionation Quality

The qualities are often expressed in terms of "gap" or "overlap" between the considered products.

If the fractionation were perfect, there would be no common compounds between two successive cuts. The TBP (True Boiling Point) final point of the lighter cut would coincide with the TBP initial point of the heavier cut. The ASTM curves of the two products would then show a positive shift called a gap. This gap is indicative of the quality of the fractionation.

In the opposite case, where the ASTM curves show an overlap, the (negative) shift is referred to as **overlap**.

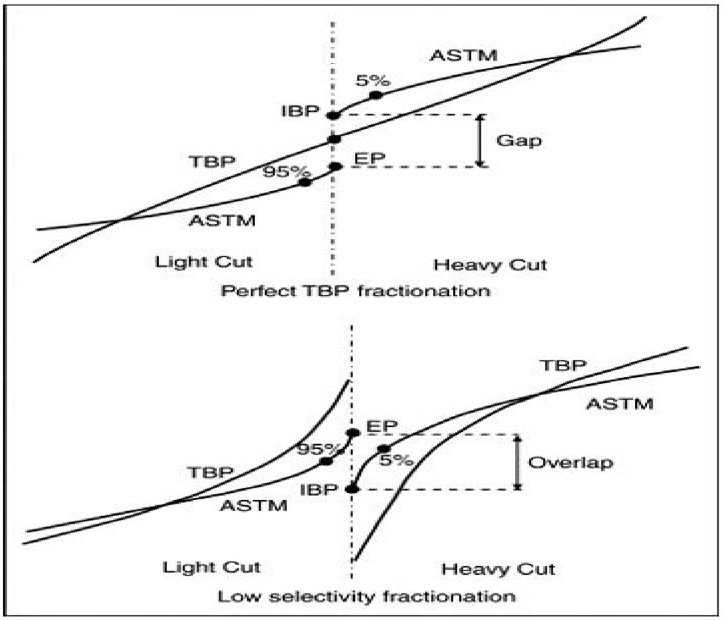


Figure I.2- *Degree of Separation of Petroleum Fractions (GAP and OVERLAP)****[16]***

I.6 Characteristics of Distillation Products

Atmospheric distillation of crude oil yields several hydrocarbon fractions, each with unique chemical, physical, and performance characteristics. The major products include gases, light naphtha, heavy naphtha, kerosene, diesel, and atmospheric residue. Understanding the attributes of each is essential for further processing, quality control, and economic optimization.

I.6.1 Overview of Distillation Products

Table I.1 *Typical boiling-point ranges of crude distillation fractions,major components and primery uses* ***[17]***

Product	**Boiling Range (°C)**	**Major Components**	**Primary Uses**
Fuel gas	< 30	Methane, ethane, propane, butanes	Fuel, petrochemical feedstock
Light naphtha	30–90	Pentanes, hexanes	Gasoline blending, reforming feedstock
Heavy naphtha	90–150	Heavier paraffins, naphthenes, aromatics	Gasoline blending, reforming
Kerosene	150–300	C10–C15 hydrocarbons	Jet fuel, domestic fuel, solvents
Light Gas Oil (Diesel)	300–370	C15–C20 hydrocarbons	Automotive fuel, heating oil
Heavy Gas Oil	320 – 425	C18–C25 hydrocarbons (long-chain alkanes, aromatics, naphthenes)	Fuel oil, diesel blending, catalytic cracking feedstock
Vacuum Gas Oils	425 – 565	C25–C35 hydrocarbons (high molecular weight alkanes & aromatics)	FCC (Fluid Catalytic Cracking) feedstock, hydrocracking to produce diesel/gasoline
Atmospheric Residue	> 425 (Vac.) / >565 (Atm.)	C35+heavy hydrocarbons, asphaltenes, resins	Feed for vacuum distillation, bitumen, lubricants, fuel oil,..

Table 1.2- *Comparative Characteristics of Major Fractions [17]*

Property	**Naphtha**	**Kerosene**	**Diesel**	**Residue**
Density (kg/m³)	680–730	780–840	830–900	>950
Flash Point (°C)	< -10	> 38	> 55	> 100
Viscosity (cSt)	< 1	1.3–1.9	2–4.5	> 10
Sulfur Content (%)	0.01–1.0	< 0.3	< 0.5	1–5
Color	Clear	Pale yellow	Yellow-brown	Dark brown

I.6.2 Kerosen fraction :

I.6.2.1 Kerosen characteristics:

Kerosene (also called jet fuel or paraffinic kerosene) is the fraction distilled between naphtha and diesel. It consists mainly of C10–C15 hydrocarbons: predominantly straight- and branched-chain alkanes and cycloalkanes. Aromatic hydrocarbons (single-ring aromatics) are present but typically <25% by volume in kerosene, and olefins are very limited due to initial catalyst desulfurization steps. The boiling range is approximately 150–300 °C (varying with specification grade). Kerosene is a clear, low-viscosity liquid; its density is about 0.78–0.84 g/cm³ at 15 °C. Important physical properties include:

Table I.3 - *Typical properties of kerosene (petroleum fraction)* ***[18]***

Property	**Typical Value**	**Relevance**
Boiling range (°C)	150 – 300	Defines the cut for separation
Density (15 °C) (g/cm³)	0.78 – 0.84	Affects combustion efficiency
Flash point (°C)	< 38	Safety parameter
Freezing point (°C)	–40 to –47 (aviation)	Essential for high-altitude applications
Carbon number range	C9–C16	-
% Paraffins/Naphthenes	~75–80% by vol.	-
% Aromatics	<25% by vol.	-
Smoke point	> 20 mm	Indicative of aromatics content
Viscosity at 20°C	1.3–1.9 cSt	Affects flow and atomization
Sulfur content	< 0.3 wt%	Environmental and corrosion concern

I.6.2.2 Types of Kerosene and Their Applications:

Each type of kerosene is formulated to meet specific needs in terms of performance, safety, and application. Below are the main types of kerosene used in industry:

I.6.2.2.1 Aviation Kerosene:

Primarily used as fuel for commercial and military jet aircraft. It is mainly composed of light aliphatic and aromatic hydrocarbons. ASTM D1655 distinguishes three types of jet fuel:

a) ***Jet A :***

Jet A Jet A-type kerosene generally has a density between 0.775 and 0.803 g/cm^3 at 15 °C, a freezing point of only –40 °C, and a maximum aromatic content of 25% (by volume). Its production is somewhat less expensive, but it freezes at –40 °C. It meets less stringent international specifications, suitable for the typical climate conditions of warmer regions**[19]**.

b) ***Jet A-1 :***

This is a variant of Jet A, meeting stricter specifications in terms of freezing point and pour point. It has a density between 0.775 and 0.842 g/cm^3 at 15 °C. Its freezing point is –47 °C with a maximum aromatic content of 25% (by volume). It complies with more rigorous specifications, especially regarding freezing resistance and lower pour point, making it better suited for cold and variable climate conditions.

c) ***Jet B :***

Jet B is a blend of kerosene (70%) and naphtha (30%), making it lighter than Jet A. It has a much lower freezing point, reaching down to –60 °C, which makes it suitable for extremely cold environments. Its density is slightly lower due to its naphtha content, ranging between 0.73 and 0.77 g/cm^3 at 15 °C. It is mainly used in very cold regions, such as Arctic and sub-Arctic zones, and for military aircraft and certain helicopters. Due to its higher volatility, it is not used in standard commercial flights **[20]**.

I.6.2.2.2 Domestic Kerosene (or Lamp Oil):

Used for home heating and sometimes for lighting in certain parts of the world. It has a composition similar to aviation kerosene but without the specific additives required for aviation use.

I.6.2.2.3 Military Grade Kerosene:

a) *JP-5* :

Used by the navy for carrier-based aircraft. It has a higher flash point for safety reasons.

b) JP-6 and JP-7:

JP-6 and JP-7 were developed specifically for a single type of aircraft — the XB-70 Valkyrie and the SR-71 Blackbird, respectively. They also have higher flash points, which provide properties better suited to the physical demands encountered during supersonic flights (Mach 3) **[21]**.

c) *JP-8* :

Used by the U.S. armed forces and NATO. It is similar to Jet A-1 but contains additives to enhance its performance and safety under military conditions **[22]**.

d) JP-10 :

It contains only a single, non-aromatic molecule to eliminate UV emissions from its signature. It is an exclusively military fuel.

I.6.2.2.4 Industrial Kerosene:

Used in certain industrial applications such as cleaning, solvents, and other specific industrial uses.

1.6.2.3 Kerosene Treatment (Unit 200):

The kerosene obtained from condensate distillation is treated to produce Jet A-1. The treatment process is carried out as follows:

- Mixing with caustic soda (4% by weight)
- Removal of naphthenic acids using a precipitation process, through electrofining (Electrofining Precipitator). Naphthenic acids, if present, cause corrosion in aircraft turbomachinery systems**[23]**.
- Water and impurities are removed using a filter and a coalescer. The presence of water within the kerosene fraction can cause clogging of turbomachine pipe filters due to freezing at high altitudes.
- Removal of impurities and particulate matter is carried out using a filter and a clay tower.

Once the kerosene is treated, it is sent to storage tanks.

Figure I.3- *Kerosen treatment unit (Unit 200)*

I.6.2.4 Kerosene Storage:

The produced kerosene is transferred to the two kerosene storage tanks of the complex. Two pumps, used alternately, are employed to transport the kerosene to the existing storage tanks at the RA1K refinery. Each tank is equipped with an internal floating roof and has a capacity of 5,360 m³.

Figure I.4 *-Kerosene Storage Tank*

I.7 Conclusion

In this chapter, we explored the essential role of atmospheric distillation in separating crude oil into various fractions based on their boiling ranges. We saw that kerosene, as a middle distillate, is one of the key products obtained from this process. Its yield and quality are influenced by critical operating parameters such as temperature, pressure, and reflux ratio. We also examined the different types of kerosene, including aviation, domestic, industrial, and military grades, each tailored to specific applications. Furthermore, the treatment and storage of kerosene are crucial steps to ensure it meets the required safety and performance standards.

Chapter II

General characteristices of condensate

II.1 Introduction

The global energy landscape is undergoing continuous transformation, driven by growing demand, technological advancements, and the need for cleaner fuel sources. Among the various resources contributing to this dynamic sector, certain hydrocarbon liquids have gained strategic importance due to their economic and industrial value. One such resource, often overlooked in broader discussions, plays a critical role in both upstream and downstream operations: condensate.

As exploration expands into more complex and unconventional reservoirs, the understanding and management of all by-products of hydrocarbon extraction become essential. Condensate, in particular, presents unique challenges and opportunities across production, transportation, processing, and commercialization. Its characteristics, behavior under reservoir and surface conditions, and impact on infrastructure make it a subject of increasing interest in both academic and industrial settings.

This chapter aims to explore condensate from multiple perspectives, providing a comprehensive overview of its origin, handling, applications, and significance within the broader petroleum and natural gas industry.

II.2 Definition and origin of condensates

Condensate is a light hydrocarbon liquid, often referred to as pentane plus ($C5^+$), which designates a hydrocarbon fraction mainly composed of compounds ranging from pentane ($C5H12$) to decane ($C10H22$), and in some cases even longer chains. It is also known as "natural gas well liquids." Condensate occupies an intermediate position in the classification of unrefined hydrocarbons, between natural gas and crude oil.

What fundamentally distinguishes condensate from crude oil is its initial state in the reservoir. While crude oil is extracted in liquid form, condensate is generally present as a gas in the reservoir due to the high temperature and pressure at depth. It is only once brought to the surface, when the pressure drops significantly, that it undergoes spontaneous condensation and transforms into a liquid.

Condensate is usually colorless to slightly yellow, very fluid, volatile, and highly flammable. It is rich in light paraffinic hydrocarbons, and sometimes contains cycloalkanes and aromatics. Thanks to its high content of light compounds, it is particularly sought after in refineries and petrochemical complexes, especially for the production of naphtha, light gasoline, solvents, or as a raw material for the plastics industry **[24]**.

II.3 Geological Origin and Formation Process

Condensates come from so-called “rich” or “wet” natural gas reservoirs, which contain heavier fractions than methane. These hydrocarbons are often mixed with other components such as water, acid gases (CO_2, H_2S), and various impurities.

Condensates are primarily extracted from reservoirs containing a complex mixture of hydrocarbons, and their composition varies greatly depending on the geological source.

During production, the hydrocarbons in the reservoir are released in the form of a gaseous mixture, in which the heavier components remain in the gaseous state due to the high temperature and pressure at the bottom of the well. When this gas reaches the surface, the sudden drop in pressure causes cooling via the Joule-Thomson effect, which leads to the condensation of the heavier hydrocarbons. This condensed liquid is then collected and referred to as condensate **[25]**.

II.4 Chemical Composition of Condensate

Condensate is primarily composed of molecules formed by the combination of carbon and hydrogen atoms, known as hydrocarbons. It also contains sulfur, chlorine (Cl_2), and nitrogen (N_2). In addition, trace metals can be found, such as mercury (Hg), nickel (Ni), vanadium (V), arsenic (As), lead (Pb), and others**[26]**.

II.4.1 Chemical Families of Hydrocarbons:

Condensate can be divided into three families of hydrocarbons:

II.4.1.1 Paraffinic Hydrocarbons:

These are saturated hydrocarbons with the general formula C_nH_{2n+2}. They can be structured in straight chains (known as normal paraffins) or branched chains (known as isoparaffins)**[26]**.

II.4.1.2 Aromatic Hydrocarbons:

These are unsaturated hydrocarbons with the general formula C_nH_{2n}. Aromatic hydrocarbons are characterized by a higher carbon-to-hydrogen (C/H) ratio compared to that found in other hydrocarbons.

II.4.1.3 Mixed Hydrocarbons:

These are also unsaturated hydrocarbons, with the general formula C_nH_{2n-2}.

II.4.1.4 Heteroatomic Compounds:

II.4.1.4.1 Sulfur Compounds:

Sulfur is the most common heteroatom found in crude oil and condensate. In low boiling point fractions, you can find:

- Hydrogen sulfide (H_2S)
- Mercaptans (R–SH)
- Sulfides (R–S–R)
- Disulfides (R–S–S–R)

II.4.1.4.2 Nitrogen Compounds:

These are found in quantities two to ten times lower than sulfur compounds in crude oil and condensate. They are mainly present in heavy fractions, in the form of:

- Saturated or aromatic amides, such as:
- Amines: $R–NH_2$, R–NH–R, or $(R)_3–N$
- Carbazoles
- Pyridines

II.4.1.4.3 Oxygen Compounds:

Oxygen is found in the form of:

- Carboxylic acids (R–COOH)
- Esters (R–CO–R)
- Phenols
- Compounds of the furan and benzofuran types.

II.4.1.4.4 Metals:

In the heaviest fractions (such as resins and asphaltenes), metallic elements like nickel and vanadium are found, often in the form of porphyrins, with the metal in the center (e.g., Ni^{2+} or V^{5+}).

Traces of iron, zinc, chromium, manganese, and cobalt are also present.

These metals can cause serious problems such as pollution, catalyst poisoning, and corrosion **[31]**.

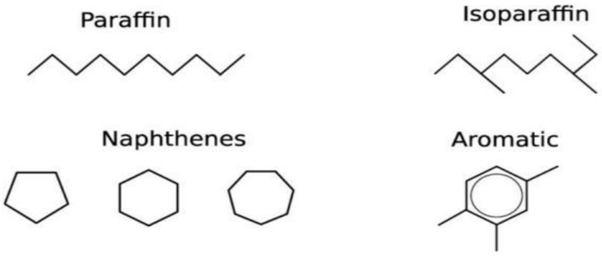


Figure II.1-*chemical structure of paraffin, isoparaffin,naphtenes and aromatic*

II.5 Separation and Treatment Processes

The treatment of condensates is part of the initial stages of natural gas processing. The objective is to separate the components based on their physical and chemical properties (such as boiling point, molar mass, solubility, etc.). Two main scenarios exist depending on the type of gas associated with the condensate:

II.5.1 Wet Gas:

Wet gas reservoirs contain a significant proportion of condensable compounds, particularly $C3^{+}$ hydrocarbons (propane, butane, pentane, hexane, etc.). The treatment involves

- Cooling the gas through isenthalpic expansion (Joule-Thomson effect) to lower its temperature to around –60°C, which promotes maximum condensation of the heavier fractions.
- Separating the recovered liquids (LPG and $C5^{+}$) in a high-pressure separator, before sending them to a fractionation column to extract the different cuts.

The condensates extracted in this process can then be stored, transported, or directly sent to refineries for further processing and valorization **[27]**.

II.5.2 Dry Gas:

In the case of dry gas reservoirs, the proportion of condensable components is very low. The gas is composed mostly of methane, and therefore yields very little to no condensate**[27]**.

Table II.1- *examples of approximate of dry gas, wet gas and gas*

Component or property	**Dry gas**	**Wet Gas**	**Condensate**
Carbon DioxideCO_2	0.10	1.41	2.37
Nitrigene N_2	2.07	0.25	0.31
Methane CH_4	86.12	92.46	73.19
EthaneC_2H_6	5.91	3.18	7.80
Propane C_2H_8	3.58	1.01	3.55
Iso-Butane i-$C_4'H_{10}$	1.72	0.28	0.71
n-Butane n-C_4H_{10}	-	0.24	1.45
Iso-Pentane i-C_5H_{12}	-	0.13	0.64
n-Pentane n-C_5H_{12}	-	0.08	0.68
Hexane deriviativesC_6H_{14}	-	0.14	1.09
Heptanes plus$\geq C_7H_{16}$	-	0.82	8.21

II.6 Recovry methods

The recovery of hydrocarbon condensates is a crucial step in enhancing the value of gas resources, especially in fields containing gas rich in liquid components. Condensates are light hydrocarbons that exist in gaseous form within the reservoir but condense into liquids when pressure and temperature drop at the surface. Several methods allow for effective recovery of these condensates, either directly at the wellhead or through more advanced industrial processes **[28]**.

II.6.1 Wellhead Recovery:

In some cases, pressure and temperature conditions allow for the spontaneous condensation of part of the hydrocarbons as soon as they exit the well. This primary recovery is typically accompanied by multi-stage separators (three or four pressure levels), which separate the gas, liquid condensates, and sometimes formation water from the production stream.

II.6.2 Condensate Stabilization:

After raw recovery, condensates must be stabilized to improve their safety for storage and transport. Stabilization is performed by distillation in a stabilization column, which removes the most volatile fractions (such as methane, ethane, or propane), thereby reducing the vapor pressure of the liquid **[29].**

The final product is a stabilized condensate, heavier and better suited for storage or export.

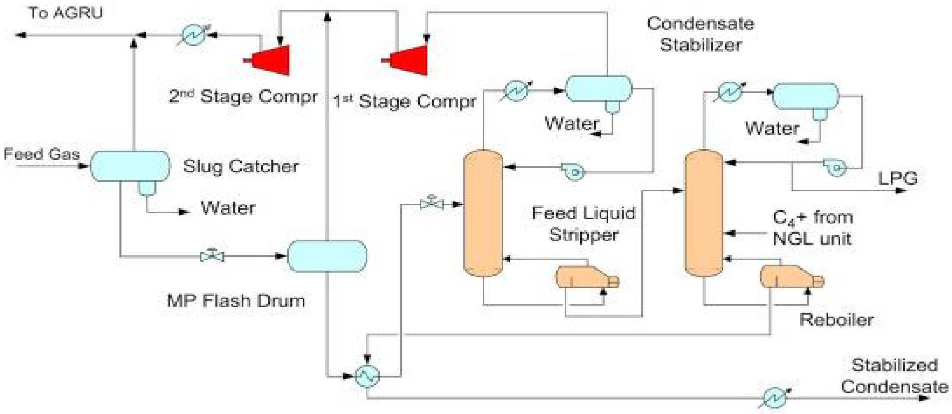


FIgure II.2- *Condensate Stabilization*

II.6.3 Natural Gas Processing Plants (GTP):

Gas Treatment Plants are designed to separate and recover the various components of raw natural gas. These facilities typically include:

- Joule-Thomson (JT) expansion units, which lower pressure to promote condensation of liquids.
- Refrigeration units, using cooling cycles to liquefy condensable hydrocarbons.

- Fractional distillation columns, to separate the condensates by boiling point (e.g., naphtha, natural gasoline, …)**[34]**.

II.6.4 Refineries:

When condensates are sent to refineries, they undergo more complex processing, similar to crude oil refining. Condensates may be:

- Cracked
- Reformed
- Blended with other streams

to produce fuels or petrochemical products such as ethylene, propylene, or BTX (benzene, toluene, xylene)**[14].**

II.7 Condensate Transport

Condensate transport refers to the process of moving condensate, which is the liquid formed when vapor or gas is cooled, from its point of origin to a desired location. Condensate is a byproduct of many industrial processes such as steam generation, refrigeration, and air conditioning.Condensate can be transported by various methods, including :

II.7.1 Gravity Drainage:

This method relies on gravity to move the condensate from a higher point to a lower one. It is commonly used in small-scale applications where the distance between the condensate source and the discharge point is relatively short **[29]**.

II.7.2 Pumping:

When the distance between the source and the discharge points is too great for gravity drainage, a pump can be used to move the condensate. Pumps may be centrifugal or positive displacement, and the choice of pump depends on factors such as the required flow rate and pressure **[30]**.

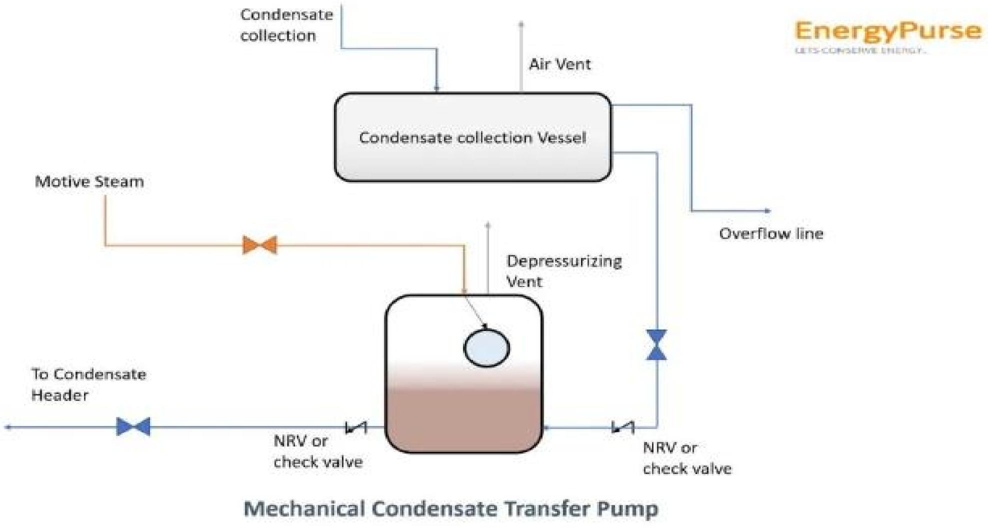
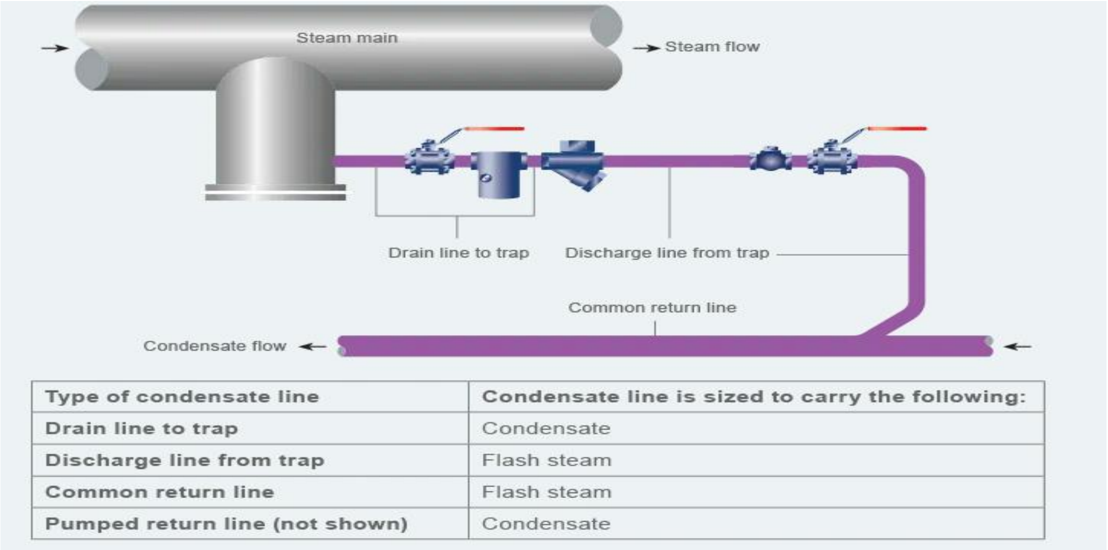


FIgure II.3- *Mecanical condensate transfert pump*

II.7.3 Condensate Return Lines:

In some industrial environments, a network of pipes and valves is used to transport condensate back to the steam or hot water source. This method is often used in large-scale applications where condensate is continuously produced **[31]**.



Type of condensate line	Condensate line is sized to carry the following:
Drain line to trap	Condensate
Discharge line from trap	Flash steam
Common return line	Flash steam
Pumped return line (not shown)	Condensate

Figure II.4- *Steam main trap set discharging condensate into a common return line.*

II.7.4 Vacuum Systems:

In vacuum systems, steam is used to create a pressure differential that draws the condensate through the pipes. This method is often used in industries such as food processing and pharmaceuticals, where maintaining a sterile environment is essential **[32]**.

II.8 Use in Refining

In refining, condensate can follow one of two possible pathways:

II.8.1 Distillation:

II.8.1.1 LPG (Liquefied Petroleum Gas):

Natural gas is a widely distributed, clean primary energy source that is increasingly used. It offers many advantages: relative abundance, flexibility of use, ecological benefits, and competitive pricing. Natural gas is a fossil fuel like coal or lignite. It is a mixture, primarily composed (75% to 95%) of methane (CH_4) **[33]**.

II.8.1.2.Naphtha:

Two types of requirements are typically specified in naphtha supply contracts: composition and defined impurity content. Composition is usually represented by a distillation curve and may be supplemented by certain compositional analyses, such as aromatic content. Physical properties like density or vapor pressure are also often measured. Purity is indicated by color or specific tests (e.g., copper strip corrosion test). Sometimes, specific elemental or compound content (sulfur, chlorine, lead, mercaptans, hydrogen sulfide, ethers, alcohols) must also be measured **[34]**.

II.8.1.3 Kerosene:

Kerosene is a cut of hydrocarbons located just above gasoline. Its approximate composition includes hydrocarbons ranging from C10 to C14. It is a pale yellow or colorless oily flammable liquid with a characteristic odor. It was first produced in the 1850s from coal tar, which is why it is sometimes referred to as “coal oil.” After 1859, kerosene became a petroleum-derived product, obtained through distillation or cracking of the less volatile fractions of crude oil at atmospheric pressure and high temperatures. However, its quantity and quality vary depending on the type of crude oil **[35]**.

II.8.1.4 Diesel (Gasoil):

Diesel fuels are complex mixtures of hydrocarbons heavier than those found in gasoline. They are typically paraffinic, naphthenic, or aromatic hydrocarbons ranging from about C12 to C25. Their boiling points at atmospheric pressure are generally between 180°C and 360°C **[36]**.

II.8.2 Blending:

In blending, condensate has two main uses: either to lighten a heavy crude oil or to reconstitute a crude oil.

- **In the first case:** blending condensate with a heavy crude results in the formulation of a light crude oil.
- **In the second case:** blending condensate with a heavy residue such as fuel oil produces a reconstituted crude, also known as "synthetic crude."
- Finally, condensate can also be used in the production of solvents, meaning special-purpose gasolines **[37]**.

II.9 General Characteristics of Algerian Condensate

Algerian condensate is a complex mixture of light hydrocarbons, characterized by a final distillation point around 280°C. This property classifies it among the very light, paraffinic-dominant crude oils. This type of condensate is notable for its very low sulfur content—generally 40 to 50 times lower than that of conventional Saharan Blend—which provides a significant environmental and processing advantage.

Due to this excellent intrinsic quality, Algerian condensate requires no specific pre-treatment before being introduced into refining units. A standard atmospheric distillation is sufficient to effectively separate the different fractions: liquefied petroleum gas (LPG), gasoline, naphtha, kerosene, diesel, and fuel oil. These products are distinguished by their high purity and superior physicochemical properties, meeting both local and international market demands **[38]**.

II.10 Typology of Algerian Condensates

Two main grades of condensate can be distinguished based on their geographic origin and chemical characteristics:

- **Arzew Condensate,** primarily derived from the Hassi R'mel field, is rich in paraffins and may contain traces of mercury. Despite the presence of such contaminants, it is highly valued in the petrochemical sector for its high worth as a raw material.
- **Skikda Condensate,** on the other hand, comes from various fields in southeastern Algeria, notably Alrar, Rhourde Nouss, Haoud El Hamra, and Hassi Messaoud (HMD). It has a distinctive coloration due to the presence of iso-paraffins and traces of crude oil, which slightly reduce its purity. As a result, this type of condensate is less favored by petrochemical industries, although it remains usable after appropriate treatment **[39]**.

Table II.2- *The Physico-Chemical Characteristics of Algerian Condensate and Its Two Grades* ***[39]***

Origin **Characteristics**	**ARZEW**	**SKIKDA**
	Hassi R'mel	Haoud El Hamra Mix of Rhourde Nouss, Hamra, and Alrar
d_{45}^{15} (Density at 15°C)	0.7140	0.7190
At 0°C	0.91	0.91
At 20°C	0.436	0.77
At 37.8°C	0.383	0.66
Cloud point (°C)	-55	-50
Pour point (°C)	< -65	-60
Aniline point (°C)	63.3	66
Water and BSW (%vol)	0.075 and 0	0.6
Hg (ppb)	53.8	16
n-paraffins (%wt)	42.7	32.5
Total sulfur (ppm)	20	9
Average molecular weight (PM)	117	117.6

II.11 Use in Steam Cracking and Petrochemicals

Algerian condensate also plays a strategic role in the petrochemical industry, particularly as feedstock for steam cracking units. In fact, approximately 53.9% of the condensate produced is directly routed to these units for the production of light olefins such as ethylene and propylene, which are key components in the manufacture of plastics, solvents, and other petrochemical derivatives.

Due to its high naphtha content, this condensate can also be blended with other crude oils to improve their overall naphtha yield, thereby optimizing cracking operations. However, it is important to note that pre-fractionation is required before using it in steam crackers, to remove undesirable compounds that could interfere with the process **[38]**.

II.12 Conclusion

In summary, condensate represents a vital component of the hydrocarbon value chain, bridging the gap between natural gas production and refined petrochemical outputs. Its unique physical and chemical characteristics, especially those found in Algerian condensate, highlight its high industrial value and strategic importance.

Algerian condensate, known for its low sulfur content and rich paraffinic composition, has proven particularly suitable for advanced refining and petrochemical applications. Its role in steam cracking processes, where it serves as a valuable feedstock for the production of ethylene, propylene, and other base chemicals, underscores its contribution to the growing petrochemical sector.

Through an in-depth analysis of condensate typologies, production behaviors, and industrial uses, this chapter has demonstrated that optimizing the handling and valorization of condensate—especially in resource-rich countries like Algeria—is essential for maximizing both economic returns and industrial development. As the global demand for light hydrocarbons and clean fuels increases, the strategic exploitation of condensate resources will remain a key focus in energy policy and technological innovation.

Chapter III

Presentation and operation of topping unit

III.1 Introduction

The objective of the condensate topping unit is to fractionate the condensate feed into several main cuts: butane, naphtha (light and heavy), kerosene, light gasoil (LGO), and heavy gasoil (HGO).The unstabilized light naphtha is first sent to a stabilization section to separate propane and butane, before being blended with heavy naphtha to form the composite naphtha destined for storage.The kerosene produced in Unit 100 is subsequently processed in downstream Unit 200 to remove naphthenic acids and improve its properties. The light and heavy gasoils are directed to their respective storage zones as finished products.

III.2 Manufacturing process

The unit can be divided into various sections, integrating the following main equipment:

- Preheating exchanger train (E101 to E108)
- Pre-fractionation column (T101)
- Pre-fractionator reboiler furnace (F101)
- Atmospheric furnace (F102)
- Atmospheric distillation column (T103)
- Atmospheric reboiler furnace (F103)
- Debutanizer (T201)
- Depropanizer (T301)
- Butane dryer
- Vacuum system with accessories: heat exchangers, drums, pumps, associated piping ...

The processing unit operates under moderate pressure and temperature conditions, requiring suitable instrumentation for process control and monitoring. A distributed control system (DCS) has been implemented to measure and regulate key operational parameters such as pressure, temperature, flow rate, and levels in columns and tanks.

To ensure safe operation, an Emergency Shutdown System (ESD) is installed, which automatically and safely shuts down critical equipment such as furnaces, pumps, and all columns and vessels.

In parallel, the unit is equipped with safety valves on all sensitive installations to protect personnel and equipment in case of overpressure. Fire and gas detection systems are deployed at strategic locations for early incident detection. Firefighting resources include a firewater network, hydrants and monitors at critical points, as well as CO_2 fire extinguishers distributed throughout the unit.

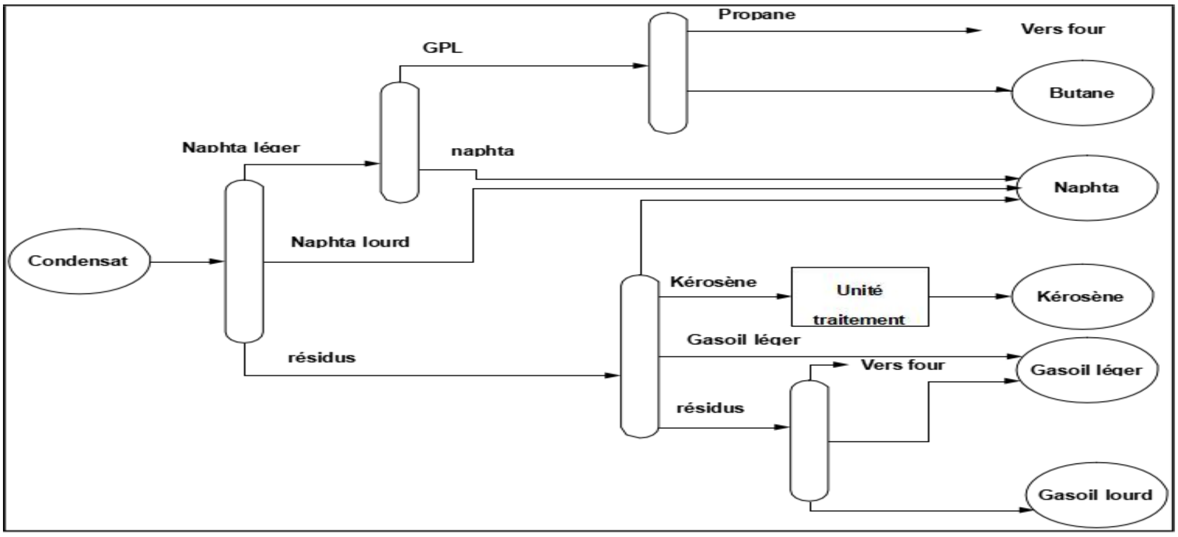


Figure III.1 *– Block diagram of the Topping complex (U100)* ***[3]***

III.2.1 Preheating exchanger train :

The condensate feed, sourced from storage tanks, is pumped by P101 at a pressure of 20 bars and a temperature of 30°C into a battery of heat exchangers divided into two parallel circuits to facilitate 50% feed rate operation **[40]**.

The feed is sequentially heated in the following exchangers:

- E101 A/B/C/D: shell side, countercurrent with overhead vapor from the pre-fractionation column (exit temp: 78°C).

- E102 A/B/C/D: shell side, countercurrent with overhead vapor from the atmospheric distillation column (exit temp: 123°C).
- E103 A/B: tube side, countercurrent with top circulating reflux from the atmospheric column (exit temp: 138°C).
- E104 A/B: shell side, countercurrent with LGO from the vacuum column (exit temp: 141°C).
- E105 A/B: shell side, countercurrent with kerosene from the atmospheric column (exit temp: 148°C).
- E106 A/B: tube side, countercurrent with LGO from the atmospheric column (exit temp: 155°C).
- E107 A/B: tube side, countercurrent with bottom circulating reflux from the atmospheric column (exit temp: 165°C).
- E108 A/B: tube side, countercurrent with HGO from the vacuum column (exit temp: 166°C).

The preheated feed enters the pre-fractionation column (T101) at around 158°C before the control valve, and 128°C after the valve (design temp = 136°C). The upstream pressure in the control valve of the pre-fractionator feed line must be at least 13 bar absolute to avoid vaporization at the valve inlet **[40]** .

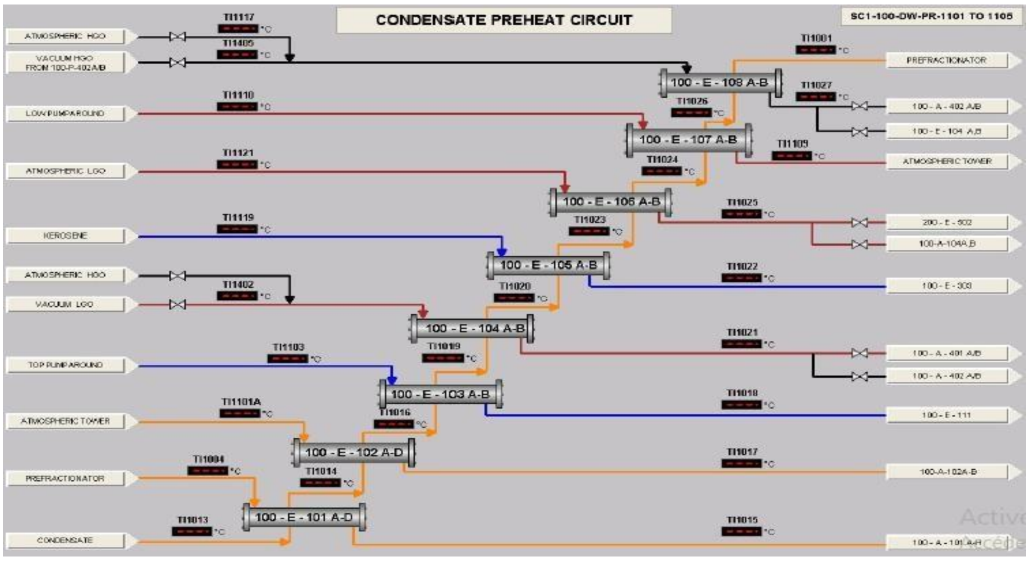


Figure III.2 – Schematic process of train of exchangers

III.2.2 Pre-fractionation Column Section (T101):

The pre-fractionation column (T101) aims to separate the condensate feed into three products:

- An overhead cut (gas and naphtha)
- A side draw (stabilized naphtha)
- A bottom product (stabilized condensate)

The column has 35 trays and receives the partially vaporized condensate at the 28th tray.

III.2.2.1 Overhead Vapors :

The overhead vapors from the pre-fractionation column (T101) are almost entirely condensed by the exchangers E101 A/B/C/D (condensate) and air coolers A101 A–H. The condensed liquid (unstabilized naphtha) is collected in the reflux drum (V101). The unstabilized naphtha is drawn from the drum by pumps P103 A/B and partly sent, under level control, to the naphtha stabilization column (T201) for LPG recovery. The other part is returned as reflux to the top of the pre-fractionation column (T101) under temperature control in cascade with flow rate **[40]**.

III.2.2.2 Stabilized Naphtha Side Draw :

The naphtha cut is drawn from the column (T101) at the 15th tray and sent to the stripper (T102) under level control. The stripper has six (6) trays and a reboiler (E111). The naphtha from the bottom of the stripper, stripped of light components, is partly pumped by P104 A/B and sent, under flow control, for cooling in the air coolers A106 A–F and water exchangers E115 A/B to a temperature of 40°C. It is then mixed with the stabilized naphtha from the debutanizer (T201) and sent to storage. The other part is sent to the reboiler (E111) and reintroduced into the bottom of the stripper. The heating fluid is the top circulating reflux from column T103. The light fraction from the naphtha exiting the stripper overhead is returned to column T101 at the 14th tray **[40]**.

III.2.2.3 Bottoms Residue :

The bottom residue from the condensate pre-fractionation column is split into two streams. One stream is pumped by P105 A/B and sent to the reboiler furnace F101, then reintroduced at the bottom of the column. The other stream, under level control, is pumped by P106 A/B and, after heating in furnace F102, is fed to the atmospheric distillation column.

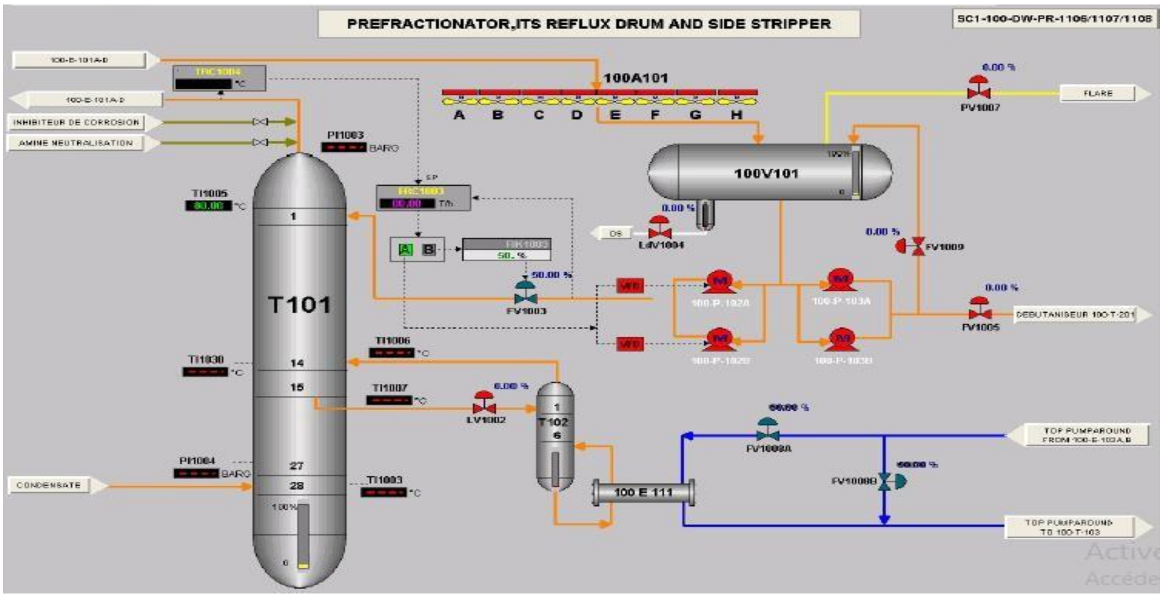


Figure III.3 – Schematic process of the pre-fractionation column T101 with naphtha stripper T102

III.2.3 Atmospheric Distillation Column Section (T103):

The atmospheric distillation column (T103) contains 46 trays. Its objective is to fractionate the feed (residue from the pre-fractionation column or stabilized condensate) into four stabilized cuts that can be used as finished products: naphtha, kerosene, light gasoil (LGO), and heavy gasoil (HGO).

III.2.3.1 Feed to the Atmospheric Distillation Column :

The feed to the atmospheric distillation column (T103) comes from the bottom product of the pre-fractionation column (stabilized condensate). This feed is preheated in furnace F102 to a temperature of 216°C and introduced at the 41st tray.

III.2.3.2 Overhead Vapors :

The overhead vapors of the atmospheric distillation column (T103) are almost entirely condensed by exchangers E102 A/B/C/D (condensate on shell side) and air coolers A103 A/B. The condensed liquid is collected in the reflux drum V102 at approximately 116°C and 0.3 bar pressure. This liquid is pumped by P107 A/B and, under level control, partly sent as naphtha to storage after cooling in air coolers A106 A–H and water exchanger E115 A/B. The other part is returned as reflux to the top of the atmospheric distillation column (T103), with temperature control in cascade with the flow rate **[40]**.

III2.3.3 First Kerosene Side Draw :

The kerosene cut is withdrawn from the 22nd tray of the column under level control and sent to the kerosene stripper T104, equipped with 8 trays and reboiler E109. The kerosene, stripped of light components, is pumped by P108 A/B and sent either to the kerosene treatment unit for the removal of naphthenic acids or directly to storage after cooling to 40°C in exchangers E105 A/B, E303 (reboiler of the depropanizer), air coolers A103 A/B, and water coolers E112 A/B.coolers A103 A/B, and water coolers .

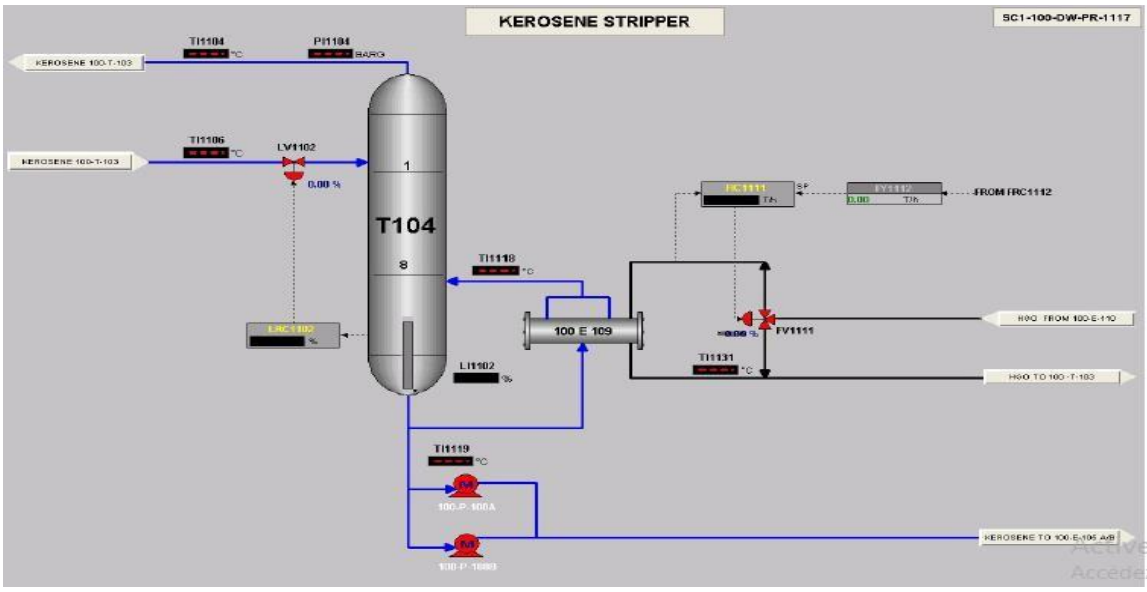


Figure III.4 – Schematic process of the kerosene stripper T104

III.2.3.4 Second Light Gasoil Side Draw :

The light gasoil (LGO) cut is withdrawn from the 32nd tray of the column under level control and sent to the stripper (T105), equipped with 6 trays and reboiler E110. The LGO, stripped of light components, is pumped by P109 A/B, then cooled in exchangers E106 A/B, E502, E501, and air coolers A104 A/B. It is then mixed with vacuum LGO, and the mixture is cooled to 40°C in water coolers E113 A/B before being sent to storage under flow control.

III.2.3.5 Column Bottoms Residue :

The bottom product of the atmospheric distillation column is partially drawn by pumps P114 A/B and discharged into two streams: one is sent to the vacuum column (T401) under flow control in cascade with the level, and the other is used as heating fluid for the reboilers of the kerosene and light gasoil strippers (E109 and E110), then returned to the bottom of the atmospheric distillation column under flow control **[40]**.

The other portion of the column bottoms, under flow control, is drawn by pumps P113 A/B/C, sent to the reboiler furnace F103, and reintroduced into the bottom of the atmospheric distillation column.

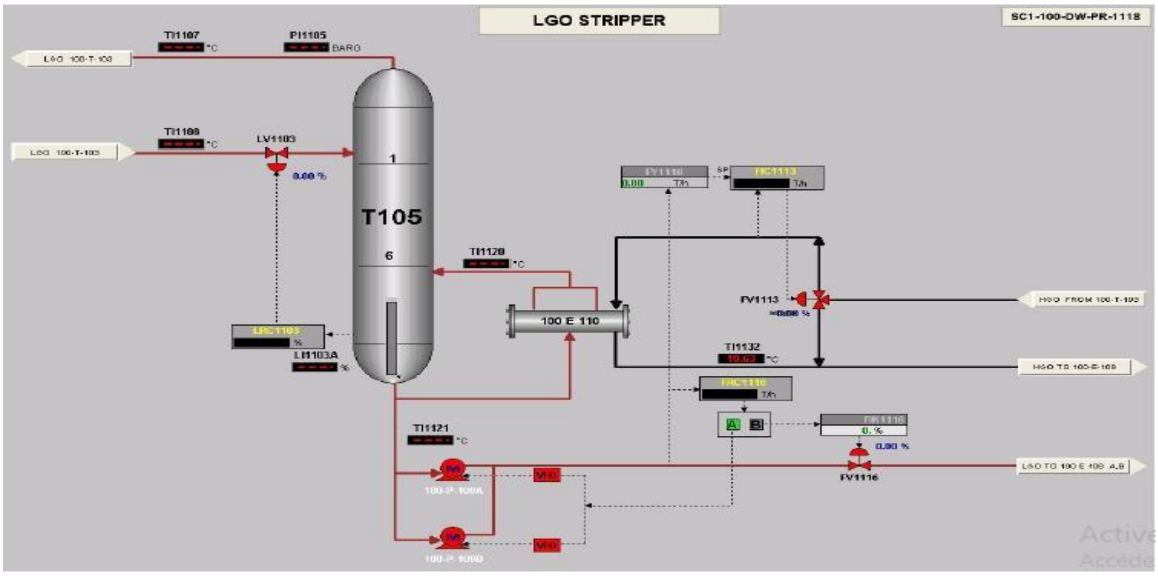


Figure III.5 – Schematic process of the LGO stripper T105

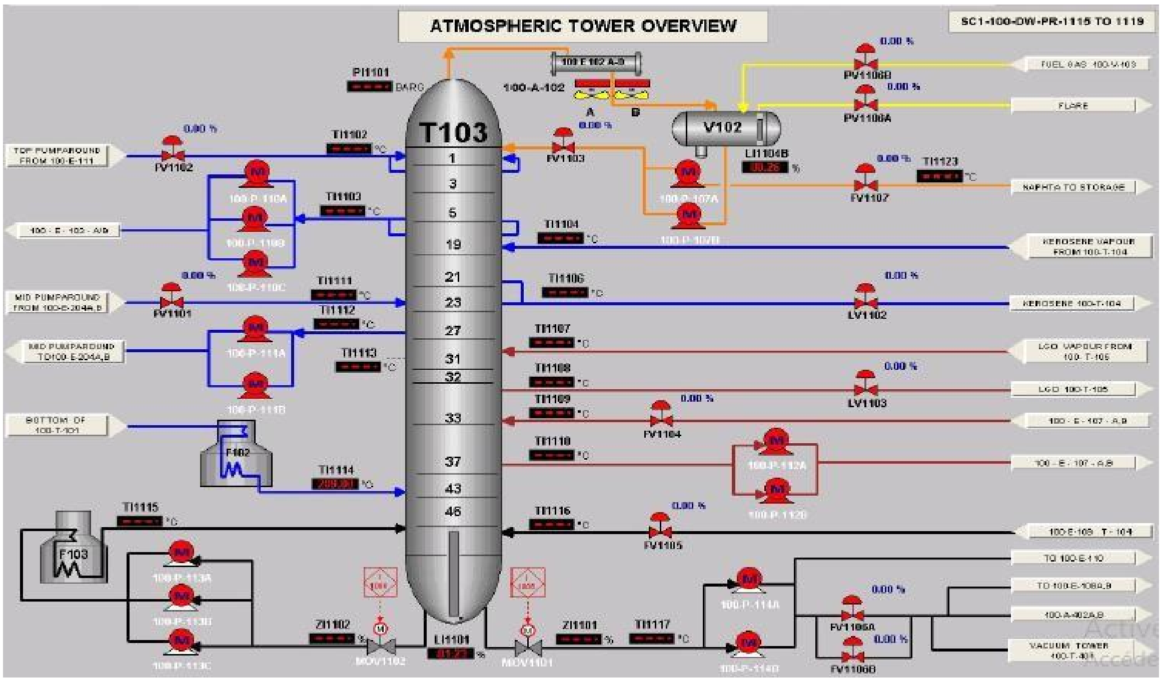


Figure III.6 – *Schematic process of the atmospheric column T103*

III.2.4 Furnace Section :

The operation of industrial units requires that the process streams be brought to appropriate operating conditions, such as pressure and temperature. With regard to temperature, it is generally raised above ambient levels, most often through heating. These temperature levels are achieved using two types of equipment:

- Heat exchangers, which allow for the optimal recovery of thermal energy from various fluid streams
- Furnaces, which generate the majority of the energy required for various operation

Furnaces are key equipment in the refining, gas, and petrochemical industries. Their design must meet numerous user requirements, including a specified thermal load, the highest technically achievable thermal efficiency, a high operational reliability (on-stream factor), and satisfactory operational flexibility, all while ensuring compliance with safety standards. This underlines the importance of furnace design, construction, operation, and maintenance.

Combustion is a chemical reaction between a fuel and an oxidizer. This reaction occurs at a high rate and releases heat — it is thus exothermic. Combustion in furnaces can only occur if the following three elements are present simultaneously:

- An oxidizer (oxygen)
- A fuel (gaseous or liquid combustible)
- An ignition source (flame)

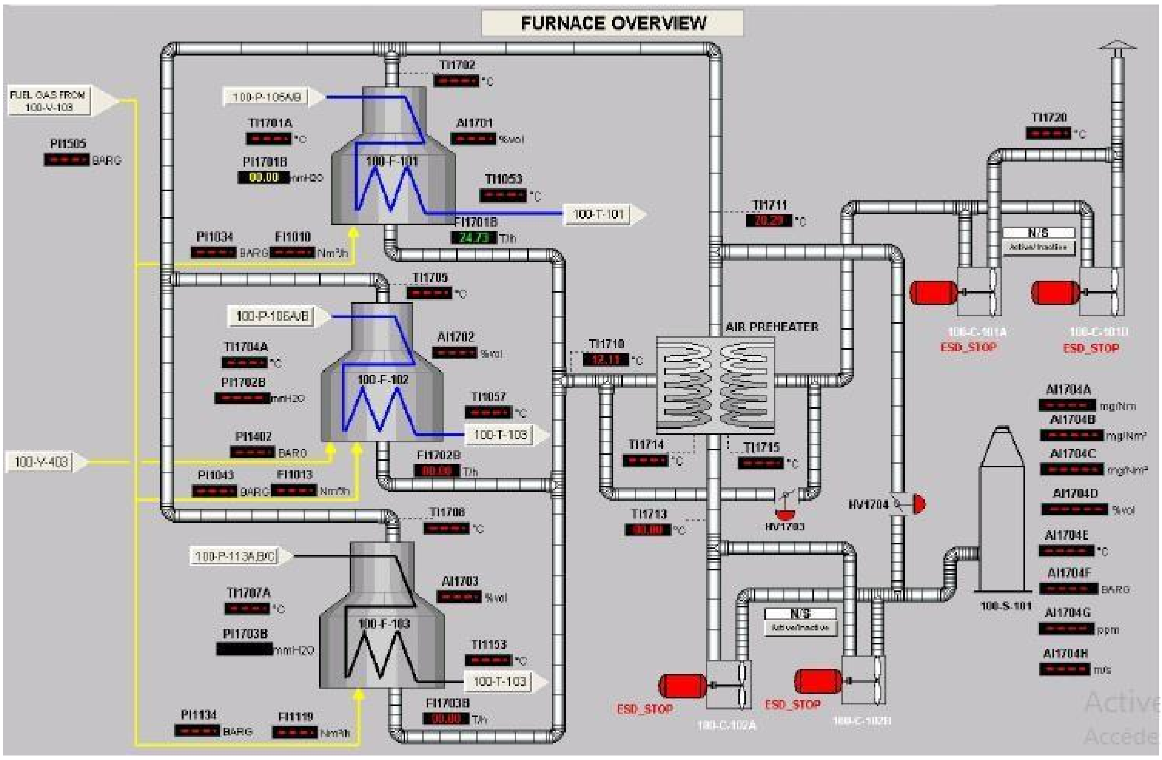


***Figure III.7** – Schematic process of the furnace section*

III.2.5 Light Naphtha Stabilization Section (Debutanizer T201) :

The naphtha stabilization section is designed to stabilize the naphtha from the top of the pre-fractionator in order to recover LPG. It can also process off-spec butane from storage, if necessary.The naphtha from the top of the pre-fractionator is preheated in exchangers 100-E-201A-C (Feed/Bottom exchanger of the debutanizer), then fed into column 100-T-201 (Debutanizer) at the 26th tray at approximately 110°C. This column, equipped with 50 trays, separates the feed into two products: a top product (raw LPG) and a bottom product (stabilized naphtha).The thermal energy required for the debutanizer is supplied by a side draw from the atmospheric distillation column via the thermosiphon reboiler 100-E-204A/B, under temperature control. The temperature at the 45th tray is regulated by two opposing flow control valves: one on the heating fluid feed line to 100-E-204, and the other on the bypass line. When the first valve opens, the second one closes, and vice versa **[40]**.

The stabilized naphtha, under level control, is drawn as the bottom product of 100-T-201. It is used to preheat the feed in 100-E-201A-C, then cooled in air coolers 100-A-202A/B and water coolers 100-E-203A/B. This naphtha is then blended with the cooled heavy naphtha from the condensate distillation section, and sent to storage.The overhead vapors from column 100-T-201 are fully condensed by air coolers 100-A-201A-D and water coolers 100-E-202A/B. The condensed liquid is collected in the reflux drum 100-V-201. From this drum, under level control, the LPG product is pumped via 100-P-203A/B to the depropanizer section to remove excess propane from the butane. A bypass is also available, allowing direct routing to the butane dryer.

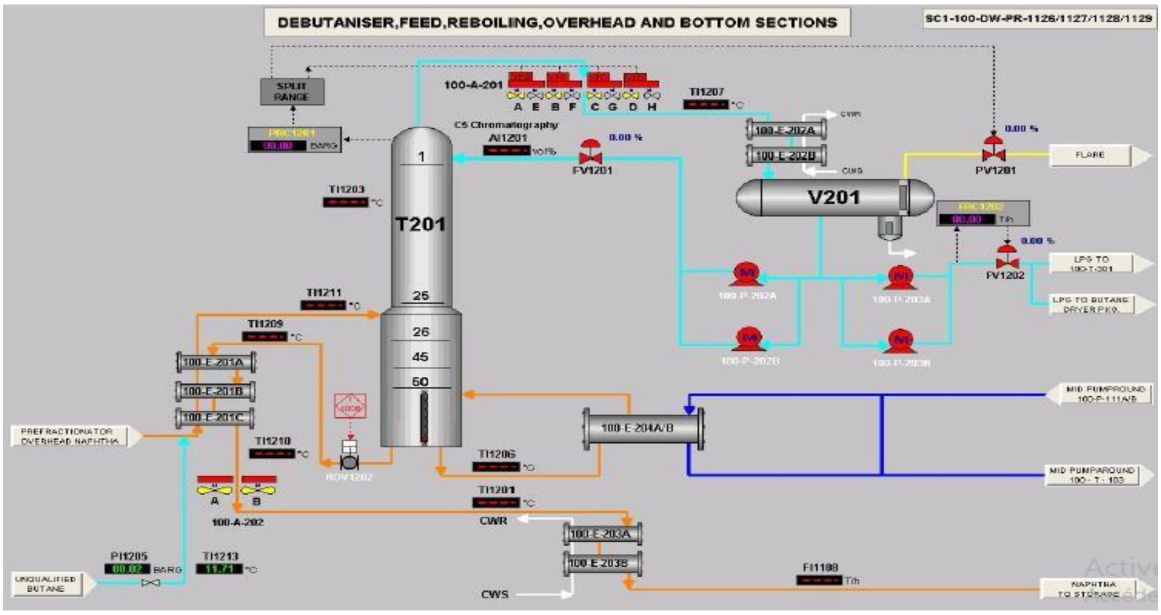


***Figure III.8** – Schematic process of the debutanizer T201*

III.2.6 LPG Stabilization Section (Depropanizer T301) :

The depropanizer is designed to separate raw LPG into butane and propane containing a small amount of ethane. The propane is sent to the furnace as fuel gas, while the butane is either sent to storage or to the butane drying unit (100-PKG-301) for drying, and then routed to storage as a final product.The LPG from the naphtha stabilization section is first heated in exchangers 100-E-301A/B (Feed/Butane exchangers), then fed into column 100-T-301 (Depropanizer) at the 27th tray, at around 85°C. Column 100-T-301, equipped with 56 fractionation trays, separates the feed into a top product (propane) and a bottom product (butane).The overhead vapor from the depropanizer is cooled and partially condensed in air coolers 100-A-301A/B (Depropanizer overhead air coolers), and the condensed liquid is sent to the reflux drum 100-V-301. From this drum, the reflux pumps 100-P-301A/B, under flow control cascaded with the drum level, return the liquid to the column as reflux.The propane from the depropanizer reflux drum, under pressure control, is routed to the high-pressure fuel gas separator for use as fuel gas.A portion of the depropanizer bottom product, under pressure control, is reheated in reboiler 100-E-303 (Depropanizer reboiler) using kerosene as the heating medium, then returned to the column. The temperature at the 50th tray of the depropanizer is controlled by a three-way regulating valve on the kerosene line.The bottom product of the depropanizer is first cooled in 100-E-301A/B, followed by 100-E-304A/B (Butane water coolers), then, under level control, it is directed either to the butane drying unit (100-PKG-301) or directly to storage. From the drying unit, the butane product is sent to either the on-spec butane storage or the off-spec butane storage, if necessary**[40]**.

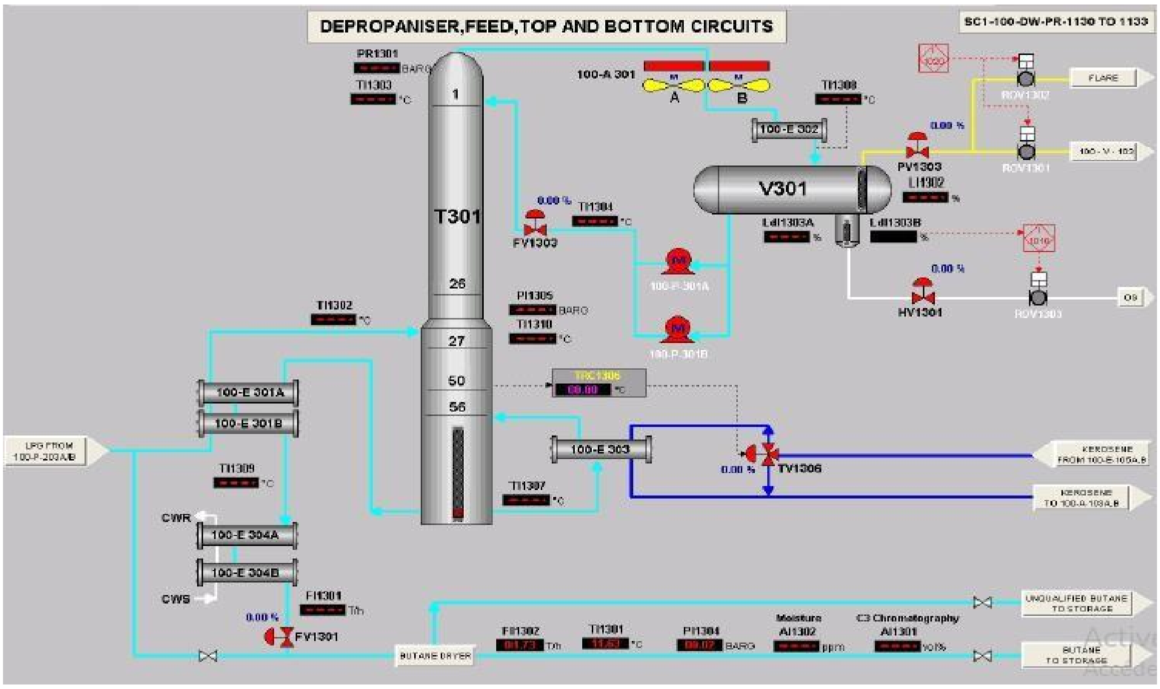


Figure III.9 – Schematic process of the depropanizer T301

III.2.7 Butane drayer unit :

The butane drying installation is designed to process 25.2 tons per hour of butane (including the recycled flow) with the objective of reducing its moisture content to 20 ppm.The drying system mainly consists of two absorbers, 100-V-310A and 100-V-310B (molecular sieve drying columns), which operate alternately — one in service (drying) while the other undergoes regeneration. The system also includes substitution/twin valves, connecting piping, and a complete regeneration system comprising:

- Two regeneration pumps: 100-P-310A/B
- A heating system with:

  1. Electric heaters 100-E-310A/B (Stage 1)
  2. Heaters 100-E-310C/D/E (Stage 2)

- A cooling system with:

1. Condenser 100-E-311
2. Condensate cooler 100-E-312

- Separator 100-E-311 for separating butane from water
- Substitution/twin valves and associated piping

When one absorber begins the loading process, the other undergoes regeneration. Via remotely operated valves (ROV 1801A), the butane to be dried is directed into absorber 100-V-310A. As it flows upward through the column, it releases a large portion of its moisture to the molecular sieves. A small amount of solvent is also absorbed.

III.2.7.1 Regeneration involves three main phases :

1. Activation: Heating of the sieves with hot dry gas (dry butane), flowing in the opposite direction to the moist gas stream, for a duration of 4 hours and 20 minutes.
2. Cooling 1: Cooling of the electric heaters for 59 minutes.
3. Cooling 2: Cooling of the molecular sieves after regeneration for 1 hour and 50 minutes.

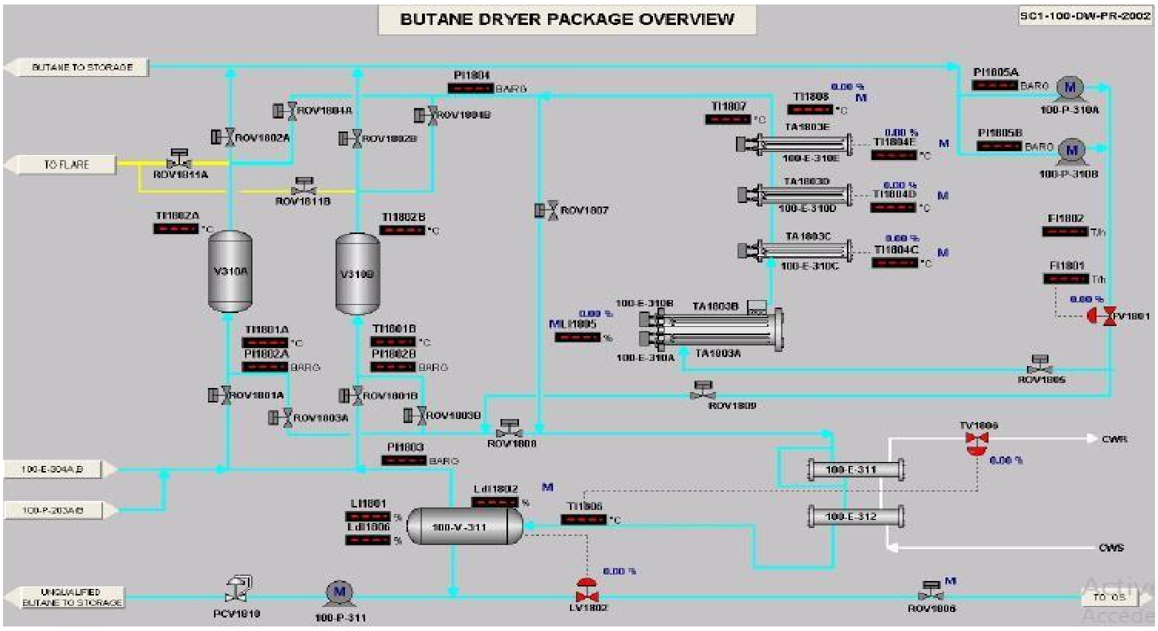


Figure III.10 – Schematic process of the butane dryer

III.2.7.2 Vacuum Distillation Section and Its Package :

The bottom product from the atmospheric distillation tower in the CTU (U-100) contains the gasoil stream, which is recovered in the vacuum column of the vacuum unit. The objective of the Vacuum Tower (100-T-401) is to recover part of the light gasoil (LGO) contained in the heavy gasoil (HGO) from the bottom of the Atmospheric Distillation Column (100-T-103).The stream's enthalpy is sufficient to ensure proper vaporization in the vacuum column without the need for an external furnace. The Vacuum Tower (100-T-401) is equipped with two structured sections. The HGO feed enters at the bottom of the tower at approximately 355°C and is separated into two main cuts: vacuum LGO at the top and vacuum HGO at the bottom.

The vacuum LGO is drawn from the collector tray below the first structured section using pump 100-P-401A/B. Part of this stream, under flow control, is returned to the vacuum tower as reflux. The other part is used to preheat the condensate feed in exchanger 100-E-104A/B and is then cooled in air coolers 100-A-401A/B.

From 100-A-401A/B, the vacuum LGO stream is split into two parts:

- One part, under flow control, is returned to the top of the tower as reflux
- The other part, under cascade flow and level control, is cooled in water coolers 100-E-113A/B, mixed with atmospheric LGO, and sent to storage

The vacuum HGO, under cascade flow and level control, is pumped by 100-P-402A/B and cooled in 100-E-108A/B (while preheating the condensate feed), then further cooled in 100-A-402A/B (HGO air cooler) and 100-E-402A/B (HGO water cooler), before being sent to storage.The overhead vapors from the Vacuum Tower are partially condensed in 100-E-401 (Vacuum Overhead Pre-condenser) before entering the vacuum system (100-PKG-401). The recovered gas is sent either to the furnace as fuel or to the flare/atmosphere **[40]**.

III.2.7.3 Vacuum Package :

To generate vacuum, a dedicated vacuum system has been installed. It is designed to remove approximately 421 kg/h of hydrocarbon vapor and inert gases with an average molecular weight of 191. The system operates at an absolute pressure of 450 kPa and can reach near-total vacuum.

The installation includes:

- Liquid ring vacuum pumps: 100-P-403 A/B
- Vacuum overhead pre-condenser: 100-E-401
- Effluent separator: 100-V-401
- Liquid seal condenser: 100-E-404
- Liquid seal separator: 100-V-402

The vacuum pre-condenser condenses hydrocarbons and water and cools inert gases before they enter the effluent separator. The cooled effluents then enter the effluent separator, which includes compartments for liquid, vapor, oil, and water separation. Level indicators are provided for both the water and oil compartments.A liquid seal is maintained by an overflow system, with the water flow regulated by a level control regulator (LRC) on the liquid seal separator. The water level in the effluent separator is maintained by an LRC located in the water compartment at the outlet of the seal overflow.

Off-spec products from the vacuum separator may be routed to the slop system.

The vapors from the effluent separator are drawn into the liquid ring vacuum pumps (100-P-403 A/B), which create the desired vacuum. Approximately 20% of the flow is recycled to stabilize pressure in the vacuum column.

Each pump includes the following main components:

- A pump casing
- A multi-blade impeller
- A central body
- A mechanical seal

The liquid ring vacuum pump creates and maintains a vacuum of 0.5 kg/cm² absolute at the vacuum tower head. The pump is continuously supplied with sealing liquid (usually water) to dissipate the heat generated by gas compression and to replenish the liquid ring, as some of the liquid exits the pump along with the gas. This liquid is separated downstream and reused.

Operating principle:

As shown in the diagrams, within a cylindrical casing partially filled with sealing liquid, a multi-blade impeller on an eccentric shaft rotates. A distribution plate with suction and discharge ports is mounted beside the impeller. A liquid ring is formed by the centrifugal force generated by the rotating impeller, pressing the liquid against the inner wall of the pump chamber. Because the impeller is offset from the chamber center, the depth at which the blades penetrate the liquid ring varies during rotation. This creates increasing cell volumes on the suction side, generating vacuum, and decreasing volumes on the discharge side, increasing pressure until discharge occurs through the outlet port. A continuous supply of fresh sealing liquid is delivered through the inlet to maintain the ring.

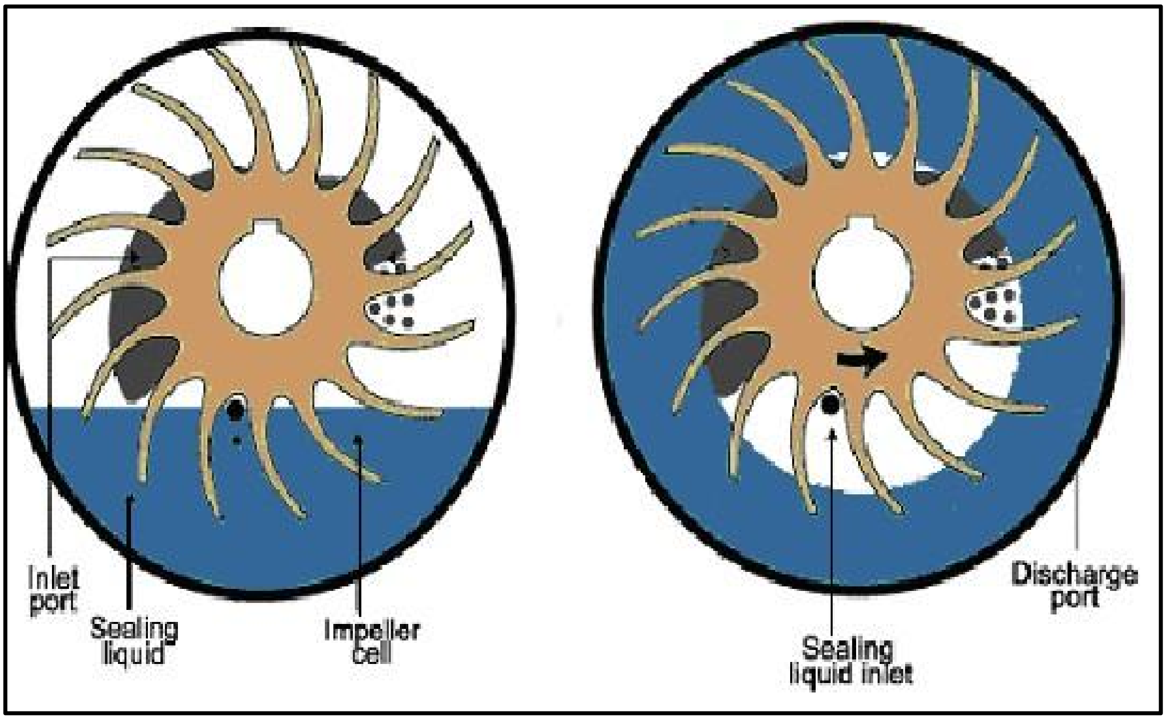


Figure III.11 – Schematic of the liquid ring vacuum pump [41]

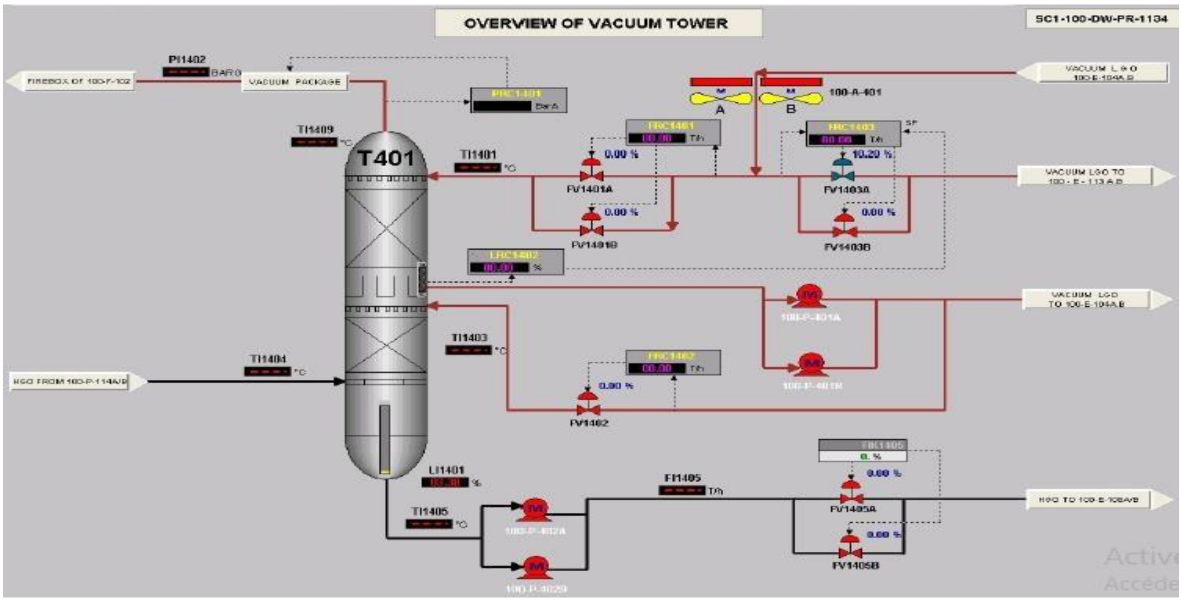


Figure III.12 – Schematic process of the vacuum distillation column

III.2.8 Chemical Injection Sections

III.2.8.1 Neutralizing Amine Injection Section :

Neutralizing amine is injected into the steam piping of the pre-fractionator column (100-T-101) in order to:

1. Neutralize residual hydrochloric acid. The amine reacts with hydrochloric acid to form ammonium chloride.
2. Maintain the pH of the reflux drum water (100-V-101) within the range of 6 to 6.5, since the effectiveness of the corrosion inhibitor is higher within this pH interval.

Dosing is carried out in the steam piping of the pre-fractionator column (100-T-101) at a rate of approximately 1 to 3% of the overhead product. The actual injection dose varies depending on the acidity of the feedstock and is adjusted based on the pH of the separation water, analyzed during the drainage of V-102.The neutralizing amine is delivered to the unit in cylinders or tankers. It is poured manually or allowed to flow by gravity into the amine storage drum (100-V-109). The amine solution is injected into the overhead steam line of column 100-T-101 through a T-connection installed on the chemical injection line using the amine injection pump (100-P-119A/B), to maintain the pH of the reflux drum water (100-V-101) between 6 and 6.5 **[40]**.

III.2.8.2 Corrosion Inhibitor Injection Section :

The corrosion inhibitor prevents direct contact between the metal surfaces and corrosive agents in the system by forming a continuously renewable monolayer on the metal surface.Dosing is performed in the steam piping of the pre-fractionator column (100-T-101) at a rate of 5 ppm of the overhead product.The inhibitor, which must form an amine-type protective film, is supplied to the unit in cylinders or tankers. It is poured manually or flows by gravity into the inhibitor drum (100-V-110).The corrosion inhibitor is injected into the steam line of the pre-fractionator column (100-T-101) through a T-connection installed on the chemical injection line using the inhibitor injection pump (100-P-120A/B).

The Corrosion Monitoring System (SSC) uses:

- Electrical resistance probes, and
- Corrosion coupons,

which are installed at the inlet of 100-A-101A-H. Based on the results, the inhibitor dosage is adjusted accordingly.

III.2.8.3 Water Injection Section :

Water is injected into the steam line of the pre-fractionator column (100-T-101) to dissolve amine salts.

Dosing is carried out in the steam line of column 100-T-101 at a rate of 1% to 3% of the overhead product, depending on the salt content in the feedstock and in the final products.

Water is injected into the steam line using the production water pump (100-P-118A/B).

Water collected in the lower part of the reflux drum (100-V-101) is drained.

III.3 Conclusion

This chapter presented a detailed overview of the condensate topping unit, focusing on the configuration and operation of its main components. From feed preheating through distillation and stabilization sections to safety systems and chemical injection, each process step was explored to highlight its role in the overall separation and treatment of condensate. This understanding provides the technical foundation necessary for evaluating performance and identifying opportunities for simulation and optimization in the next chapters

Chapter IV

Simulation and discussion of results

IV.1 Introduction

In this chapter, a study is presented with the objective of increasing kerosene production. The goal of the study is to determine the new optimized operating parameters of the atmospheric distillation column T103.

The Aspen HYSYS simulator is used to model the flowsheet of Unit 100, or more specifically, a portion of Unit 100, focusing on the prefractionation column T101 and the atmospheric distillation column T103. The simulator enables the adjustment of the operating parameters in order to achieve the desired improvement in kerosene yield.

This work is structured into three main sections:

1. The HYSYS simulator
2. Problem statement and methodology.
3. Simulation and validation of the design case using Aspen HYSYS.
4. Simulation and optimization of the real case using Aspen HYSYS.

IV.2 Process Simulation on a Computer

The design of a chemical production unit is a complex operation that requires significant financial and human resources. In today’s context, an industrial process must meet three key criteria: economic viability, safety, and environmental compliance.

When a new process is being developed, the engineer’s role is to identify the most suitable system—not only in terms of efficiency and safety, but also in terms of cost-effectiveness and profitability for producing the intended product.

In this regard, simulation can be an extremely valuable tool, as it enables the analysis and management of these challenges—especially when numerous variables are involved, such as the diversity of components, the complexity of interactions, and the non-linearity of underlying phenomen...

IV.2.1 Introduction to HYSYS Software:

HYSYS is a highly flexible simulation software widely used in the industry, known for its user-friendly interface and ease of use once the basic elements are understood. Although originally developed for the oil and gas industry, HYSYS is also applicable to a wide range of chemical process simulations.

Simulations in HYSYS are carried out using intuitive menu-driven tools, and the software features a graphical interface for building Process Flow Diagrams (PFDs) **[1]**.

The HYSYS simulator is built around mathematical models of unit operations, which involve specific equipment such as vessels, compressors, distillation columns, heat exchangers, and more. These operations are connected within the PFD through information streams that carry calculated process data between them.

As such, HYSYS is a powerful computing platform designed for simulating gas processing, refining processes, and petrochemical operations.

Using HYSYS, engineers can:

- Estimate production capacity
- Size equipment that makes up a given unit
- Determine operational limits
- Understand critical phases of the process

Furthermore, the software supports real-time flow simulations, helping to define safe operating boundaries and to evaluate risks based on dynamic variations of key parameters such as pressure (P) and temperature (T) **[2]**.

IV.2.2 How HYSYS Works :

In order for HYSYS to solve a process flow diagram and/or assist in the sizing of specific equipment within that process, the user must first:

- Specify the components involved (gas, liquid, or mixture).
- Define the necessary parameters required for each unit operation calculation.
- Build the Process Flow Diagram (PFD) of the section being studied.
- Select an appropriate thermodynamic model suited to the type of system being simulated.

This model is used to determine thermodynamic properties, volumetric characteristics, and the physical state of compounds or mixtures.

The success of the simulation therefore depends on the choice of the thermodynamic model, as each model is designed for a specific class of fluids and is valid within a recommended range of pressure and temperature conditions.

IV.2.3 Mathematical Model:

A mathematical model consists of a set of equations developed to describe the behavior of a given system (such as a unit operation: phase separation, compression, heat exchange, or others). These include mass, energy, and momentum conservation equations. The equations may be algebraic or differential, depending on the complexity and dynamics of the process being modeled.

IV.2.4 Selection of the Thermodynamic Model:

Simulation work begins with the selection of a thermodynamic model that is best suited to the system under study and that ensures minimal deviation from the design data.

An equation of state for a pure substance is a mathematical relationship that links temperature (T), pressure (P), and molar volume (V).

The simplest such equation is the ideal gas law, but a more refined example is the Van der Waals equation of state for a pure gas:

$$\frac{RT}{(V-b)} - \frac{a}{V^2} \qquad \textbf{Eq IV.1}$$

The equation of state most commonly used for hydrocarbons is the **Peng–Robinson** equation, which is written as:

$$P = \frac{\mathrm{RT}}{v-b} - \frac{\mathrm{a}}{v^2+2bv-b^2} \qquad \textbf{Eq IV.2}$$

$$b = 0{,}0078\,\frac{RT_C}{P_C} \qquad \textbf{Eq IV.3}$$

$$\mathrm{a} = 0{,}45724\,\frac{(RT_C)^2}{P_C}\left[1+(0{,}37346+1{,}54226-0{,}26992w^2)\left(1-T_r^{0.5}\right)\right] \qquad \textbf{Eq IV.4}$$

One can identify a repulsion term, which accounts for the molecular volume through the parameter b (also known as co-volume), and an attraction term, or pressure correction, represented by the parameter a.

IV.3 Problem Statement and Methodology

The RA2K condensate topping refinery located in Skikda was designed to operate under three possible processing scenarios:

- **Case A**: Maximum naphtha, maximum light gas oil production.
- **Case B**: Maximum kerosene production.

- **Case C**: Maximum naphtha, minimum light gas oil production.

The facility was originally designed and calculated to process condensate feedstock from five different sources:

- Rhourd Nous,
- Alrar,
- Bejaia,
- OB #1,
- New OB #1.

IV.3.1 Problematic :

The design operating parameters were defined by the licensor based on one reference condensate. However, since the characteristics of each condensate source vary, the optimal operating parameters change depending on the specific feedstock being processed.

The present study aims to evaluate the possibility of determining a new set of optimized operating parameters that could be considered ideal for maximizing kerosene production using the actual feed composition.

IV.3.2 Methodology :

The methodology applied in this study consists of the following steps:

- Initially, a simulation study was carried out using **ASPEN HYSYS V11** to reproduce and validate the design case conditions.
- Once the design case simulation was validated, the model was updated and run with actual operating data.
- Finally, an optimization study was performed on the real case in order to determine the optimal operating conditions that would maximize kerosene

production while meeting the required product specifications.

IV.4 Simulation and Validation by HYSYS of the Design Case

IV.4.1 Condensate Preparation:

The TBP distillation data of the design condensate used for the simulation are presented in Table IV-1 :

Table IV.1 - *TBP Distillation Data of the Design Condensate*

TBP Range (°C)	Liquid Distilled (%)	Density at 20°C (kg/m³)
IBP - 15	2.73	642.0
15 - 65	29.84	642.0
65 - 70	2.70	642.0
70 - 75	2.71	668.9
75 - 80	2.74	687.3
80 - 85	3.00	697.0
85 - 90	3.30	702.2
90 - 95	3.18	706.4
95 - 100	2.77	710.7
100 - 105	2.38	714.9
105 - 110	2.19	723.6
110 - 115	2.12	728.1
115 - 120	2.13	732.6
120 - 125	2.25	737.1
125 - 130	2.28	741.0
130 - 135	2.11	744.6
135 - 140	1.85	748.5
140 - 145	1.67	751.2
145 - 150	1.61	752.5
150 - 155	1.60	753.7
155 - 160	1.63	756.7
160 - 165	1.67	762.9
165 - 170	1.48	765.5
170 - 175	1.48	766.2

TBP Range (°C)	**Liquid Distilled (%)**	**Density at 20°C (kg/m³)**
175 - 180	1.12	766.7
180 - 185	0.94	768.8
185 - 190	0.93	771.1
190 - 195	1.11	775.6
195 - 200	1.12	780.3
200 - 205	0.99	782.0
205 - 210	0.93	783.3
210 - 215	0.86	784.8
215 - 220	0.80	787.4
220 - 225	0.74	789.8
225 - 230	0.71	791.1
230 - 235	0.68	792.2
235 - 240	0.62	795.2
240 - 245	0.58	799.4
245 - 250	0.57	802.2
250 - 255	0.56	805.1
255 - 260	0.54	806.7
260 - 265	0.45	810.1
265 - 270	0.37	810.4
270 - 275	0.34	811.7
275 - 280	0.33	814.6
280 - 285	0.32	818.4
285 - 290	0.30	822.5
290 - 295	0.28	826.8
295 - 300	0.27	830.9
300 - FBP	2.13	838.2

The global characteristics of the design condensate, as entered into the Petroleum Assay module of Aspen HYSYS, are presented in Table IV.2

Table IV2- *Global Properties of the Design Condensate*

Property	**Result**
API Gravity (°API)	67.88
Density at 15°C (g/cm³)	0.7095
Density at 20°C (g/cm³)	0.7051
Viscosity at 20°C (mm²/s)	0.59
Viscosity at 40°C (mm²/s)	< 0.50
Kuop Characterization Factor	12.2

The chromatographic analysis of the light fraction of the real condensate feed is presented in Table IV.3

Table IV.3 - *Chromatographic Analysis of the Light Fraction of the Feed*

Component	Weight %	Volume %
C2	0.002	0.003
C3	0.020	0.030
i-C4	0.330	0.390
n-C4	1.910	2.260
i-C5	0.390	0.370
n-C5	0.020	0.020
Total	**2.672**	**3.073**

	Whole Crude	Cut 1	Cut 2	Cut 3	Cut 4	Cut 5	Cut 6	Cut 7	Cut 8	Cut 9	Cut 10
Initial Temperature: (C)	IBP	IBP	15.0000	65.0000	70.0000	75.0000	80.0000	85.0000	90.0000	95.0000	100.000
Final Temperature: (C)	FBP	15.0000	65.0000	70.0000	75.0000	80.0000	85.0000	90.0000	95.0000	100.0000	105.000
CutYieldByWt (%)		2.73	29.84	2.70	2.71	2.74	3.00	3.30	3.18	2.77	2.38
StdLiquidDensity (kg/m3)	708.9899		642.0000	668.9000	687.3000	697.0000	702.2000	706.4000	710.7000	714.9000	719.2000
SulfurByWt (%)											
KinematicViscosity (cSt)...	0.590										
ParaffinsByVol (%)											
NaphthenesByVol (%)											
OlefinsByVol (%)											
AromByVol (%)											
PourPoint (C)											

Figure IV.1- *Condensate Installation in the HYSYS Simulator*

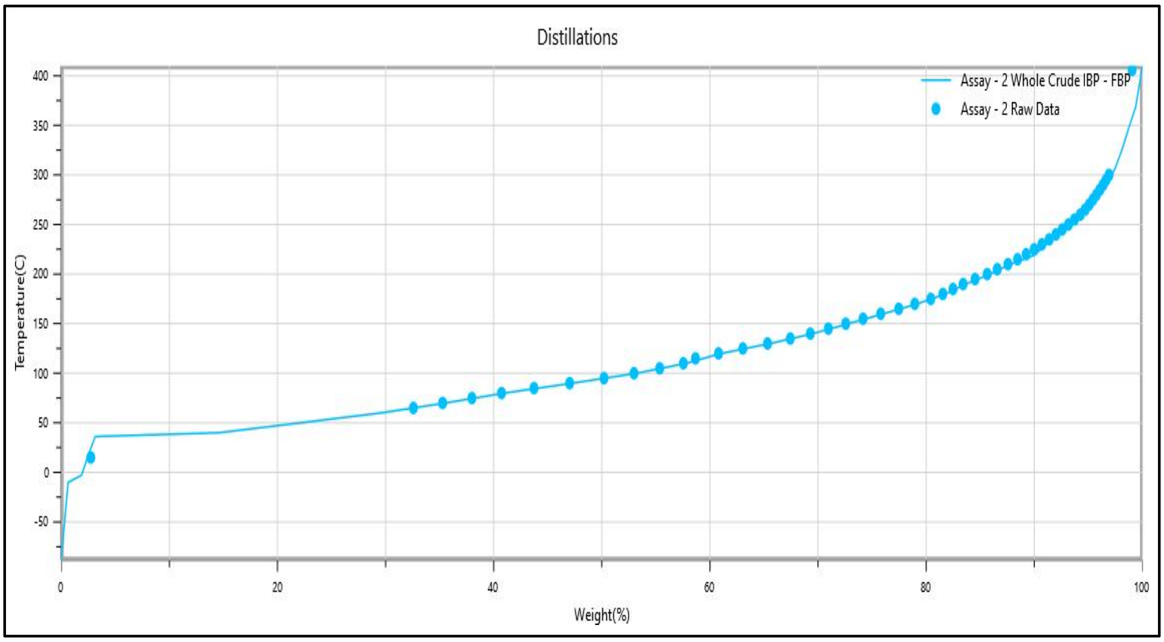


Figure IV.2- *TBP Distillation Curve of the Design Condensate*

IV.4.2 Installation of the Prefractionation Column T101 and the Naphtha Stripper T102 :

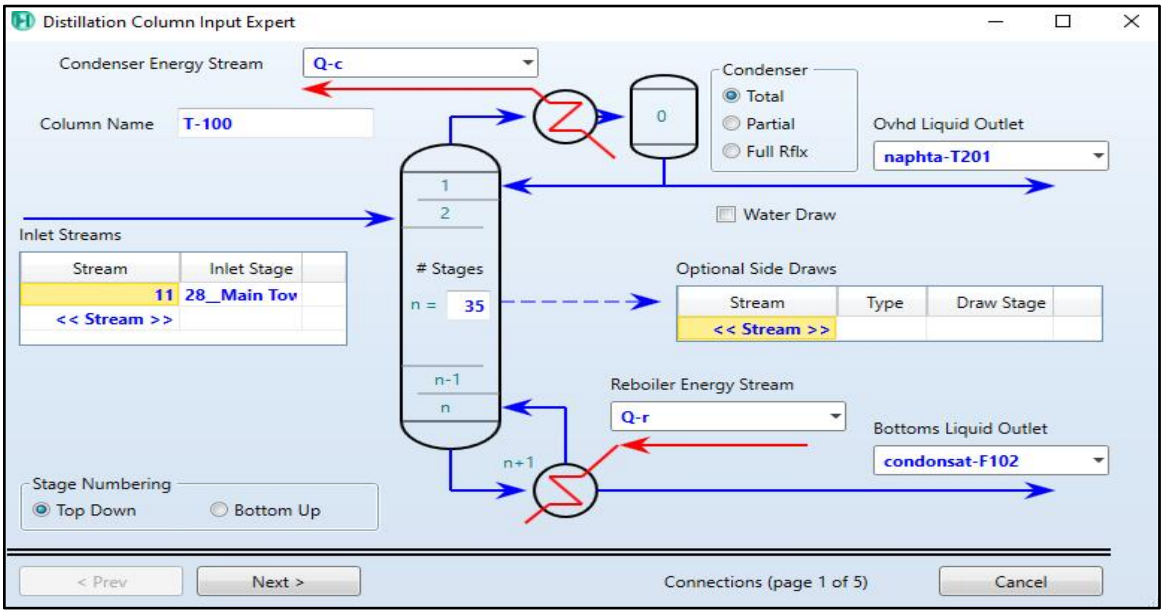
The installation of the prefractionation column T101 and the naphtha stripper T102 was carried out using Aspen HYSYS simulation software. The operating data obtained from the design case are summarized in Tables IV.4 and IV.5.

Table IV.4- *Product Properties of Prefractionation Column T101*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**
	Design	Simulated	Design	Simulated	
			Inlet		
Feed	631.3	631.3	136	136.3	436.3
Reflux	279.4	279.7	72	75	1011
			Outlet		
Overhead	410.7	—	87	88	421.3
Distillate	131.3	131.3	72	—	1501
Naphtha Product	200	200.5	124	—	1061
Naphtha Draw	234.4	—	119	116	421.3
Bottom	300	300.5	191	191.8	1481

Table IV.5- *Parameters of Naphtha Stripper Column (T102)*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		Pressure (kPa)
	Design	Simulated	Design	Simulated	
Liquid Inlet	234.4	228.5	119	118	426.3
Vapor Outlet	34.4	33.4	119	118	426.3



Distillation Column Input Expert

Condenser Energy Stream: Q-c

Column Name: T-100

Condenser: ● Total ○ Partial ○ Full Rflx

Ovhd Liquid Outlet: naphta-T201

☐ Water Draw

Inlet Streams

Stream	Inlet Stage
11	28__Main Tow
<< Stream >>	

Stages n = 35

Optional Side Draws

Stream	Type	Draw Stage
<< Stream >>		

Reboiler Energy Stream: Q-r

Bottoms Liquid Outlet: condonsat-F102

Stage Numbering: ● Top Down ○ Bottom Up

Connections (page 1 of 5)

Figure IV.3 - *Installation of the Pre-fractionation Column T101 in the HYSYS Simulator*

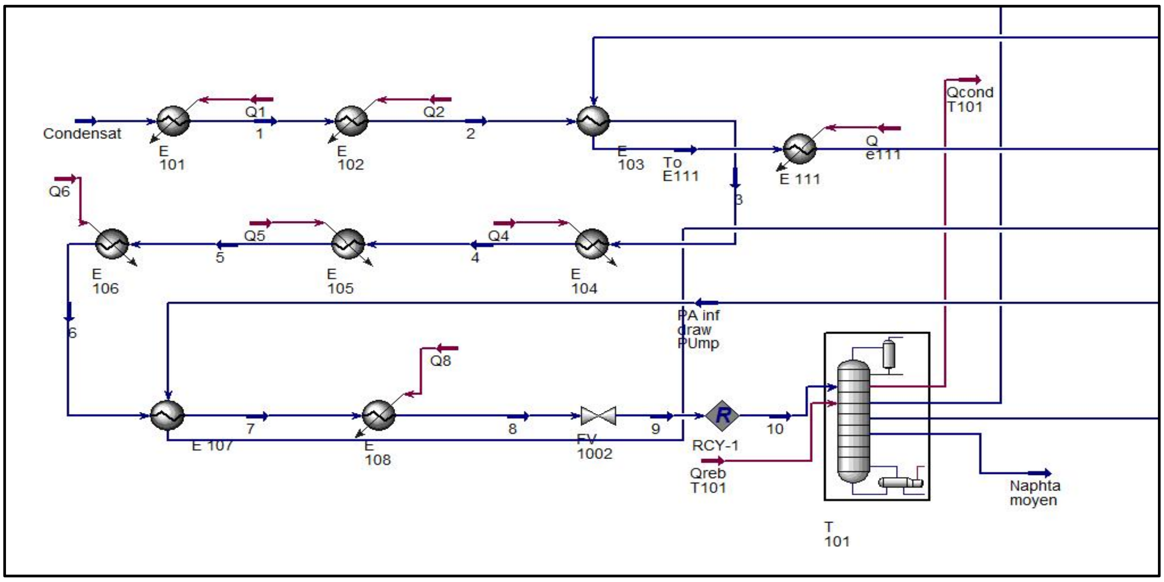


Figure IV.4 - *Simulation Diagram of the Pre-fractionation Column T101*

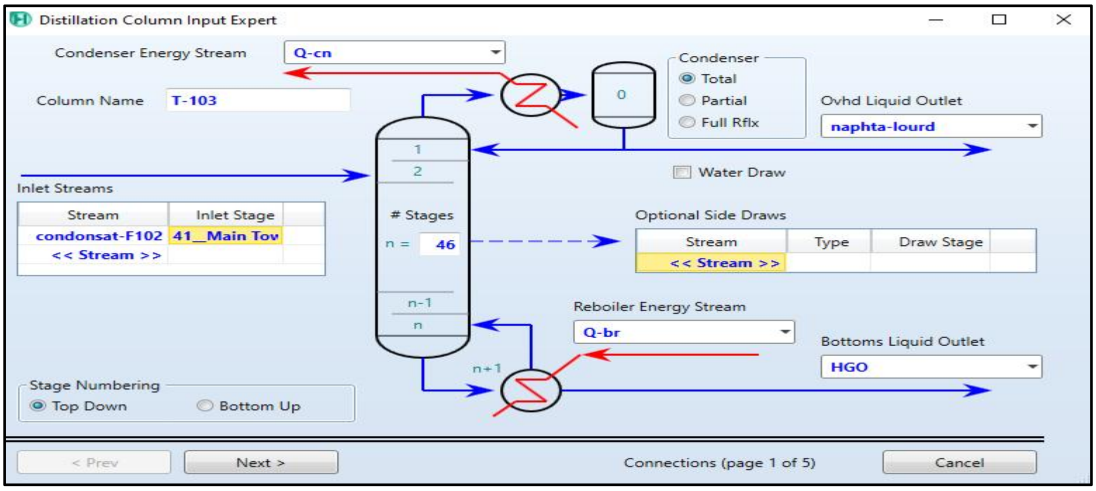
IV.4.3 Installation of the Atmospheric Distillation Column T103 :

The atmospheric distillation column T103, along with the kerosene stripper T104, the light gas oil (LGO) stripper T105, and the pump-around circuits PA110, PA111, and

PA112, were installed and simulated using the Aspen HYSYS software. The operating parameters of these units, both in the design case and after optimization, are presented in the following tables.

Table IV.6 - *Parameters of Atmospheric Distillation Column T103*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**	
	Design	Simulated	Design	Simulated	Design	Simulated
<u>Inlet</u>						
Charge	300.0	300.0	216	216	206.3	118
Reflux	60.4	68.0	116	116	1121	118
<u>Outlet</u>						
Overhead	239.6	240.0	155	129	181.3	118
Distillate	179.2	180.0	116	116	821.3	118
Kerosene Draw	117.6	128.0	194	215	1211	118
LGO Draw	71.5	42.0	228	250	971.3	118
Kerosene Product	72.5	76.8	211	215	192.3	118
LGO Product	34.9	30.5	279	279	200.3	118
Bottom	13.5	13.0	355	355	911.3	118



Condenser Energy Stream: Q-cn

Column Name: T-103

Condenser: ● Total ○ Partial ○ Full Rflx

Ovhd Liquid Output: naphta-lourd

☐ Water Draw

Inlet Streams

Stream	Inlet Stage
condonsat-F102	41__Main Tov
<< Stream >>	

Stages n = 46

Optional Side Draws

Stream	Type	Draw Stage
<< Stream >>		

Reboiler Energy Stream: Q-br

Bottoms Liquid Outlet: HGO

Stage Numbering: ● Top Down ○ Bottom Up

Connections (page 1 of 5)

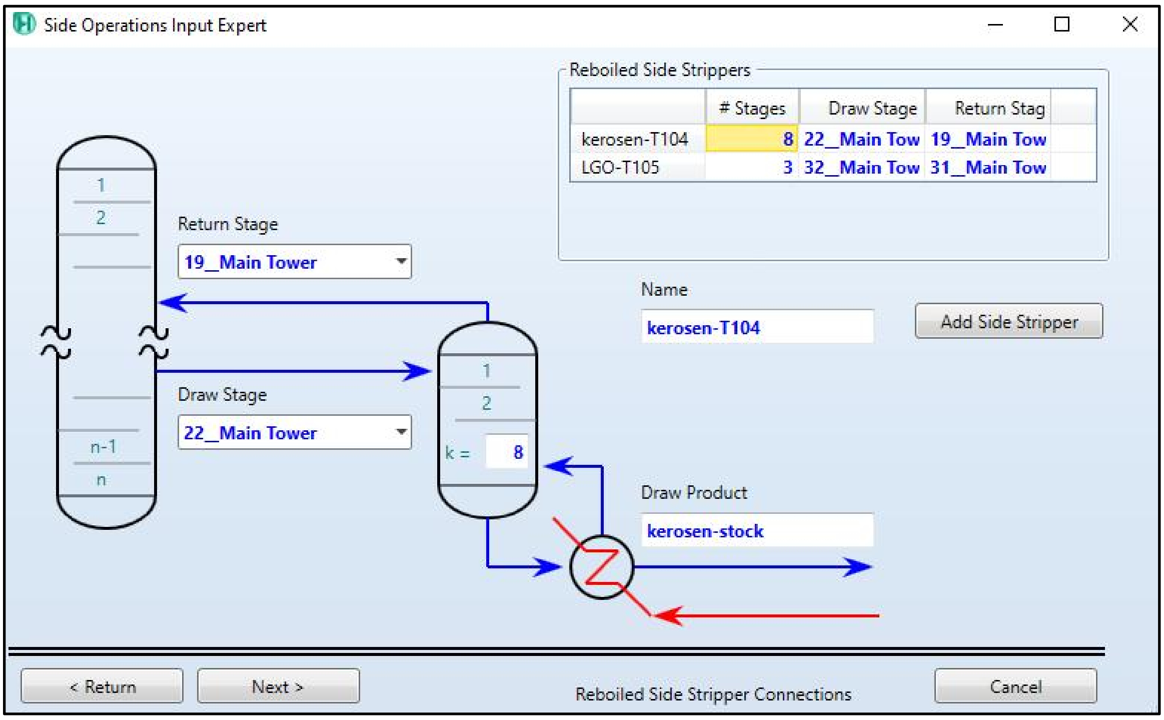
Figure IV.5 - *Installation of the Atmospheric Column T103 in the HYSYS Simulator*

Table IV.7 *- Parameters of Kerosene Stripper Column (T104)*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**	
	Design	Simulated	Design	Simulated	Design	Simulated
Liquid Inlet	117.63	128.0	194	215	192.3	192.3
Vapor Outlet	45.13	50.0	194	215	192.3	192.3

Table IV.8 *- Parameters of LGO Stripper Column (T105)*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**	
	Design	Simulated	Design	Simulated	Design	Simulated
Liquid Inlet	71.50	42.0	228	255	191.3	191.3
Vapor Outlet	36.60	21.0	251	265	191.3	191.3



Reboiled Side Strippers

	# Stages	Draw Stage	Return Stag
kerosen-T104	8	22__Main Tow	19__Main Tow
LGO-T105	3	32__Main Tow	31__Main Tow

Return Stage: 19__Main Tower

Draw Stage: 22__Main Tower

k = 8

Name: kerosen-T104

Draw Product: kerosen-stock

Figure IV.6 *- Installation of the stripper T104 and T105 in the similator of HYSYS.*

Table IV.9 - *Parameters of Pump Around PA110*

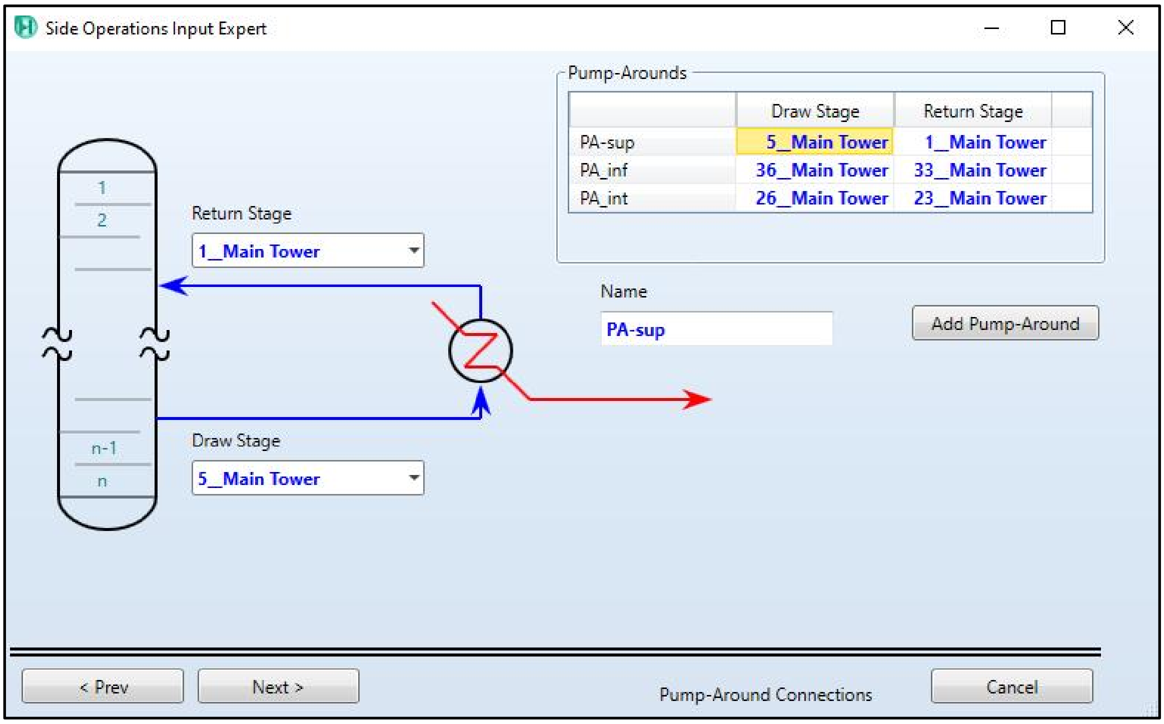
Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**	
	Design	Simulated	Design	Simulated	Design	Simulated
Liquid Inlet	758.0	710.0	151	148	1121	118
Liquid Outlet	758.0	710.0	131	129	921.3	118

Table IV.10 - *Parameters of Pump Around PA111*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**	
	Design	Simulated	Design	Simulated	Design	Simulated
Liquid Inlet	418.0	245.0	212	210	1041	118
Liquid Outlet	148.0	145.0	172	170	941.3	118

Table IV.11- *Parameters of Pump Around PA112*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**	
	Design	Simulated	Design	Simulated	Design	Simulated
Liquid Inlet	132.0	215.0	249	240	891.3	118
Liquid Outlet	132.0	215.0	199	195	801.3	118



Side Operations Input Expert

Pump-Arounds

	Draw Stage	Return Stage
PA-sup	5__Main Tower	1__Main Tower
PA_inf	36__Main Tower	33__Main Tower
PA_int	26__Main Tower	23__Main Tower

Return Stage: 1__Main Tower

Draw Stage: 5__Main Tower

Name: PA-sup

Pump-Around Connections

Figure IV.7 - *Installation of Pump rounds PA110, PA111, and PA112 in the HYSYS Simulator*

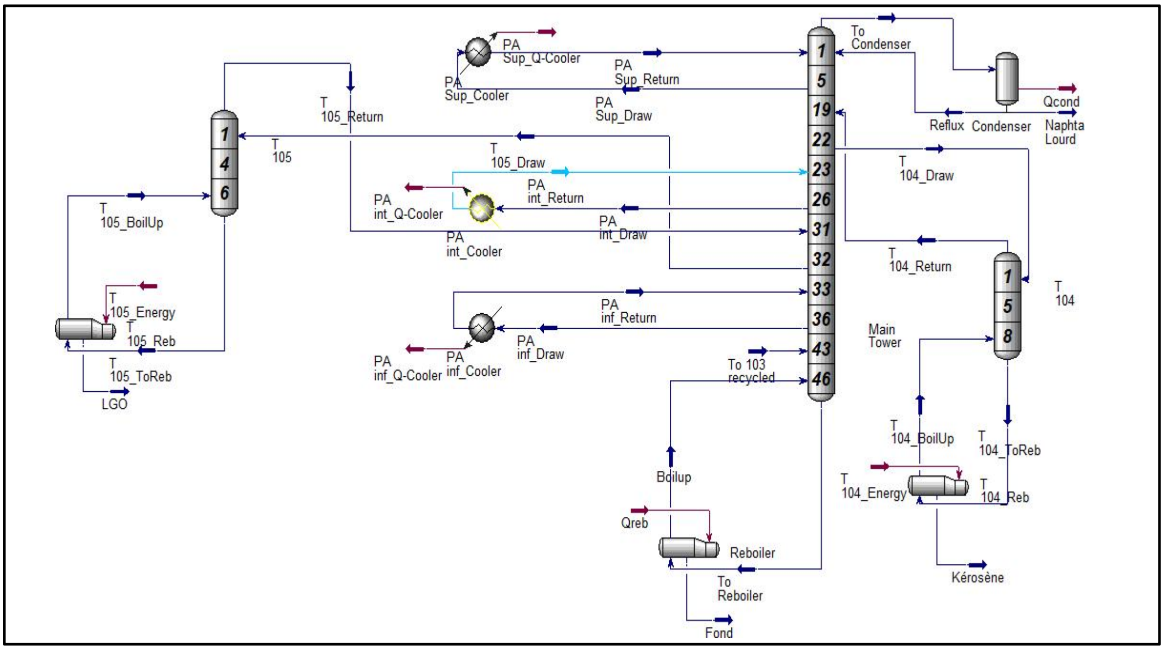


Figure IV.8 - *Simulation Diagram of the Atmospheric Column T103*

IV.5 Simulation and Optimization of the Real Case Using HYSYS

After confirming the validity of the design case simulation, the simulation of the real case was carried out in order to proceed with the maximization of kerosene production.

This simulation was conducted using the **ASPEN HYSYS V11** process simulator. The **Peng-Robinson thermodynamic model** was selected as the most suitable model for the simulation of this distillation unit.

Upon completion of the real case simulation, an optimization study was performed with the objective of determining the optimal operating conditions that allow for maximizing kerosene yield, while ensuring that the product specifications are fully met.

IV.5.1 Real Case Simulation Data :

The actual operating data used for the simulation of the real case are presented in the tables below.

IV.5.1.1 Condensate Preparation :

Table IV.12 - *TBP Distillation Data of the Real Condensate*

TBP Range (°C)	Liquid Distilled (%)	Density at 20°C (kg/m³)
IBP – 35	1.5	—
35 – 65	36.0	—
65 – 90	14.7	641.2
90 – 150	27.1	693.6
150 – 180	7.7	768.0
180 – 240	7.8	784.6
240 – FBP	5.2	823.7

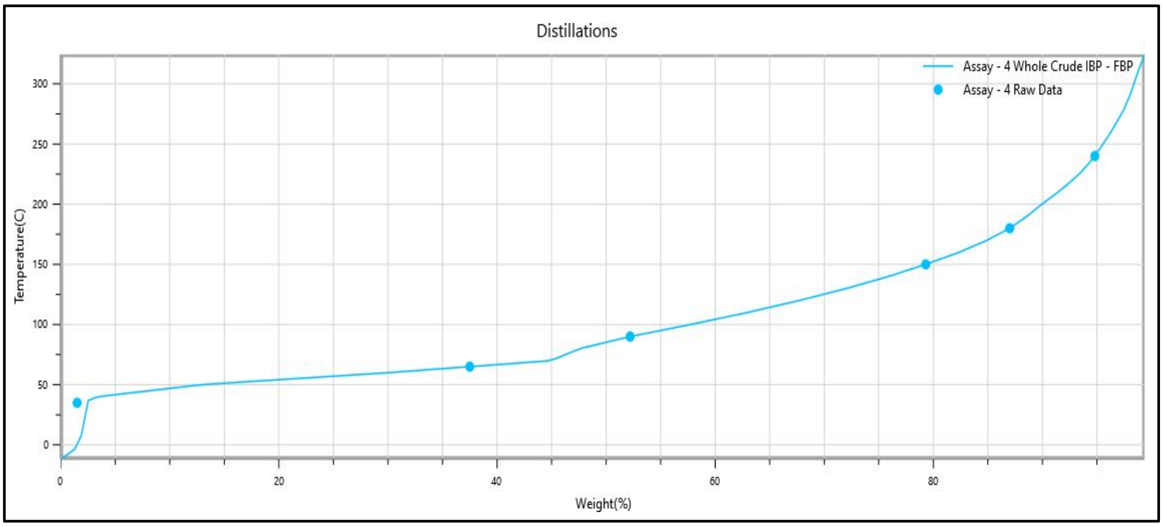


Figure IV.9 -*TBP Distillation Curve of the Current Condensate*

Table IV.13 - *Chromatographic Analysis of the Light Fraction of the Real Feed*

Component	**Weight %**
Propane	0.00
Isobutane	0.20
n-Butane	1.80
Isopentane	0.30
n-Pentane	0.10
n-Hexane	0.10
Total	**2.50**

Table IV.14 - *Global Properties of the Real Condensate*

Property	**Value**
Density (g/cm³)	0.7001
Viscosity at 37.8°C (cSt)	0.518
Viscosity at 50°C (cSt)	0.47

Table IV.15 - *Properties of the Drawn Products*

ASTM Cut Point	**Condensate**	**Naphtha**	**Kerosene**	**LGO**	**HGO**
ASTM Distillation (°C)					
IBP	38	38	156	225	260
5%	46	47	164	235	282
10%	50	50	170	238	290
30%	62	60	181	245	306
50%	84	74	191	251	322
65%	—	—	—	255	337
85%	—	—	—	263	—
90%	195	131	218	266	—
95%	244	145	225	270	—
FBP	274	164	242	286	—
Residue (%)	0.9	0.4	0.9	1.2	—
Loss (%)	1.2	1.2	0.3	0.2	—
Densities of Drawn Products g/cm^3					
	0.7001	0.6423	0.7749	0.81	0.8425

Table IV.16 - *Product Parameters of Prefractionation Column T101*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**
	Design	Simulated	Design	Simulated	
Inlet					
Charge	617.0	617.0	121.4	121.4	1659
Reflux	190.0	195.0	91.0	90.0	—
Outlet					
Overhead	—	—	87.0	85.0	427.3
Distillate	145.0	145.0	71.0	68.0	—
Naphtha Product	169.2	172.0	106.7	102.0	—
Naphtha Draw	—	—	108.5	—	—
Bottom	—	—	175.4	178.0	451.3

Table IV.17 - *Parameters of Naphtha Stripper Column T102*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**	
	Design	Simulated	Design	Simulated	Design	Simulated
Liquid Inlet	—	—	108.5	105.0	3531	3531
Vapor Outlet	—	—	108.5	105.0	3531	3531

Table IV.18 - *Parameters of Atmospheric Distillation Column T103*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**	
	Design	Simulated	Design	Simulated	Design	Simulated
<u>Inlet</u>						
Charge	297.5	295.0	193.5	193.5	206.3	118.0
Reflux	44.6	52.0	150.5	147.0	—	—
<u>Outlet</u>						
Overhead	—	—	148.2	129.0	—	118.0
Distillate	257.9	258.0	103.3	103.0	—	—
Kerosene Draw	—	—	177.5	—	—	—
LGO Draw	—	—	203.7	—	—	—
Kerosene Product	60.41	76.8	215.3	215.0	213.3	118.0
LGO Product	7.3	6.2	286.2	280.0	621.3	118.0
Bottom	348.6	336.0	26.2	22.4	211.3	118.0

Table IV.19 - *Parameters of Kerosene Stripper Column T104*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**
	Design	Simulated	Design	Simulated	
Liquid Inlet	—	—	177.5	180.0	228.3
Vapor Outlet	—	—	180.0	183.0	228.3

Table IV.20 - *Parameters of LGO Stripper Column T105*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**	
	Design	Simulated	Design	Simulated	Design	Simulated
Liquid Inlet	—	—	203.7	205.0	213.3	213.3
Vapor Outlet	—	—	236.5	238.0	213.3	213.3

Table IV.21 - *Parameters of Upper Pump-Around PA110*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**	
	Design	Simulated	Design	Simulated	Design	Simulated
Liquid Inlet	517.5	517.5	134.5	133.0	—	—
Liquid Outlet	517.5	517.5	153.0	148.0	—	—

Table IV.22 - *Parameters of Intermediate Pump-Around PA111*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**
	Design	Simulated	Design	Simulated	
Liquid Inlet	412.0	412.0	168.0	166.0	—
Liquid Outlet	412.0	412.0	190.0	184.0	—

Table IV.23 **-***Parameters of Lower Pump-Around PA112*

Stream	**Flowrate (T/h)**		**Temperature (°C)**		**Pressure (kPa)**
	Design	Simulated	Design	Simulated	
Liquid Inlet	62.0	62.0	148.0	146.0	—
Liquid Outlet	62.0	62.0	205.0	200.0	—

IV.5.2 Optimization of Operating Parameters :

In this section, we aim to investigate the possibility of maximizing kerosene production while maintaining the required specifications for all products withdrawn from the atmospheric distillation column and ensuring its proper operation.

The key operating parameters of interest in this study are as follows:

Table IV.24 **-** *Operating Parameters*

Parameter	**Value**
Temperature (°C)	
PA110 return temperature (°C)	134.5
PA111 return temperature (°C)	168.0
PA112 return temperature (°C)	148.0
flowrate (T/h)	
PA110 flowrate (T/h)	517.5
PA111 flowrate (T/h)	412.0
PA112 flowrate (T/h)	62.0

The product yields were calculated using the following formula:

Yield (%) = (Product flowrate / Feed flowrate) × 100

Table IV.25 - *Product Characteristics*

Product	**Density (g/cm³)**	**Flowrate (T/h)**	**Yield (%)**
Naphtha	0.6423	257.89	41.79
Kerosene	0.7749	60.41	9.79
LGO	0.8100	7.30	1.18

IV.5.2.1 Effect of the Return Temperature of Intermediate Pump-Around PA111:

The variation in the return temperature of the intermediate pump-around PA111 yielded the results presented in the table below :

Table IV.26 - *Influence of PA111 Return Temperature on the Properties of the Produced Kerosene*

PA111 Return Temperature (°C)	**Kerosene Flowrate (T/h)**	**Yield (%)**	**Density (g/cm³)**
145	68.2	11.06	0.7751
148	67.9	11.00	0.7746
150	67.5	10.95	0.7743
153	66.9	10.85	0.7742

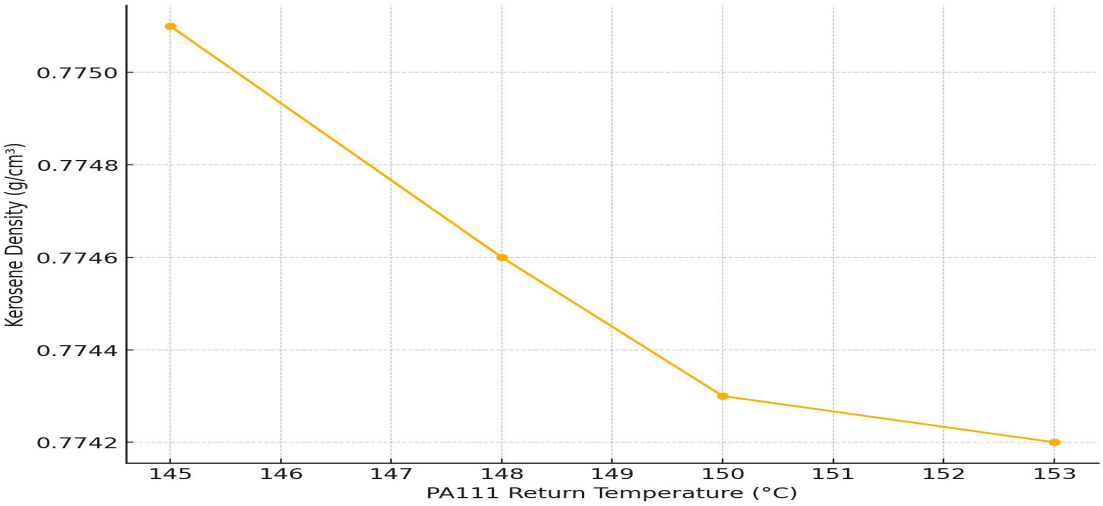


Figure IV.10 - *Variation of Kerosene Density as a Function of the Return Temperature of the Circulating Reflux PA111.*

IV.5.2.1.1 Interpretation of Results :

Based on the table and the graph, we note that lowering the return temperature of PA111 increases the density and yield of the produced kerosene. This is explained by the fact that a lower temperature creates a cooler gradient in the intermediate section of the column, which enhances the condensation of lighter hydrocarbons and reduces the condensation of heavier ones within the PA111 zone. As a result, more light gas oil vapors escape toward the kerosene draw-off zone and condense, increasing both the density and the quantity of the kerosene cut. This confirms that reducing the temperature of PA111 favors kerosene recovery.

IV.5.2.2 Effect of the Return Temperature of the Lower Pump-Around PA112 :

The variation in the return temperature of the lower pump-around PA112 yielded the results presented in the table below:

***Table IV.27 -** Influence of PA112 Return Temperature on the Properties of the Produced Kerosene.*

PA112 Return Temperature (°C)	**Kerosene Flowrate (T/h)**	**Yield (%)**	**Density (g/cm³)**
165	66.7	10.80	0.7740
168	67.2	10.88	0.7744
172	67.9	11.00	0.7746
175	68.3	11.07	0.7750

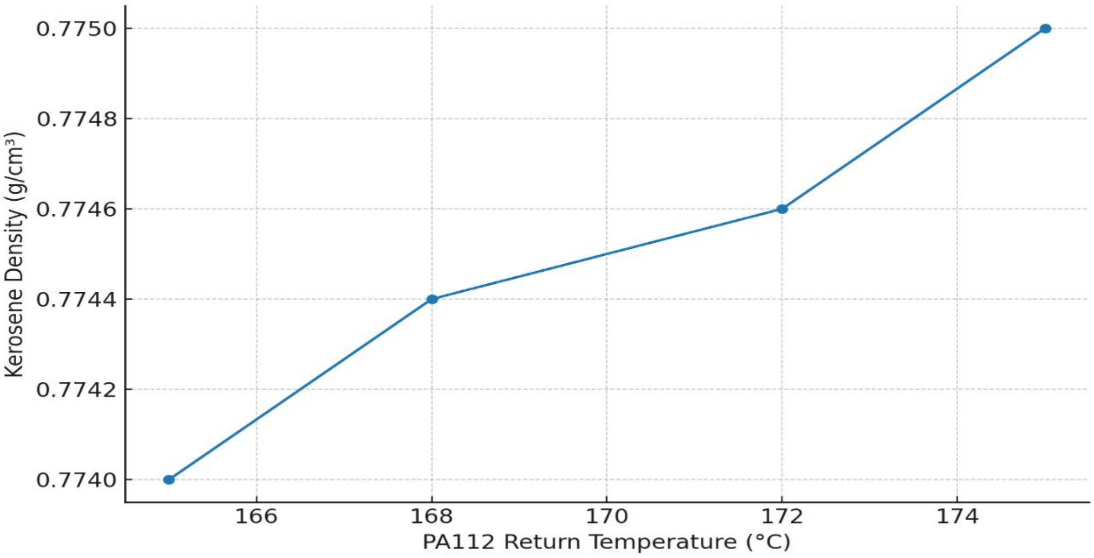


Figure IV.11 - *Variation of Kerosene Density as a Function of the Return Temperature of the Circulating Reflux PA112*

IV.5.2.2.1 Interpretation of Results :

The results indicate that increasing the return temperature of PA112 leads to a noticeable rise in the density of the produced kerosene. This is primarily due to the enhanced upward migration of heavier hydrocarbons, particularly from the light gas oil fraction, which are driven into the kerosene draw-off zone by the increased thermal gradient. As these heavier components condense alongside the kerosene, the resulting product becomes denser. The elevated temperature in the lower section of the column thus favors a richer cut in terms of hydrocarbon chain length, contributing to both improved yield and product density.

IV.5.2. 3 Effect of Intermediate Pump-Around PA111 Flowrate :

The variation in the flowrates of the intermediate pump-around PA111 yielded the results presented in the table below:

Table IV.28 - *Influence of PA111 Reflux Flowrate on the Properties of the Produced Kerosene.*

PA111 Flowrate (T/h)	Kerosene Flowrate (T/h)	Yield (%)	Density (g/cm³)
85	67.5	10.95	0.7743
90	67.9	11.00	0.7746
95	68.0	11.02	0.7748
100	68.1	11.04	0.7750

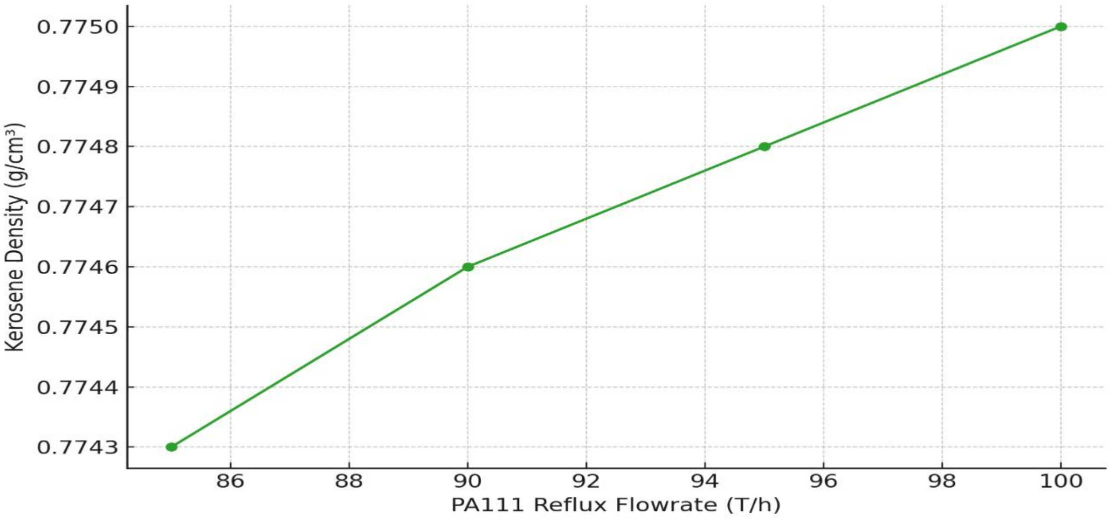


Figure IV.12 - *Variation of Kerosene Density as a Function of the Circulating Reflux Flowrate PA111.*

IV.5.2.3.1Interpretation of Results :

The results show that increasing the reflux flowrate of PA111 slightly increases the kerosene density and yield. This is explained by a stronger cooling effect in the intermediate section of the column, which enhances condensation and traps more light gas oil (LGO) vapors. However, to precisely reach the target of **11.00%** yield, the optimal flowrate selected is 90 T/h. This value reduces the cooling effect enough to allow more LGO vapors to migrate upward and condense in the kerosene zone, improving separation efficiency while meeting process specifications.

IV.5.2.4 Effect of Lower Pump-Around PA112 Flowrate :

The variation in the flowrates of the lower pump-around PA112 yielded the results presented in the table below:

Table IV.29 - *Influence of PA112 Reflux Flowrate on the Properties of the Produced Kerosene*

PA112 Flowrate (T/h)	**Kerosene Flowrate (T/h)**	**Yield (%)**	**Density (g/cm³)**
370	67.2	10.88	0.7743
375	67.6	10.94	0.7745
380	67.9	11.00	0.7746
385	68.0	11.02	0.7748

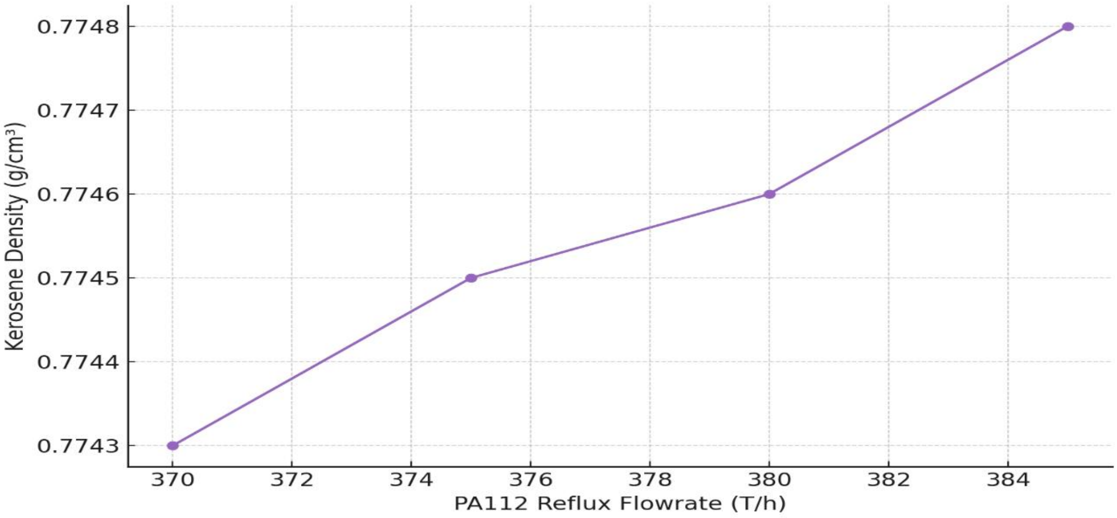


Figure IV.13 -*Variation of Kerosene Density as a Function of the Circulating Reflux Flowrate PA112.*

IV.5.2.4.1 Interpretation of Results :

The results show that increasing the flowrate of the lower circulating reflux PA112 slightly increases the density of the produced kerosene. This effect is explained by enhanced heat removal in the lower section of the column, which promotes the upward migration and subsequent condensation of heavier hydrocarbons in the kerosene draw-off zone. As a result, the kerosene becomes marginally denser due to the presence of components from the light gas oil range. This behavior confirms the importance of PA112 in regulating product separation and cut quality in the lower part of the column.

IV.5.2.5 Optimized Operating Parameters of Column T103 to Improve Kerosene Production :

Based on the previously obtained results, we continue the present work using the newly optimized parameters summarized in the following table:

Table IV. 30 - *Optimized Operating Parameters*

Parameter	**Value**
Temperature (°C)	
PA110 Return Temperature (°C)	134.5
PA111 Return Temperature (°C)	148.0
PA112 Return Temperature (°C)	172.0
Flowrate (T/h)	
PA110 Flowrate (T/h)	517.5
PA111 Flowrate (T/h)	90.0
PA112 Flowrate (T/h)	380.0

Table IV.31 - *Product Characteristics After Optimization*

Product	**Density (g/cm³)**	**Flowrate (T/h)**	**Yield (%)**
Naphtha	0.6445	258.76	41.92
Kerosene	**0.7746**	**67.91**	**11.00**
LGO	0.7841	6.12	0.99

IV.6 Conclusion

This study has demonstrated the possibility of increasing kerosene production while maintaining the required product specifications, particularly in terms of density and quality. However, this optimization resulted in a slight reduction in LGO yield, which remains an acceptable trade-off given the higher economic value of kerosene.

General conclusion

General conclusion

The work conducted at the RA2K condensate topping refinery falls within the framework of a final year project aiming to evaluate the potential for optimizing the operating parameters of the atmospheric distillation column T103 in order to increase kerosene yield while preserving the specification standards of all withdrawn products.

Achieving this objective required a thorough understanding of the column's operational behavior, along with a detailed analysis of how each process variable influences the separation of different product fractions.

By performing a dynamic simulation of the topping section using **Aspen HYSYS V11**, we reached the following conclusions:

- It is feasible to raise kerosene yield to **11.00%** while respecting JET-A1 quality standards, although this results in a slight decrease in LGO production (from 1.18% to 0.99%) due to intensified bottom reboiling.
- Overall, the **most effective strategy** for maximizing kerosene production is to **enhance reboiling at the bottom of the column**, specifically by **increasing the return temperature and flowrate of the lower pump-around (PA112)**. This encourages the upward migration of LGO vapors toward the kerosene draw-off zone.

To further improve the performance of the unit, we recommend extending the optimization scope to include the operating conditions of the **LGO stripper column (T105)** and the **upper pump-around circuit (PA110)**, which may help refine the distillation profile of column T103 even further.

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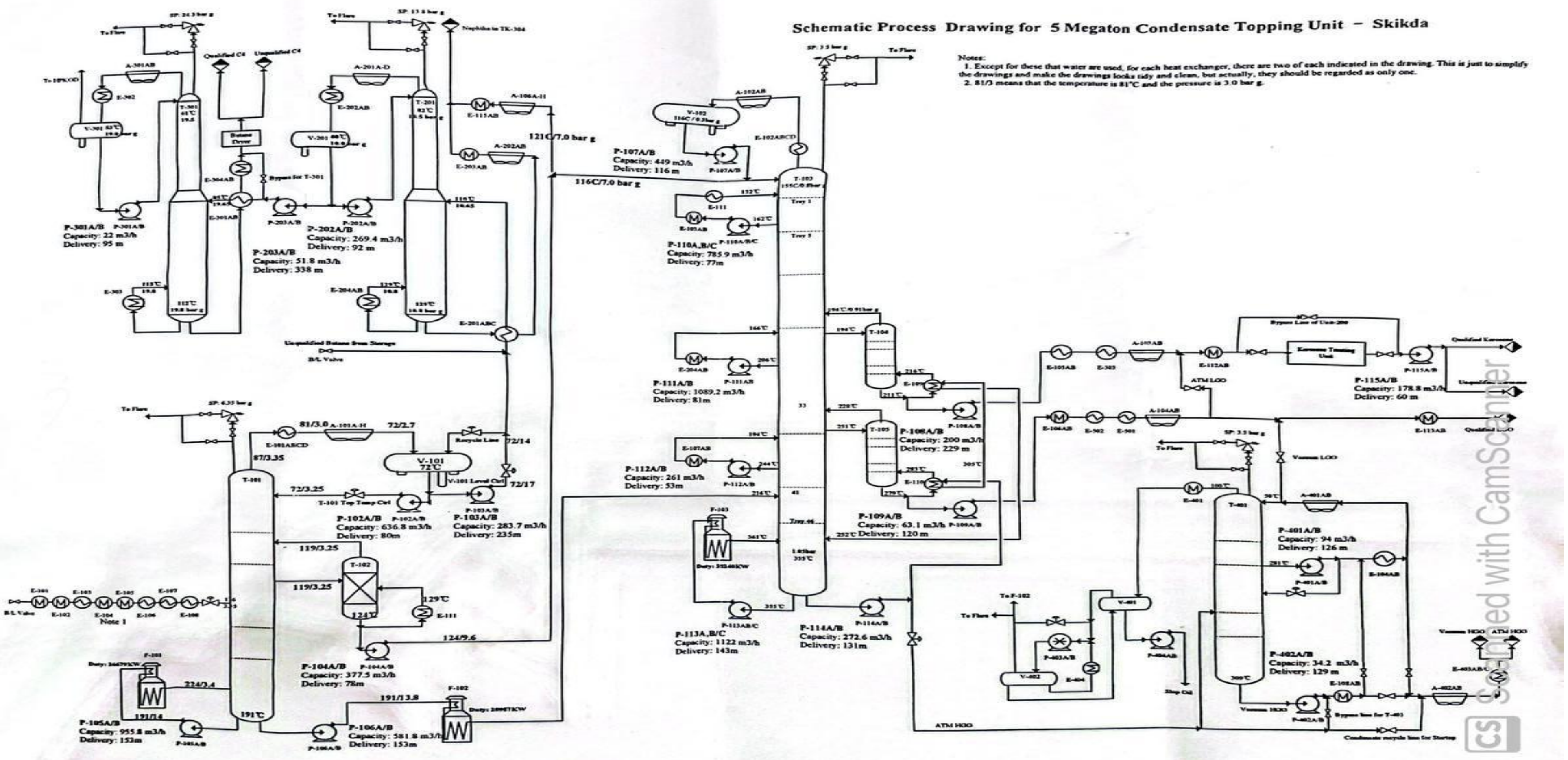
Annex o1 : Schematic of condensate topping unit (100) RA2K



Schematic Process Drawing for 5 Megaton Condensate Topping Unit – Skikda

Notes:
1. Except for these that water are used, for each heat exchanger, there are two of each indicated in the drawing. This is just to simplify the drawings and make the drawings looks tidy and clean, but actually, they should be regarded as only one.
2. 81/3 means that the temperature is 81°C and the pressure is 3.0 bar g.

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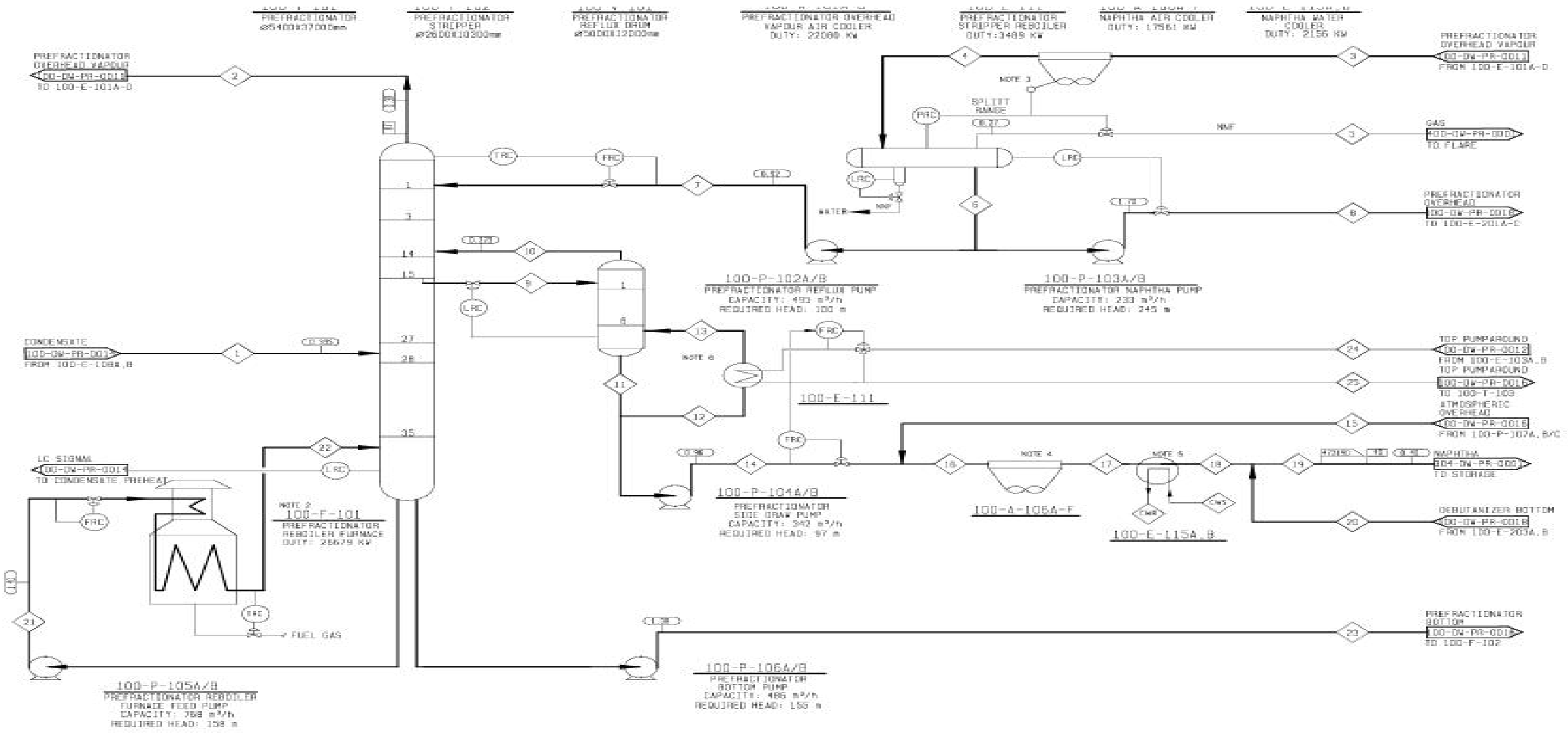
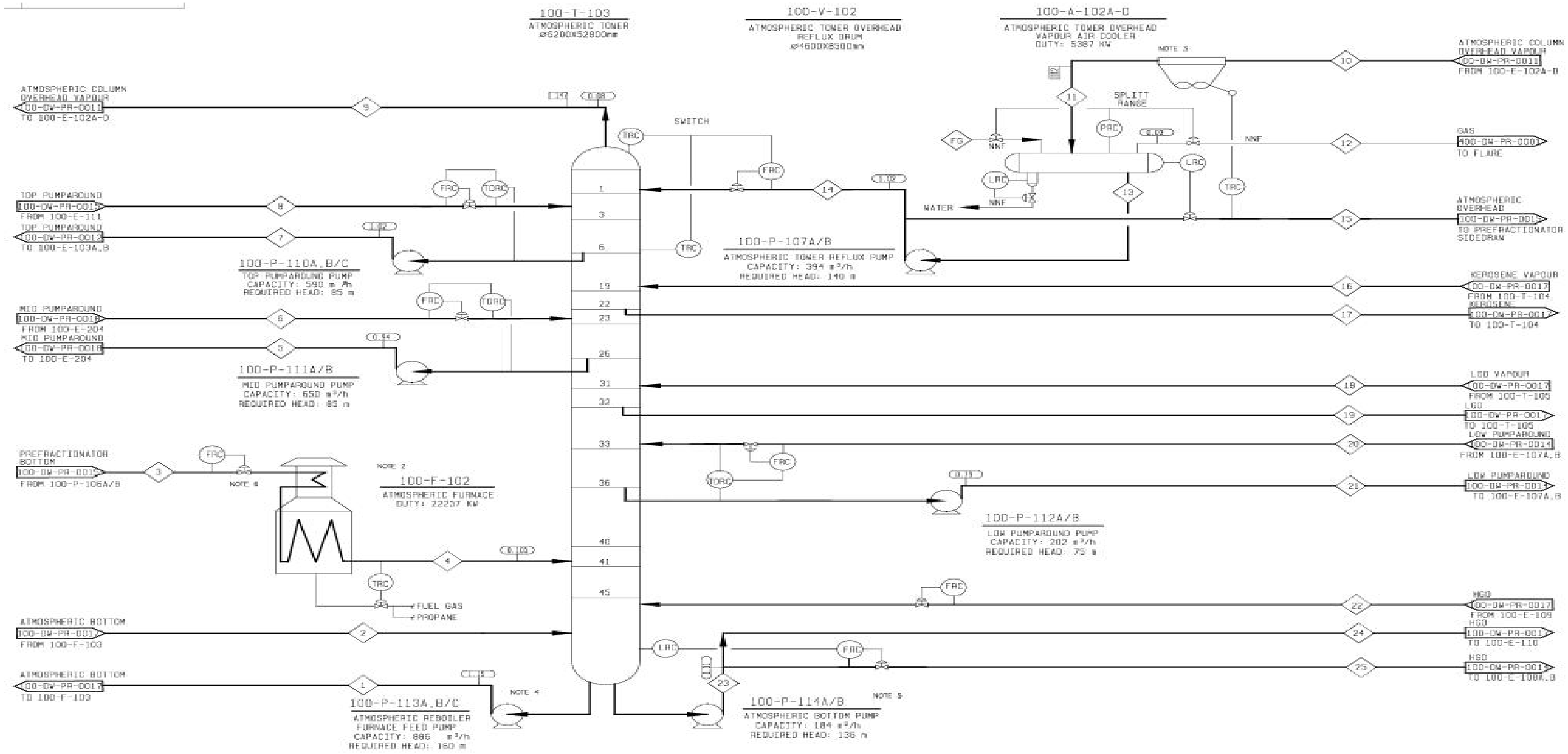
Annex 02 : PFD and material balances of the prefractionation section of the RA2K complex



	Stream number	1		2	3		4	5	6	7	8	9	10	11	12	13		14	15	16	17	18	19	20	21	22		23	24	25
	Phase(Liq.or vap.)	Vap	Liq	Vap	Vap	Liq	Liq	Vap	Liq	Liq	Liq	Liq	Vap	Liq	Liq	Vap	Liq	Liq	Liq	Liq	Liq	Liq	Liq	Liq	Liq	Vap	Liq	Liq	Liq	Liq
Flow	kg/hr	168197	463113	410781	218484	192297	410781	NNF	410781	279471	131310	234352	34352	343904	143904	35981	107923	200000	153450	353450	353450	353450	472190	118740	472039	209238	262801	300000	758002	758002
Temperature	℃	136	136	87	81	81	72	72	72	72	72	119	119	124	124	129	129	124	112	119	50	40	40	40	191	224	224	191	139	131
Pressure	MPa(g)	0.335	0.335	0.32	0.30	0.30	0.27	0.27	0.27	0.92	1.40	0.325	0.325	0.325	0.325	0.325	0.325	0.96	0.70	0.70	0.54	0.40	0.40	0.40	1.40	0.34	0.34	1.38	0.93	0.82
Density (actual)	kg/M3	10.0	617	9.8	9.4	560	564		564	564	564	583	10.1	584	584	10.3	586	584	653	618	687	695	574	610	614	13.1	605	617	655	661
Viscosity (actual)	cP	0.010	0.180	0.009	0.009	0.169	0.181		0.181	0.181	0.181	0.155	0.009	0.154	0.154	0.009	0.154	0.154	0.234	0.183	0.324	0.356	0.306	0.201	0.174	0.010	0.166	0.175	0.240	0.258

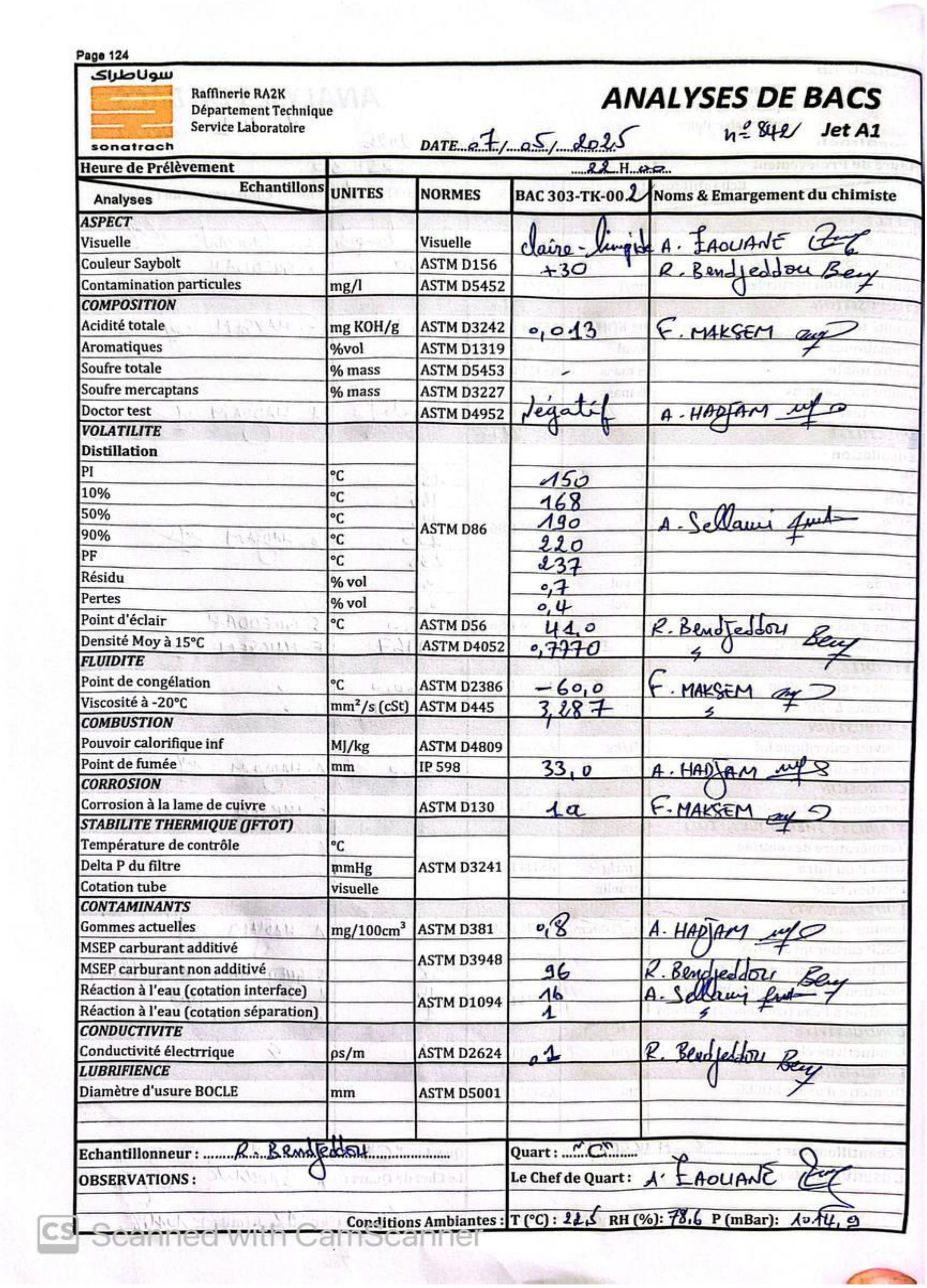
Annex 03 : PFD et bilan de matière de la section de distillation atmosphérique T103 du complexe RA2K



	Stream number	1	2		3	4		5	6	7	8	9
	Phase(Liq.or vap.)	Liq	Vap	Liq	Liq	Vap	Liq	Liq	Liq	Liq	Liq	Vap
Flow	kg/hr	1094392	554662	539730	300000	248260	51740	418071	418071	758002	758002	257046
Temperature	℃	356	361	361	191	214	214	212	172	151	131	147
Pressure	MPa(g)	1.15	0.11	0.11	1.38	0.105	0.105	0.94	0.84	1.02	0.82	0.08
Density (actual)	kg/m3	605	10.6	595	617	6.4	661	644	683	642	661	5.3
Viscosity (actual)	cP	0.169	0.010	0.164	0.258	0.010	0.232	0.213	0.285	0.207	0.238	0.009

	Stream number	10		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Phase(Liq.or vap.)	Vap	Liq	Liq	Vap	Liq	Liq	Liq	Vap	Liq	Vap	Liq	Liq	Liq	Liq	Liq	Liq	Liq
Flow	kg/hr	39612	217434	257046	NNF	257046	103596	153450	54281	163681	29354	53054	132306	132306	100000	113450	100000	13450
Temperature	℃	128	128	112	116	112	112	112	187	187	261	232	199	249	258	356	356	356
Pressure	MPa(g)	0.06	0.06	0.03	0.03	0.03	1.02	0.70	0.091	0.091	0.099	0.099	0.70	0.79	0.81	1.01	1.01	0.81
Density (actual)	kg/m3	5.0	645	653		653	653	653	3.4	642	7.1	648	697	654	700	617	617	617
Viscosity (actual)	cP	0.009	0.212	0.228		0.228	0.228	0.228	0.009	0.210	0.009	0.215	0.309	0.219	0.312	0.172	0.172	0.172

Annex 04 : Analyses of Jet A1 tanks



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Raffinerie RA2K
Département Technique
Service Laboratoire

ANALYSES DE BACS

DATE 07/05/2025 n° 842 **Jet A1**

Echantillons / Analyses	UNITES	NORMES	BAC 303-TK-002	Noms & Emargement du chimiste
Heure de Prélèvement			22 H 00	
ASPECT				
Visuelle		Visuelle	claire-limpide	A. LAOUANE
Couleur Saybolt		ASTM D156	+30	R. Bendjeddou
Contamination particules	mg/l	ASTM D5452		
COMPOSITION				
Acidité totale	mg KOH/g	ASTM D3242	0,013	F. MAKSEM
Aromatiques	%vol	ASTM D1319		
Soufre totale	% mass	ASTM D5453	-	
Soufre mercaptans	% mass	ASTM D3227		
Doctor test		ASTM D4952	Négatif	A. HADJAM
VOLATILITE				
Distillation				
PI	°C	ASTM D86	150	A. Sellami
10%	°C		168	
50%	°C		190	
90%	°C		220	
PF	°C		237	
Résidu	% vol		0,7	
Pertes	% vol		0,4	
Point d'éclair	°C	ASTM D56	41,0	R. Bendjeddou
Densité Moy à 15°C		ASTM D4052	0,7770	
FLUIDITE				
Point de congélation	°C	ASTM D2386	-60,0	F. MAKSEM
Viscosité à -20°C	mm²/s (cSt)	ASTM D445	3,287	
COMBUSTION				
Pouvoir calorifique inf	MJ/kg	ASTM D4809		
Point de fumée	mm	IP 598	33,0	A. HADJAM
CORROSION				
Corrosion à la lame de cuivre		ASTM D130	1a	F. MAKSEM
STABILITE THERMIQUE (JFTOT)				
Température de contrôle	°C	ASTM D3241		
Delta P du filtre	mmHg			
Cotation tube	visuelle			
CONTAMINANTS				
Gommes actuelles	mg/100cm³	ASTM D381	0,8	A. HADJAM
MSEP carburant additivé		ASTM D3948		
MSEP carburant non additivé			96	R. Bendjeddou
Réaction à l'eau (cotation interface)		ASTM D1094	1b	A. Sellami
Réaction à l'eau (cotation séparation)			1	
CONDUCTIVITE				
Conductivité électrrique	ρs/m	ASTM D2624	01	R. Bendjeddou
LUBRIFIENCE				
Diamètre d'usure BOCLE	mm	ASTM D5001		

Echantillonneur : R. Bendjeddou
Quart : "C"
OBSERVATIONS :
Le Chef de Quart : A. LAOUANE
Conditions Ambiantes : T (°C) : 22,5 **RH (%):** 78,6 **P (mBar):** 1014,9

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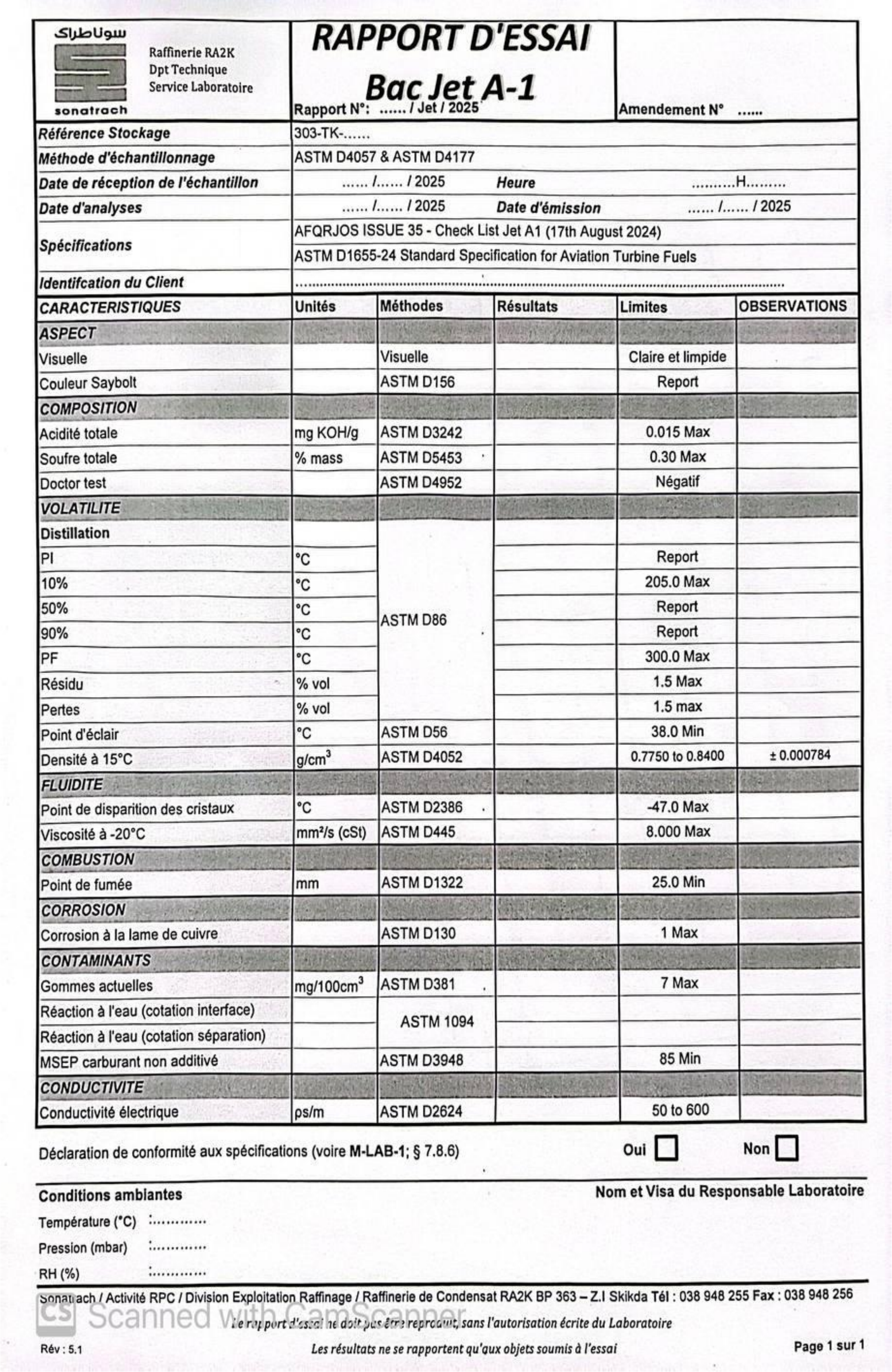
Annex 5 : Test report of Jet A1 tank



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Dpt Technique
Service Laboratoire

RAPPORT D'ESSAI

Bac Jet A-1

Rapport N°: …… / Jet / 2025

Amendement N° ……

Référence Stockage	303-TK-……		
Méthode d'échantillonnage	ASTM D4057 & ASTM D4177		
Date de réception de l'échantillon	…… /…… / 2025	***Heure***	……….H………
Date d'analyses	…… /…… / 2025	***Date d'émission***	…… /…… / 2025
Spécifications	AFQRJOS ISSUE 35 - Check List Jet A1 (17th August 2024) ASTM D1655-24 Standard Specification for Aviation Turbine Fuels		
Identifcation du Client	………………………………………………………………………………………		

CARACTERISTIQUES	**Unités**	**Méthodes**	**Résultats**	**Limites**	**OBSERVATIONS**
ASPECT					
Visuelle		Visuelle		Claire et limpide	
Couleur Saybolt		ASTM D156		Report	
COMPOSITION					
Acidité totale	mg KOH/g	ASTM D3242		0.015 Max	
Soufre totale	% mass	ASTM D5453		0.30 Max	
Doctor test		ASTM D4952		Négatif	
VOLATILITE					
Distillation		ASTM D86			
PI	°C			Report	
10%	°C			205.0 Max	
50%	°C			Report	
90%	°C			Report	
PF	°C			300.0 Max	
Résidu	% vol			1.5 Max	
Pertes	% vol			1.5 max	
Point d'éclair	°C	ASTM D56		38.0 Min	
Densité à 15°C	g/cm^3	ASTM D4052		0.7750 to 0.8400	± 0.000784
FLUIDITE					
Point de disparition des cristaux	°C	ASTM D2386		-47.0 Max	
Viscosité à -20°C	mm²/s (cSt)	ASTM D445		8.000 Max	
COMBUSTION					
Point de fumée	mm	ASTM D1322		25.0 Min	
CORROSION					
Corrosion à la lame de cuivre		ASTM D130		1 Max	
CONTAMINANTS					
Gommes actuelles	mg/100cm^3	ASTM D381		7 Max	
Réaction à l'eau (cotation interface)		ASTM 1094			
Réaction à l'eau (cotation séparation)					
MSEP carburant non additivé		ASTM D3948		85 Min	
CONDUCTIVITE					
Conductivité électrique	ps/m	ASTM D2624		50 to 600	

Déclaration de conformité aux spécifications (voire **M-LAB-1**; § 7.8.6) **Oui** ☐ **Non** ☐

Conditions ambiantes

Température (°C) :…………
Pression (mbar) :…………
RH (%) :…………

Nom et Visa du Responsable Laboratoire

Sonatrach / Activité RPC / Division Exploitation Raffinage / Raffinerie de Condensat RA2K BP 363 – Z.I Skikda Tél : 038 948 255 Fax : 038 948 256

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Rév : 5.1

Les résultats ne se rapportent qu'aux objets soumis à l'essai

Page 1 sur 1

Annex 06 : Specification of the withdrawn products

Product	Spécification	Method		Value	Unit	Remark
Jet/kerosene	Flash point	IP 170	≥	38	°C	
	Freezing point	ASTM D2386	≤	-47	°C	For jet
	Specific gravity at 15 c°	ASTM D1298	≤	0.84		
	Specific gravity at 15 c°	ASTM D1298	≥	0.775		
	ASTM D86 10%	ASTM D86	≤	205	°C	
	ASTM D86 EP	ASTM D86	≤	300	°C	
	Total acidity	ASTM D3242	≤	0.015	MgKOH/g	
	Sulfur mercaptans	ASTM D3327	≤	0.003	Wt%	
	Sulfur total	ASTM D1266	≤	0.30	Wt%	
Diesel	ASTM D86 65%	ASTM D86	≥	250	°C	
	ASTM D86 95%	ASTM D86	≤	360	°C	
	Flash point	NF EN 22719	≥	55	°C	
	Specific gravity at 15°C	NF EN ISO 3675	≤	0.845		
	Specific gravity at 15°C	NF EN ISO 3675	≥	0.82		