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Presented by:
Ms LOBZA Nour Echourouk
Mr BELOUL Salah

Topic

**Study and monitoring of Algerian crude oil desalting
system by chemical analysis (Case study - Field of
OURHOUD)**

Publicly defended on 05/06/2023 in front of the Jury composed of:

Mr	A. MOHREM	President	M.A.A	University of El Oued.
Me	K. AHMOUDA	Examiner	M.C.B	University of El Oued.
Mr	I. BOUDOUH	Supervisor	M.C.A	University of El Oued.

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Abréviations

AC: Courant alternatif .

IPA: American Petroleum Institute.

ASTM: Société américaine pour l'essai des matériaux Sédiments de base et eau .

FCP: Installations centrales de production .

DC: Courant continu .

DCS: Système de contrôle distribué .

NF: Norme française .

PPM: Partie par million .

PSI: Pouce carré livre.

TAGI: Trias Argilo Gréseux Inférieur .

TVR: Tension de vapeur raid.

UOP: Universal Oil Products.

Symbols and Ratings

Symbol	Designation	unity
A	Coefficient of proportionality	/
BS&We	Entrance water and sediment content	%
BS&Ws	Water and sediment content at the outlet	%
D	Diameter of the water droplet	M
D_c	Density of the continuous phase	/
D_d	Density of the dispersed phase	/
D²⁰₄	Density at 20°C	/
E_{ffT}	Experimental efficiency of the desalination unit	%
E_{ff1}	Efficiency of the first desalter	%
E_{ff2}	Efficiency of the 2nd desalinator	%
E_p	Theoretical effectiveness of desalination	%
E_c	Critical field	V/cm

E₁	Electrical field between the lower electrode and the water level	V/cm
E_i	Lower electrode	/
E_s	Top electrode	/
G	Gravity acceleration	m2/s
L	Distance between the two extremes	M

L₁	Distance between the lower electrode and the water level	M
Q	Charge flow rate	m³/h
Re	Reynolds number	/
S_e	Salinity at the entrance	mg/l
S_s	Salinity at the outlet	mg/l
T ; t	Temperature	°C
T_d	Settling time	Mn
T_s	Residence time	Mn

TDS	Dissolved and suspended solids content	mg/l
V	Desalinator volume	m³

V_d	Settling speed	m/s
X	Wash rate	%
Y	Water content in crude oil at desalinator inlet	mg/l
Z	Water content in crude oil after desalination	mg/l
ḡ	Kinematic viscosity of oil	cSt
δ	Surface tension between water and oil	g/cm³
ε	Dielectric coefficient	/
φ	Coefficient of friction	/
α	Coefficient of characterization of density variation	/

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Abstract:

Desalination of crude oil is a key operation in the treatment process for reduce the salt and water content of the crude oil (the latter's salinity is limited to 40 mg/L and BSW (Basic Sediment and Water) less than 1%) and for ensure the proper functioning of the various oil treatment facilities and avoid phenomena caused during treatment such as corrosion and clogging equipment. The purpose of this study is based on the verification of the desalination section to improved performance in quality with less cost. To this end, we have a technical study on the desalter (VW-21-01/02) followed by a verification calculation and we make the comparison between the obtained results and the designation then we conclude with an economic study. Keywords: desalination, electrostatic desalter, salinity, emulsion, coalescence ,Decantation, wash rate, demulsifier, electric field.

Résumé :

Le dessalement du pétrole brut est une opération clé dans le procédé de traitement pour réduire la teneur en sel et en eau du pétrole brut (la salinité de ce dernier est limitée à 40 mg/L et le BSW (Basic Sediment and Water) inférieur à 1%) et pour assurer le bon fonctionnement des différentes installations de traitement des huiles et éviter les phénomènes provoqués lors du traitement tels que la corrosion et le colmatage des équipements. Le but de cette étude est basé sur la vérification de la section de dessalement pour améliorer les performances en qualité à moindre coût. A cet effet, nous disposons d'une étude technique sur le dessaleur (VW-21-01/02) suivie d'un calcul de vérification et nous faisons la comparaison entre les résultats obtenus et la désignation puis nous concluons par une étude économique. Mots clés : dessalement, dessaleur électrostatique, salinité, émulsion, coalescence, décantation, taux de lavage, désémulsifiant, champ électrique.

ملخص:

تعد تحلية النفط الخام عملية رئيسية في عملية المعالجة لتقليل محتوى الملح والماء في النفط الخام (تقتصر ملوحة الأخير على 40 ملغم / لتر و BSW (الرواسب الأساسية والماء) أقل من 1٪) ولضمان حسن سير العمل في مرافق معالجة النفط المختلفة وتجنب الظواهر التي تحدث أثناء المعالجة مثل تآكل وانسداد المعدات. ويرتكز الغرض من هذه الدراسة على التحقق من قسم التحلية لتحسين الأداء من حيث الجودة وبتكلفة أقل. وتحقيقاً لهذه الغاية، لدينا دراسة فنية عن التحلية (VW-21-01/02) متبوعة بحساب التحقق ونجري المقارنة بين النتائج المتحصل عليها والتسمية ثم نختم بدراسة اقتصادية. الكلمات المفتاحية: تحلية المياه، تحلية الملوحة الكهروستاتيكية، الملوحة، المستحلب، الالتحام، التصفية، معدل الغسل، مزيل الاستحلاب، المجال الكهربائي.

General Introduction

General Introduction

Algeria ranks fifteenth in the world and third in Africa with 9.2 billion barrels of oil and proven reserves of 0.9 % of the world total. The country's geology and Proximity to European markets is good. Algerian oil called Sahara Blend refers to a mixture of crudes from several regions ,it represents a set of qualities that allow it to gain an important place in the classification of oils, it is characterized by its low sulphur content and low density and it is light oil .In order for oil to meet marketing standards, treatments are carried out to clean it of any impurity but also to separate it from the injection gas lift and water present in emulsion. Among these treatments is desalination which is very important because the presence of mineral salts in the oil causes enormous damage.The presence of salt water in the oil can cause a set of disadvantages most of the corrosion of the equipment as well as plugging without forgetting the decrease in quality of the crude. For these reasons; there are three methods of desalting, mechanical which are based on the difference between the densities of the phases to be separated, chemical which consist in using compounds chemicals to eliminate emulsions and electrical that are widely used.Currently, marketing specifications require producers to set essentially salinity and water content standards, so that oil is stored, shipped and then refined. The oil must not contain more than 40mg/L of salinity and 1% of water ,the elimination of the latter two requires the installation of desalination units at train levels production. Our study carried out at the level of the OURHOUD «Sonatrach» organization is part of the purpose of studying the functioning of the desalination system in order to observe desalter performance and efficiency.This work is organized into the following parts:

The first chapter is the subject of a general presentation of the organization where we had the chance perform our manipulations and calculations and observe the process.

The second chapter deals with a bibliographical search of all phenomena which come into play during the process.A third and final theoretical chapter which describes the methods and materials necessary for Perform calculations and process description. The Experimental Results and their discussion and interpretations are presented in the fourth chapter.

A general conclusion and recommendations will be presented at the end of this work.

Chapter I: Introduction to the society

Algeria is a member of the Organization of Petroleum Exporting Countries and the World Trade Organization. As a gas exporting country, it is the 3rd largest oil producer in Africa behind Nigeria and Angola and the 11th largest exporter of oil in the world. It occupies the 15th place in the world oil reserves (45 billion tonnes of oil equivalent for proven reserves), and 18 oil producer. Oil is a liquid contained in a carbon rock, or oil mineral. The exploitation of this fossil energy is one of the pillars of the industrial economy. Oil supplies almost all liquid fuels. It is used extensively for ; plastic industry and all kinds of derivatives. Now a days, every thing we see as material mechanical, works with fossil energy released by the combustion reaction of fuel that is extracted from oil, is to say that ever ything depends on this black fluid, the most general example is the internal combustion or explosion engine that operates each motor vehicle ; or for example, the manufacturing industry, such as the iron and steel industry or the carpentry industry; must heat the metal in an oven that runs with gas and to cut wood, we use.

Electric machines that work with electricity and that comes from the power plant that uses natural gas to power its turbines (the use of electricity from dams is less rependue), if an accident occurs on the gas supply chain of the plant, there will be no mor electricity. Now, many industrial countries want to secure their energy demand, which is that huge projects and giant complexes have been realized and invested in order to produce and meet the demand of international markets, for example the European Union which receives oil and gas from Russia, Libya, Algeria, Gulf country in addition to its own production in the Sea of north.

I.1. Presentation of the company Sonatrach:

SONATRACH (National Society for Research, Production, Transport, Transport Processing, and Marketing of Hydrocarbons S.P.A) is a public company and a major player in the oil industry. The national company for the transportation and marketing of hydrocarbons is a company national by its field of activity, oil and gas industry primordial to the nation by its weight economic and national in its history and orientation, its mission was to marketing of hydrocarbons by land and sea. It was created pursuant to Decree No. 63-491 of 31/12/1963; in 1965, SONATRACH undertook the construction and installation of an oil pipeline connecting HAOUD EL HAMRA to ARZEW, this is the first experience of its kind in a developing country, this achievement was in some way the confirmation of the birth certificate of SONATRACH. After the decree. No. 66 269 of September 1966, SONATRACH becomes the

national society affecting several areas such as research, production, transport, refining, processing and marketing of liquid and gaseous hydrocarbons.

I.2.PRESENTATION OF THE ORGANISATION OURHOUD:

I.2.a.History of the organization:



Figure I.1: SONATRACH and its partners in the Ourhoud project.

Organisation OURHOUD (created in 1997, beginning of production 2003) is the Delegated Operator responsible for the development and operation of the OURHOUD field acquired by SONATRACH and the partners have designed the OURHOUD Organisation as an instrument with reliable powers and procedures approved by all parties and equipped it with material means and have assigned high-level staff to ensure its effectiveness. The OURHOUD Organization will benefit from all the experience acquired by Sonatrach and the partners (Anadarko, Cepsa, Agip, Maersk, Conoco, Philips, Talisman) for the benefit of the project and cultural diversity.

I.2.b.The creation of the Ourhoud organisation is illustrated by the following date:

Key dates:

- 09January 97: Signature of the Framework Agreement. Sonatrach designated as operator .
- 01July 97: Creation of the Ourhoud Organization (Operator delegated by Sonatrach).
- 01August 98: Presentation of the Dossier ELA (Exploitation Licence Association) to the Ministry.
- 27October 98: Signing by the parties of the Unitized Operations Procedure (UNOP).
- 21April 99: The Department issues the operating licence.
- 25March 2000: Start of site preparation work for production facilities (platforms , roads, water wells, airstrip) by GCB, ERGTS and ENAGEO.

- 05July 2000: Letter of Intent issued to JGC/INITEC for the EPC Project.
- 10August 2000: Signature of the EPC Contract with JGC/INITEC Contract Key Dates:
- First-Oil : 04 January 2003 Provisional Reception : 10 May 2003.
- 14August 2000: Signature of 2 contracts with GEPCO for the realization of two bases of life.
- 2003: Start of production .

The field should be unified in 2005, but in February 1997 a percentage participation was agreed so that three foreign operators could develop the field in association with SONATRACH. This exploitation of a field which regroups several blocks and known as field initiation and its objective is to allow an optimum development of the deposit as a whole. SONATRACH is associated with six foreign companies as the deposit overlaps three blocks. On the 404 block, SONATRACH is associated with Anadarko (which has as partner Agip and Maersk) whose contract is signed on 23/10/1989. On block 406, the national company is associated with the Spanish Cepsa whose contract is signed on 26/05/1992. While on lebloc 405 it is associated with Burlington Resource (which has as a partner Talisman) whose contract is signed 24/11/1992. In February 1997 a percentage participation was agreed so that three foreign operators could develop the field in association with Sonatrach as follows :



FigureI.2 : Partners and Share of each company's oil.

I.2.c. Technical and financial capacity:

It is 20 km long and 4 km wide. The first site preparation works (platforms, roads, water wells, landing strip) were carried out in 2000 by the companies GCB (Civil and Building Engineering), ENGTP (National Enterprise of Major Oil Works) and ENAGEO (National Enterprise of Geophysics). During the work, the population peak on the site reached about 4500 people.

The start of oil production began in November 2002, after 9.7 million hours of work. The construction balance sheet is as follows :

- 20,000 m² of buildings between the CPF (Central Processing Facilities) and the industrial base .
- 210km piping average diameter 10' in the CPF .
- 322 km piping average diameter 12' for off-site (excluding CPF and Industrial Base).
- 8,800tonnes of equipment.
- 20,000m³ of concrete. Facilities are sized as follows:
 - Rated oil treatment capacity: 230,000 barrels/day.
 - Gas processing capacity: 5.3 million m³/d.
 - Water injection capacity: 345,000 barrels/d.
 - Gas reinjection capacity: 3.2 million m³/d.
 - Treated oil storage capacity: 3 x 45 000 m³.

I.2.d. MAIN CHARACTERISTICS OF THE RESERVOIR :

Producer reservoir : TAGI sandstone.

Average depth : 3180 m.

Tank pressure : 348 bar.

Tank temperature : 102 °C.

Total height : 80-100 m.

Average porosity : 16%.

Average permeability : 200 md.

Degree API : 42.5.

AVERAGE GOR : 95 m³/m³.

I.2.e.Geographical location of the field:

The OURHOUD field is located in the Hassi Berkine basin, 320 km south-east of Hassi Messaoud and 1200 km south-east of Algiers.

Was discovered in July 1994. With a perimeter of 263.4 km, approximately 20 km long and 4 km wide.



Figure I.3: Geographical location of the field.

Flowchart of the OURHOUD field direction.



Figure I.4: OURHOUD field management organization chart.

I.2.f. Composition of the field:

The Ourhoud field includes :

- 66oil production wells.
- 09gas injection wells.
- 29water injection wells.
- 05Water and gas injection wells (WAG).
- 09wells producing water from Albien .
- 08wells producing water from Mio-Pliocene.
- 07satellite stations.
- A crude processing center (CPF or Central Processing Facilities).
- A collection and service network.
- An industrial base.
- A base of life for the staff.

I.3.Physical petrol characteristics of reservoir fluids:

I.3.a).Oil:

- Initial reservoir pressure: 5000 psi.
- -Bubble pressure: 1247 psi.
- -Reservoir temperature: 102°C.

- Background volumetric factor (FVF): 1.233.
- Initial dissolution GOR: $64 \text{ m}^3/\text{m}^3$.
- Storage oil density: 0.813 g/cm^3 .
- Oil viscosity: 0.68 Cp .
- Compressibility: $7.14 \times 10^{-6} \text{ psi}^{-1}$.

I.3.b). Water

- Compressibility: $4.3 \times 10^{-8} \text{ psi}^{-1}$.
- Viscosity: 2.75 c_p at 25°C.
- Mean salinity: 352.925 g/l.
- Density: 1.224 Kg/L at 20°C.
- Resistivity: 5.94 Ohm/cm²/m at 20°C.

PH: 4.5.

I.3.c). Gases:

- Compressibility: $1.16 \times 10^{-4} \text{ psi}^{-1}$.

I.4.Wells:

There are four types of wells:

I.4.a. Oil production wells:

Oil production wells are divided into two categories, high pressure (HP) and low pressure (LP). Most wells are equipped with a lift gas injection system. This system allows gas injection into deep wells. It changes the characteristics of the fluid in the casing by decreasing the density and it increases the output flow by decreasing the hydrostatic pressure on the fluid column. Injection pressures and rates are regulated from the satellite.

I.4.b. Injection wells:

An injection of water and gas is necessary to maintain the pressure of the deposit, and helps to promote the migration of oil in the geological formation. There are three types of injection wells:

I.4.b.1.Gas injection wells:

They are connected to satellites 5, 6 and 7, which supply them with injection gas produced by the CPF from the gas contained in the extracted oil.

The well throttle valves present are automated and are used to regulate the injected gas flow.

They are also equipped with a flare that allows the burning of waste in case of overpressure.

I.4.b.2. Water injection wells:

The injected fluid is water produced at CPF from the water coming from the deposit, added to the water of Albien/Barrémien/Moipliocene.

I.4.b3. Water injection well:

The injected fluid is water produced at CPF from water from the deposit, added to Albien/Barremian/Moipliocene water.

I.4.c. WAG wells:

They are able to inject either water or gas according to production needs.

Water and gas by their physico-chemical characteristics cause oil migrations, and allow to refine the yield of production wells.

I.4.d. Albien/Barrémien water production wells:

They capture the water of the deep aquifer of Albien/Barrémien which is widely present regionally. This water is captured between 1200 and 1700 m of depth, the fossil waters of this aquifer have at the site a static pressure of about 13 bars.

Two series of manifold gather the water conveyed by the collection lines before their arrival at the CPF.

I.4.e. Mio-Pliocene water production well:

They capture the first layer under the site, around 100 to 200 m deep. Pumps are installed to raise the water from this aquifer to a manifold and send it to the Mio-Pliocene water treatment at the CPF.

I.5. Satellites :

These are regulatory, distribution and safety bodies for the flow of fluids exchanged between wells and the CPF; there are 07 satellites to ensure:

The transit of multiphase oil to the CPF;

Gas-lift and injection water flow distribution and regulation from CPF to production wells (remote control) ; The distribution and regulation of the flow of the injection gas to the injection gas wells.

Each satellite is equipped with an overpressure protection system. The system consists of a valve that opens in case of overpressure of the manifold to discharge into a bin called PIT

COVER. The crude accumulates in the pit cover is recovered by tanker truck is re-injected into the crude processing circuit at CPF.

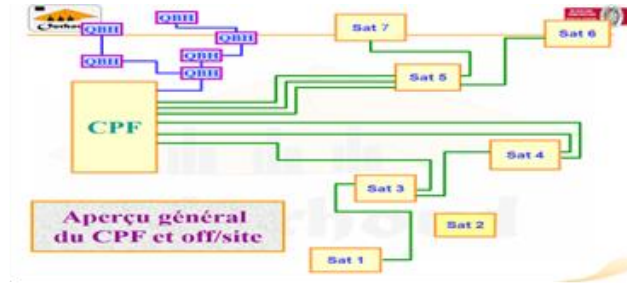


Figure I.5: Satellites.

I.6.The production centre:

It is a central crude oil processing facility consisting of:

Slug catcher.

- Two large separators.
- Separation and stabilization trains.
- Gas compression, recompression and dehydration trains.
- Fuel gas, lift gas and injection gas production.
- Storage and export facility.
- Storage out of specification.
- Production of process water and drinking water.
- Production water treatment.
- Chemical injections.
- Torch system.
- Treatment of sludge.
- Drainage systems.

I.7.Production history:

Production at the Ourhoud field began on 08/11/2002 at a slow pace to be able to test the equipment of all surface installations as well as the CPF (Central Processing Facilities) and with a limited number of wells. Oil production reached 235000 bbl/d in January 2003.

The reservoir pressure is maintained by the injection of water and gas which started respectively 25/01/2003 and 20/02/2003.

Oil production depends directly on the amount of water and gas injected and the number of producing wells.

I.8.The IWH project:

The IWH (Increase Water Handling) project aims to increase the oily water treatment capacity from 20 to 46 km³/d, and to increase the gas compression capacity for reinjection and pressure maintenance of the reservoir.

This increase in water treatment and gas compression capacity increases field oil production and improves recovery with a gain of 42,000 barrels per day by 2033.

The project consists of:

Install a new oily water treatment unit (OWTS 2) and a new Satellite 2 oil production trunkline.

Install a 4th recompressor and a 3rd turbo compressor booster/ gas lift.

Install two new three-phase separators.

Slugatcher riser gas replacement from 20' to 32.'

I.9.The departments:

The company is composed of a general management located in HASSI MESSAOUD and various offices whose headquarters of the field management where this internship was carried out. The field management is divided into 8 departments:

- HSE Department .
- Technical Department .
- Maintenance department .
- Well Department .
- Operations department .
- HR Department .
- IT department (computer-electronic)
- ADM Department.

I.10.Operations department:

This department is responsible for monitoring the entire process starting with the wells arriving at the CPF. The CPF is a plant that consists of 3 divisions:

- Laboratory Service.
- Oil and gas service.

- Water treatment, utility and shipping .

Currently 59000 barrels are sent per day, they are extracted from 26 wells (QB) assembled in 7 different satellites. The CPF has 3 steel storage bins, pipelines, 3 trains, 2 water treatment units, pumps, separators, desalinators .

The extraction of crude from wells allows us to have an unstable crude containing gas and a quantity of water with more crude oil than water and gas (GOR). The crude is sent through Booster pumps to the PKO as well as through export pumps to transport it to HOUD EL HAMRA.

VUE General CPF-Organisation OURHOUD.

Introduction:

Ourhoud has seven satellite stations, four south of CPF and three north, each of which collects fluids from a group of five to nine wells.

Flow lines transport effluent from production wells to the seven satellites, where they are collected and transported to CPF via seven main lines called trunkline at CPF all well effluents are treated starting with slug catcher and the two inlet separators to minimize the effects of liquid plugs on the operation of the other equipment in the treatment chain and separate the relatively large amounts of water from the oil. From there, the remaining oil and water are transported to the three trains to undergo a two-stage separation, to reduce the oil's water and sediment content and to lighten its gas below. After this separation step, the oil will pass through two desalination stages to reduce its salt content and to finish the oil before storage will undergo an adjustment of its TVR by a treatment in a stabilization column.

The stabilized crude will be stored in the storage bins for possible shipment, to PK0 at 21 km from the CPF, or to Haoud El Hamra.

If the treated oil is not specific, it can be diverted to the out-of-specification oil buffer flask or the amount of gas is vaporized.

This oil is then directed to the off-spec recovery balloon (boot) where the residual gas is removed and then to the off-spec oil storage tank and transferred to the BP slugcatcher before being sent back through the separation trains .

The associated gases are compressed and dried, a certain amount is used for the fuel gas (used for the internal consumption of the CPF station) hard to have it passed through the compression unit, and the rest is compressed to the pressure of the lift gas, then to the pressure of the reinjection gas. The lift gas is distributed to the BP producing wells in order to maintain the flow rate of the wellhead .

While the reinjection gas is injected back into the deposit to increase the production of the latter.

The production water (water separated from the crude oil) is re-injected into the reservoir after treatment in the oily water unit to increase the production of the deposit.

The water from the Albien Barrémien aquifer is also injected into the reservoir to maintain an adequate volume and maintain the reservoir pressure.

And the water from the Mio-Pliocene aquifer is treated and then used as service or dilution water to dilute the crude coming out of the deposit because it contains a large amount of salt.

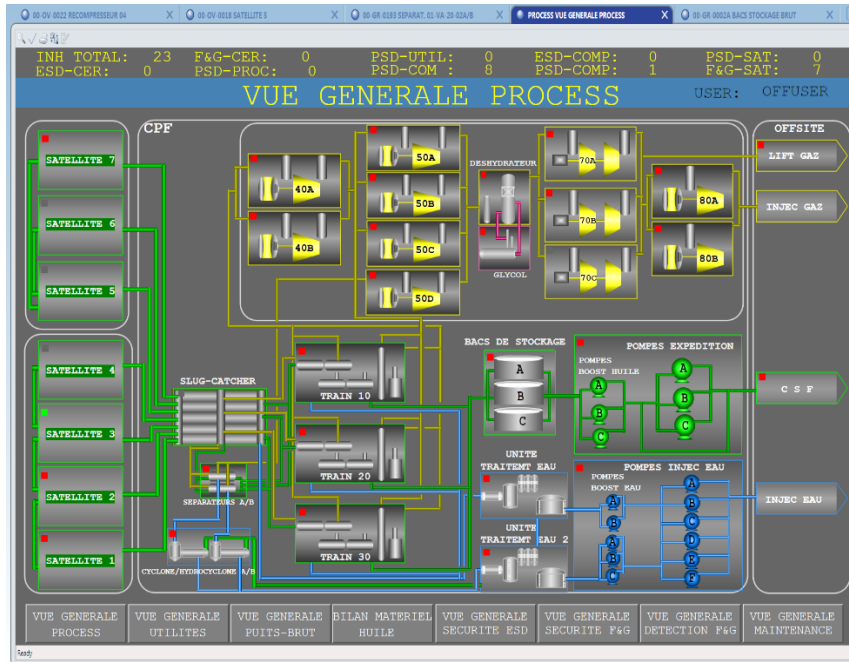


Figure I.6: General view of the process (DCS).

I.2.Treatment of crude oil (at CPF):

I.2.1Oil treatment system:

I.2.1.a. Slugcatcher:

The Slugcatcher is an assembly of several pipes that are used as long separators, usually inclined. It operates at a pressure of 21 (bar) and a temperature varying between 55-72C.

It minimizes hydrodynamic effects, and dampens the shocks of effluents entering the CPF to stabilize them and separate them into two phases: oil, gas.

Oil: Pouring towards the two new separators

The quantity of gas recovered from the slugcatcher is routed to the train separators to maintain the pressure of the first separators at 15 (bar) is 5.5 MMSm³/d .

In contrast, the amount of slugcatcher gas to the new three-phase separators is approximately 4.8 MMSm³/d.

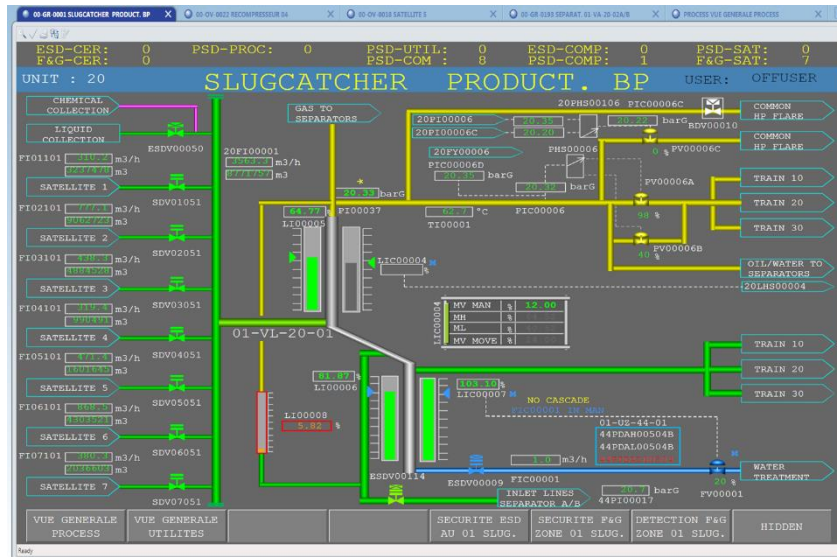


Figure I.7: General view of the Slugcatcher.



Figure I.8: Slugcatcher.

I.2.1.b. The two input separators:

The liquid charge from the slugcatcher with part of the gas must be routed to the two new three-phase separators.

The two new three-phase separators will function as a single equipment (with a common level control and a common gas outlet pressure control). They were designed with the possibility to put a separator out of service for maintenance operations (with return to service) while keeping in service the 2nd separator.

The gas flow will be routed to the suction of the recompressors. Part of the water flow (26200 Sm³/d) of the new separators will be routed to the oily water treatment system (OWTS N°2) and the remaining water flow in the new separators will be driven by overflow to the oil side of the new 3-phase separators that will be routed jointly (oil and water) to the three existing separation trains .

I.2.1. c.Oil separation train:

I.2.1.c.1. First separator:

It's a three-phase separator that separates gas, oil, water. The first separator operating at 15 (bar) and 60°C. The oil is heated upstream of the first separators by exchangers and passes to the second separator level. The gas is directed to the recompression system. The water separated from the oil is directed to the oily water treatment system.

I.2.1.c.2.Second separator:

It is also a three-phase separator operating at 12 (bar) and 80°C, which separates gas, oil and water. However, the main function of this separator is to provide adequate residence time to facilitate the separation of oil and water in the case of a major emulsion.

The water is sent to the water treatment unit. The gas is directed to the compression system and the oil to the first and second desalter which are in series.

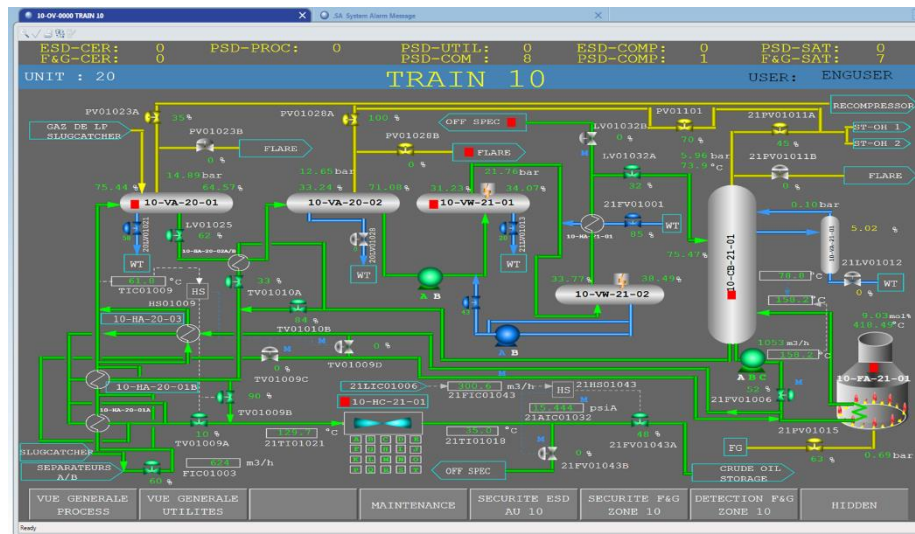


Figure I.9: General view of Train 10.

I.2.1.d. Desalinators:

Virtually all crude oils contain salt, water and sediment. Crude oils contain significant amounts of salt and impurities that must be removed to reduce corrosion and protect downstream treatment facilities.

The first desalinator receives oil from the second separator at a pressure of 21 bar after passing through a booster pump.

On the first desalination stage, low-salt water is added to the oil to charge the salt contained in the oil. The water and oil are separated by an electrostatic coalescor and the water is sent to the production water treatment.

On the second stage, the oil leaving the first stage is again mixed with dilution water preheated in an exchanger, and the whole is treated as in the first stage. From where the resulting oil is sent to the stabilization column and the water is separated by the action of an electrostatic field and is pumped to the first stage desalter to dilute the salt contained in the production water. This water at the end is sent to water treatment.



Figure I.10: Desalinators.

I.2.1.e. The stabilization column:

Stabilization takes place in a heated stripping column to produce crude oil with a maximum TVR of 0.69 (bar) (10 psi). The stabilization column (stripper) is a Vertical column of 18 trays (9 theoretical stage). It works at a head pressure of 7.0 bar with a maximum background temperature of 180°C .

The oil, coming from the second stage desalter, is sent to the top tray of the column, and the lighter components are extracted thanks to the stripper heater. The liquid, coming from the bottom tray, is extracted through the rebound pump through the rebound to ensure a temperature of 160°C at the bottom of the column. The stabilized crude oil, leaving the bottom of the stripping column, is cooled, exchanging its heat with the first and second stage separators, before the final cooling (aero-refrigerant).



Figure I.11: The stabilization column.

I.2.1.f.The oven:

It acts as an Inter stage Heater, at the outlet of the stabilization column, a part of the crude is sent to an oven and then used as a means to heat the stabilization column. The crude oil thus treated is brought back to the specifications of transport and marketing (BSW, TVR, salinity) is sent to the storage bins.

I.2.1.g.The storage bins:

The crude oil feeds the storage bins, under control of the level of the stabilization column. The storage bins are three tanks each with a capacity of 37970 (m3). Each storage tank has enough capacity for one day of production with the three trains. From the storage bins, the crude is taken back by shipping pumps and transported by a pipe to PK0 .

Table.I.1: Oil produced will meet specifications.

Specification	Value
(TVR)Maximum	0.69 bar (10 psi)
Maximum BS&W	0.5% volume
Maximum salinity	40 ppm NaCl equivalent
Maximum sulphur	0.20% weight
Maximum storage temperature	55°C

I.2.1.h. Shipment of crude oil:

The crude oil shipping pump group consists of three booster pumps, 300-PA-22-01A/B/C, and three shipping pumps, 300-PA-22-A/B/C. the crude oil is sent to the OH3 (SH/TRC) located approximately 21 km from the CPF and PK0. From there, the crude oil produced is taken to HAOUD EL HAMRA, if there is a problem at PK0 HP pumps are made available to transport the oil directly to HAOUD EL HAMRA.

➤ Crude Oil Transfer Pump

A 300-PA-22-04 crude oil transfer pump is located in the export area. The purpose of this pump is to empty the existing quantity of crude oil stored in the bins for cleaning or maintenance work. The capacity of this pump is sufficient to transfer within two hours the oil remaining below the LLL level of the tank to be emptied to another tank.

I.2.1.i.Out-of-specification storage:

An out-of-specification product system is included in CPF installations. These facilities include a return balloon (off spec), an out-of-specification product storage tank and return pumps. During the start-up phases of the installation, connections with the out-of-specification product system equip each processing train downstream of the desalinators/coalescers on the second floor as well as the line downstream of the coolant of the produced oil. These lines are used for starting up and in case of diversion of product out of specification.

Off-specification product storage is in equilibrium on the flare and operates primarily at atmospheric pressure. The recovery balloon is also in balance on the torch and operates at atmospheric pressure. The latter is high enough to ensure that the liquid flows directly to the storage tank under any conditions.

The buffer flask of the out-of-specification product operates at a pressure of 2 to 5 (bar), allowing oil to flow from the buffer flask to the recovery flask.

The out-of-spec product is sent to the out-of-spec bin when malfunctions appear in the stabilization column or desalter result in quality deviations during the operation. In the case of a stabilization column trip, the off-standard product when it reaches the bin will be sufficiently degassed to have the TVR specification. In the case of a desalinator shutdown, the water will be removed in time and the treated oil will have the salt and water specifications. The discharge of the off-spec return pumps is connected to the slug catcher PB, so as to remove the off-spec product in the PB separation train. In the event that the oil cannot be directed to the storage bins, samples must confirm that the oil has the required specifications and the off-specification pump discharge lines will be to the storage bins.

I.2.2. Gas treatment system:

I.2.2.1. Compression section:

Gas treatment facilities are designed to treat all recovered gases from separators and stabilization columns. These gases are put to the same pressure before they pass through a dehydrator. The dry gas is taken up by a compression train called Booster gas lift in most of the gas at its outlet is used as well gas lift and the other part is used as injection gas after having undergone compression. In order to minimize downtime, which can be caused by planned failures or maintenance reasons, all essential equipment in the gas section is duplicated.

I.2.2.1.a. Compressors for the heads of the stabilisation columns:

The Stabilization Column Head Compressor (OVER HEAD) is designed to compress the head gases of the three stabilization columns and the second stage separator gases. The running Over Head compressor takes its suction pressure from the head pressure of the stabilization column to 6 (bar) and compresses the gas to 12 (bar). This allows the gas to have a pressure high enough to be mixed with the gas coming from the first stage in a manifold. The discharge of this compressor is cooled via an air cooler.

I.2.2.1.b. Recompressor:

The first stage separator gases are combined and mixed with the gases of the stabilisation column heads and the gases of the second stage separators (compressed and cooled). The flow is directed to the recompression system which includes four recompressors (all four in service). The suction pressure is 12 (bar) to recover the gas from the stabilization column heads and the gas from the first stage separators. The recompressor is designed to compress these gases to a pressure of 36 (bar). The discharge gas of this recompressor is cooled through aerocoolers.

I.2.2.1.c. Dehydration and regeneration of glycol:

Before entering the dehydration column (60-CA-24-01), the wet gas from the discharge of four A/B/C/D collectors passes into a dehydration buffer flask (60-VG-24-01), from which the liquid drawn and accumulated at the bottom of the flask is returned to the slug catcher, while the wet gas passes to the dehydration column.

Water-saturated natural gas enters dehydrator (60-CA-24-01) through an input deflector that ensures a good distribution of the gas in the vertical balloon and diffuses upwards through a stacked tray that ensures a good distribution of the gas flow to come into contact against-running with TEG in the structured packing section.

Above the structured lining, a gravity distributor ensures a good distribution of the TEG to optimize the contact between the rising gas and the descending glycol. During this contact phase, water and some hydrocarbons are absorbed by the glycol solution.

Saturated TEG; recovered from bottom dehydrator; sent to regeneration unit for reuse

The dry gas recovered at the top of the dehydration column joins the production of fuel gas, or gas lift.

I.2.2.1.d. Production of lift and injection gases:

I.2.2.1.d.1.Lift gas compressor:

Part of the gas that comes out of the dehydrator is sent to the turbines called booster gas lift compressor to raise the gas pressure from 36 to 210 bar in two stages:

36-90bar and 90-210 bar.

The system is equipped with three gas turbines connected in series, two running and one stopping (emergency) , the first stage suction bag removes the heavy gases that condense at the bottom and that will be sent to LT torche (low temperature flare)the pressure of the gas rises to 90 bar in the turbine, the compression of the gas causes the temperature of the gas to rise which is why it will be cooled in the aero-refrigerants located downstream, the delivery balloon which is at the same time the suction balloon of the second stage, the gas will be compressed another time at 210 bar and goes through the aero-coolant and then it will follow the pipes that go to the satellites to be injected into the wells.

I.2.2.1.d.2.Gas injection compressor:

That includes two compression trains. One train is in service, the other train is in service. The suction pressure is 210 (bar) and the discharge pressure is 300 (bar). The compressed gas produced reaches the satellites from where it is distributed to the injection wells.

I.2.2.2.Fuel gas production:

Part of the dry gas from the dehydration column is cooled in an exchanger and relaxed in a flask. From where the produced liquids are sent to slugcatcher, while the produced dry gas enters the fuel gas storage tank. Then it goes through a filter, and part of it goes into the high-pressure fuel-gas circuit to the gas from the high-pressure separator. And the other part is relaxed to be used as low-pressure fuel gas, and the formed liquids are sent to slugcatcher. The fuel gas can be used at high or low pressure as follows:

High pressure fuel gas is used for:

- The drive of gas turbines in gas-lift production compressors.
- Compressor leak assurance.
- Keeping the Albien/Barrémien water storage tank pressurized to avoid contact with air.
- Low pressure fuel gas is used as.
- Fuel in Stabilizer Column and Flare Pilot Lights Reboilers

- Stripping gas.
- Fuel in the glycol regeneration unit reboiler.

I.2.3. Water treatment system:

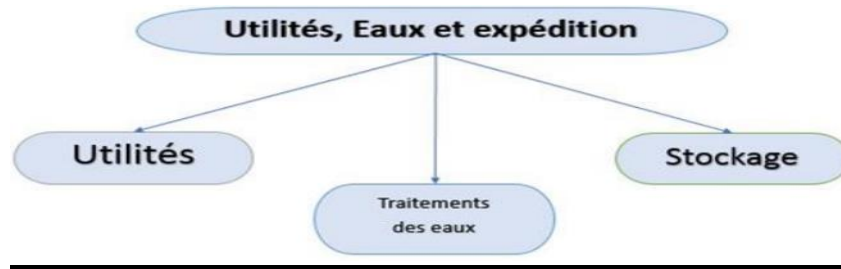


Figure I.12: Utilities, Water and Shipping.

I.2.3.1. Treatment of oily water (production water):

Since the oil coming out of the wells contains water, the water is separated from the oil and gas streams in the separation trains and then treated in the oily water treatment system (hereinafter called OWTS) before being taken back for re-injection into the reservoir.

Water separated from the well fluid consists primarily of formation water (TAGI) and small amounts of well dilution water (Albian/Barremien) and desalination unit dilution water (Mio-Pliocene).

In the long term, it is expected that the water from Albian/Barremian injected into the reservoir will be incorporated into the formation water and thus reduce both the density and salinity of the produced water.

The water introduced into the oily water treatment system is assumed to contain a maximum of 1000 mg/l of oil driven and 50 mg/l of solids.

Oil and suspended matter contained in the produced water are removed during treatment in the OWTS. The water produced has extremely high salinity. The treatment is as follows: degasser; filtration; filter washing.

I.2.3.1.A. Degasser:

The oily water from the different CPF separator balls is sent to a degasser or it will undergo a coarse separation of the oil it contained by settling.

The degasser is divided into 2 compartments by a wall that lets the oil that rises above its upper level pass through and traps the water that has settled in the first compartment. To avoid that the water level rises (which will allow the water to pass with the oil in the second compartment) or that it goes down and in this case the oil cannot pass in the second

compartment, there is a level valve that keeps the proper level of the 1st compartment for proper separation .

The water is then sent from the first degasser compartment to a tank, and the oil is sent from the second compartment to the slug catcher for reprocessing.

I.2.3.1.B.The settling tank:

The degasser water is discharged into a tank or it will be degassed, the gas separated from this water is discharged to the atmospheric flare.

A residence time will allow the settling of suspended looms that have been trained with water.

Inside the ferry there is a floating skimer that will collect traces of oil that have settled over the water.

I.2.3.1.C.Fine filters:

There are three fine filters for each system. When the water arrives in these filters it passes from the top to the bottom of the filter by a very oil-refined material which will eliminate the maximum oil that has remained in the water.

Fine filters have an automatic washing system that will trigger from a certain P value between the filter inlet and outlet, This P is due to the accumulation of oil in the adsorbent material which will make the passage of water inside the filter more difficult (decrease of the outflow) .

The washing system will trigger for a single filter.

I.2.3.1.C.1.Cartridge Filters :

To remove materials suspended in water such as oil adsorbent from fine filters or sand. The water must pass through cartridge filters just after the fine filters.

I.2.3.1.C.2.Storage Tank :

The de-oiled and filtered water is then stored in a storage tank with a residence time to allow the settling of suspended materials that have not been filtered.

I.2.3.2.Fine filter washing system:

As soon as the measuring instruments detect the P mentioned in the fine filters, one of the latter enters the washing phase, which is done in a counterproductive way, that is, the passage of the washing water from the bottom to the top.

Water recovered from the top of the fine filter is treated in the fine filter washing system which includes the following facilities:

- ✓ Wash water collector (200/210-TA-44-03).
- ✓ Flocculator for OWTS1.
- ✓ (FGD) for OWTS1 and (CPI) for OWTS2.
- ✓ Mud bin (200/210-TA-44-05).

I.2.3.3.Eaux Albien/Barrémien:

These are deep-lying fossil waters. They are salty, do not contain dissolved oxygen, but are relatively high in suspended matter. They are used for the production of CPF water, for injection water and make-up water pass to the water storage tank against fire. They reach the 11,200 m³ storage tank, which is covered with fuel gas to prevent oxygen contamination of the air.

The water is then sent to filters, after chlorination, and injection of coagulant and polyelectrolyte. To avoid the accumulation of deposits in the filters, the latter are washed every four hours.

I.2.3.4.Water injection system :

The water injection system is designed to maintain reservoir pressure by using produced water and Albien/Barremian water .

Treated produced water and Albien/Barremian water are mixed before being fed into the water injection pumps. The pumps pump the water back to the injection water mains that distribute the water to the twenty (29) injection wells in the field at 200 barg pressure. Chemicals Used are: Biocide, Corrosion inhibitor.

I.2.3.5.Mio-Pliocene Waters :

These are the waters of the first layer on site. They are used for the production of service water, drinking water and also for the desalination of separation trains.

Raw water is stored in a 400 m³ tank. It then passes through a stripping column where it circulates against the current of a fuel-gas flow, through a lining, with injection of an oxygen reducer. The deaerated water produced is sent to the separation trains continuously. The water for potabilisation is desalinated by reverse osmosis, chlorinated and stored in two bins with a capacity of 168 m³ to be used at the level of the CPF and the industrial base for sanitary and drinking water. Water before reverse osmosis is used for irrigation of green spaces.

This water also contains Sulfato-Reducing BSR bacteria: Up to 102 germs/ml.

I.2.3.6.Air instrument:

This air is of vital importance for pneumatic signals. The aspirated atmospheric air is compressed up to 8 bar through three two-stage screw air compressors. One part is used as service air and the other is used by an air dryer because of the presence of water vapour, which causes icing problems.

I.2.3.7.Chemical injections :

Regular or continuous injections of chemicals are required at all levels of the process to promote its effectiveness, and protect facilities. It is also necessary to combat the presence of oxygen and bacteria in the fluids injected into the reservoir to avoid a change in the characteristics of the extracted product. These injections are performed for:

I.2.3.7.a. Improve the various phase separations: This is a reverse emulsion switch, and an anti-foam, regularly used upstream and during the various phases of separation.

I.2.3.7.b. Facilitate filtering and backwashing: This is a coagulant, or flocculant (polyelectrolyte), injected upstream of fine filters for the production of Albien/Barrémien water.

I.2.3.7.c. Avoid the corrosion of equipment and the formation of limestone deposits: The corrosion inhibitor is regularly injected throughout the process, especially in the first phases, the fluids coming from the deposit being very salty. Anticalcaire is also required to prevent clogging of the water injection system to the wells upstream of the pumps.

I.2.3.7.d. Avoid the presence of oxygen in the injection water: In parallel with the use of cover gas, a deoxygenant injection is carried out at the water tank and upstream of fine filters. An injection is also carried out in the Mio- Pliocene water deaeration system, for the production of washing water.

I.2.3.7.e. Prevent bacterial growth: By injecting biocide into the process water system.

I.2.3.8.Treatment of sludge :

The sludge treatment system receives all effluent with the highest solid particulate matter content from:

The concentrated sludge is pumped to the drying beds outside the CPF. After each shipment, the transfer line is rinsed with water.

The sludge after drying is spread near the drying beds. Its hydrocarbon content is generally less than 5%.

The liquid is sent to the hazardous open drain system and the generated gases are flared.

I.2.3.9.The system of drains :

Several collection networks ensure the recovery of liquids that can flow at the level of retention and recovery of sewage:

I.2.3.9.a. Non-hazardous open drains :

They collect unclean runoff and chiller water. These waters pass through an oil tank in case of possible contamination, then are sent to the evaporation lagoon, which constitutes the only outlet of the waste water of the site. The waters evaporate under the action of the sun, and an evaporating cannon. The latter pumps the water in the basin and disperses it in fine droplets to promote evaporation.

I.2.3.9.b. Hazardous open drains :

They collect water resulting from accidental pollution, rainwater and contaminated fire water, sewage and sludge treatment water. These waters pass through a hydrocarbon separator and are sent to the evaporation tank and the recovered oils are pumped to slugcatcher.

I.2.3.9.c.Closed drains :

These drains recover the liquids from the shutdown and maintenance operations, and the fluids recovered in the event of an incident at the level of the retentions. They are transferred to off-specification storage.

I.2.3.10.The system of torches :

The Ourhoud site is designed to burn a minimum of gas in the atmosphere, most of which is theoretically injected back into the deposit to keep it under pressure. Flaring is necessary to avoid overpressures throughout the process, and at the storage or capacity level using a fuel gas cover. They can also be used to manage gas flows when parts of the process stop.

Chapter I: Introduction to the society

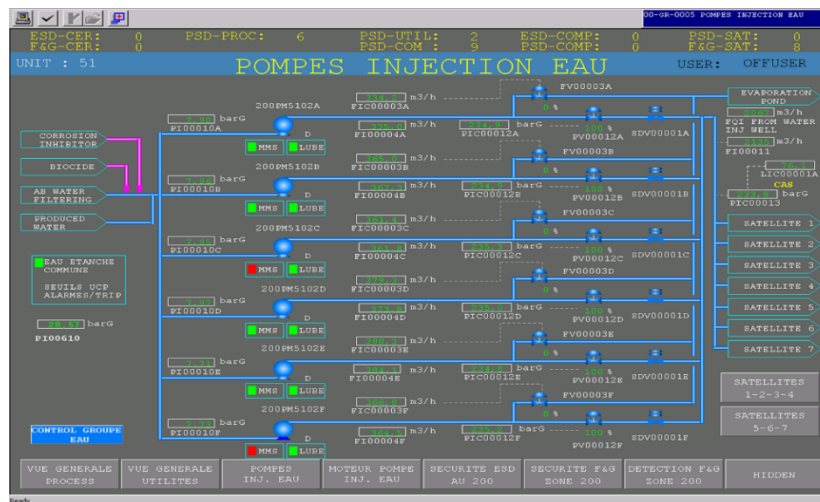


Figure I.13: Water injection pumps.

**CHAPITRE II: CARACTERISATION PHYSICO-CHIMIQUE DU PETROLE
BRUT DU CHAMP D'OURHOUD.**

Introduction

The crude oil can be found in the reservoir, associated with the gas and saline formation water during its extraction, it is composed of three phases; oil water and gas and an emulsion (water/oil mixture). The presence of this emulsion is a major problem encountered by oil tankers in terms of both production and refining. In addition, the salt and water content of crude oil requires preliminary treatment in the field. This treatment consists of destabilizing the emulsion, isolating the oil phase and removing the salt water in a way that will have a good quality of water that will be re-injected into the reservoir to maintain its pressure. Various methods exist to separate these two emulsified liquid phases, including electrostatic desalination or chemical addition .

In this chapter we will give some general information on crude oil and refining in Algeria, with a focus on the production site of the Ourhoud field.

II.1. Crude Oil General:

Crude oil is of vital importance in the modern world as it is the main source of energy along with natural gas. It provides 60% of the world's energy needs, the hydrocarbons that make up it enable the manufacture of energy products such as lubricants, bitumens and petrochemicals, the variety of which is constantly increasing :

Synthetic fibres, plastics, solvents and detergents.

II.2. Definition Crude oil:

Crude oil is a fossil energy whose formation dates back 350 million years, its name comes from the Latin word 'Petra-oleum', which means the oil of stone in liquid form, solid (bitumen) from the decomposition of living animal or plant organisms, mainly marine organisms such as plankton accumulated in sedimentary basins, The transformation of this organic matter under the influence of temperature and time, and the actions of anaerobic bacteria hatch over tens of millions of years through the use of kerogen to form this fluid that will be trapped in the mother rock, then it moves through more permeable rocks (store rocks or reservoir rock) stopping in the trap.

The whole of the source rock and the reservoir and cover rock form what is called an oil deposit.

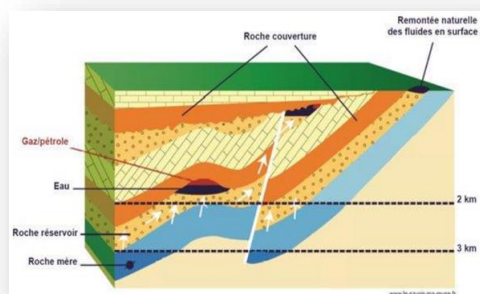


FIGURE II.1: Pattern of oil migration.

II.3.Origin of crude oil:

Since its discovery, as well as its importance, several scientists have studied the problem of the origin of this energy source. For this many theories were issued, but only two of them were taken into consideration.

The first, that of mineral origin formerly defended by notable scholars such as I A and A I. In the second, the probable today, formerly defended by ENGLER and H. n effect, The latter two were able to obtain hydrocarbons from plants and fish during laboratory tests, which helped explain the development of huge oil slicks.

The organic matter would have accumulated at the bottom of the sea mixed with fine sediments and forming with them the sapropel. The pressure is developed gradually by the accumulation of sediments during geological times, the temperature, the action of bacteria in a reducing medium, that is, in the absence of ox gene, would have gradually facilitated the transformation of this sapropel into oil.

Once the oil formed in the mother rock it was subjected to several forces the weight exerted by the sediments, the geological forces, the differences in density with the salt water that accompanies it. Oil therefore tends to migrate and make its way through the most permeable rocks or cracks within these rocks. This migration is usually done by ascending through the sediments, this is due to the fact that the density of the oil is lower than that of the water and the frequent presence of the gas dissolved in the oil. The migration of oil comes to an end when it is trapped in the porous rocks of the subsoil, impregnating like water permeates a sponge.

CHAPITRE II: CARACTERISATION PHYSICO-CHIMIQUE DU PETROLE BRUT DU CHAMP D'OURHOUD.

II.4.Classification of oils:

According to this nomenclature, crude oil, also known as hydrocarbon, is distinguished by the two words hydrogen and carbon, which are the essential components of all crude oils; their contents are (83%-87%) for carbon and (11%-14%) for heroin. These two groups form the three main families of hydrocarbons:

Aliphatic, cyclic and mixed hydrocarbons.

But there are also other elements that make it up, which are at least harmful in the treatment of crude oil. These elements are ox gene, sulphur, and nitrogen in total up to 6% - 7%) in the form of compounds. Also, we were able to detect by the anal oil ashes the presence of other compounds such, Si, Na, Fe...

II.4.1. Composition:

Crude oil is composed of various types of chemical molecules, mainly hydrocarbons, which are divided into several chemical families according to their structures:

- Paraffins: These are saturated aliphatic hydrocarbons of the general formula C_nH_{2n+2} .
- Naphthenes: These are C_nH_{2n-2} saturated cyclic hydrocarbons.
- Aromatics: These are polysaturated cyclic hydrocarbons C_nH_{2n-6} .
- Olefins: These are unsaturated aliphatic hydrocarbons C_nH_{2n} very little present in crude oil see not at all. Other organic compounds, such as sulphur compounds, oxygenates and nitrogen compounds, as well as other chemical compounds such as metals, are also present.

II.4.2. Classification:

II.4.2.A. According to density:

The quotation of crude oils depends on their densities, the knowledge of this parameter allows us to classify the oils according to several families presented in the table.

Table II.1: Classification of oils by density:

Density	classification
< 0.825	Light Oil ' LIGHT'
$0.825 < d < 0.875$	Medium oil 'MEDIUM'
$0.875 < d < 1.000$	HEAVY Heavy Oil

CHAPITRE II: CARACTERISATION PHYSICO-CHIMIQUE DU PETROLE BRUT DU CHAMP D'OURHOUD.

>1.000	Extra heavy oil ' EXTRA-HEAVY'
--------	--------------------------------

The conversion of the density to API density can be done according to the following formula:

$$\text{API} = 141.5 / \text{SG} - 131.5 \quad (\text{II.1})$$

Or SG represents the Specific Gravity or standard density which is the ratio between the density of the hydrocarbon at 15.55°C (60°F) and the density of the water at the same temperature

$$\text{SG} = 1.002 \times d_{15}^{15} \quad (\text{II.2})$$

The lighter crudes produce a lot of light cuts such as diesel, gasoline, naphtha, kerosene, etc. , and heavy crudes produce heavy cuts (bitumen, fuel oil, etc.).

II.4.2.B. According to the sulphur content:

The classification of oils by sulphur content is as follows:

Table II.2: By sulphur content.

sulfur content	Classification
<0.5%	Very low sulphur content
<1%	Low sulphur content
<2%	Average sulphur content
<3%	High sulphur content
>3%	Very high sulphur content

II.4.2.C. Depending on the chemical composition:

The chemical classification consists in classifying the oils according to the predominance of one or more families of hydrocarbons, we distinguish the following families :

- Paraffinic oils (USA) .
- Naphthenic oils (Republic of Azerbaijan).
- Paraffino-naphthenic oils (Algeria).
- Aromatic oils (Indonesia) .
- Naphthenaromatic oils (California).

CHAPITRE II: CARACTERISATION PHYSICO-CHIMIQUE DU PETROLE BRUT DU CHAMP D'OURHOUD.

To define the chemical nature of oils, an essential parameter is used, that is the characterization factor of WATSON K_W or $KUOP$ which is calculated according to the relationship.

$$K_W = \frac{\sqrt[3]{T_{eb}}}{SG} \quad (II.3)$$

With: T_{eb} represents the boiling temperature in degree Rankine ($^{\circ}R$).

Crude oil families by K_W factor are:

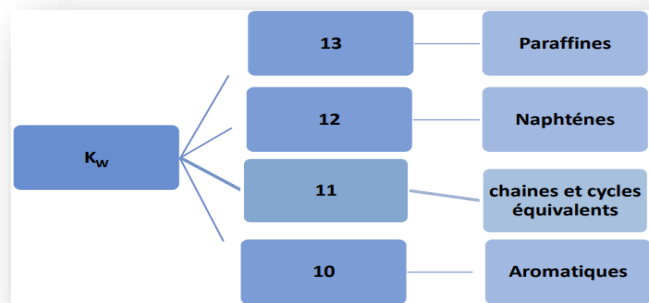


FIGURE II.2: Diagram showing the chemical nature of oil according to K_W .

Oils can also be classified according to other parameters such as viscosity, acidity, nitrogen content, heavy metal content...etc.

II.5. Algerian 'SAHARA BLEND' crude:

II.5.A. Reference crudes:

There are about 400 types of crude oils, 130 of which are marketed. In order to be able to establish prices, we represent 3 types of reference crudes to which we compare the different crude oils.

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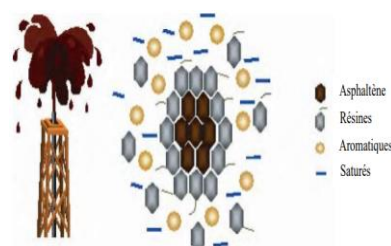


Figure II.3: Crude oil composition.

CHAPITRE II: CARACTERISATION PHYSICO-CHIMIQUE DU PETROLE BRUT DU CHAMP D'OURHOUD.

NB: Crude oil contains water, the combination of which gives an emulsion that can be stable, it also contains salts and impurities.

II.5.B. Physicochemical properties:

Density is defined as the ratio of the mass of a body to the volume it occupies. For petroleum products, it is usually given to C.

The density value of crude oils is determined by means of an aerometer according to the 60-101 standard, and knowledge of this value is very useful for carrying out mass balances.

II.5.C. Vitality:

Measuring the viscosity of crude oils at different temperatures is particularly important for calculating pressure losses in pipelines, pipelines and refinery pipelines, as well as for specifying pumps and exchangers.

The evolution of viscosity as a function of temperature is not the same for all crude oils, the viscosity of a paraffinic oil will increase rapidly if the temperature falls; by for naphthenic or mixed crudes, the increase in viscosity will be more progressive.

II.5.D. Sulphur content:

Sulphur is present in the crude in the form of sulphide hydrocarbons, dissolved sulphide and sometimes suspended sulphur (S, H₂S, thiol, sulphides, disulphides, thiophen and derivatives).

The origin of sulphur comes mainly from the decomposition of organic debris or by the reduction of sulphates by hydrogen under the action of bacteria of the type of *ulforibrio dicesulforican*.

II.5.E. Water and sediment content:

The sediments found in crude oil are fine particles of sand, drilling mud, rock debris, metals in the form of ores or in the free state such as iron, copper, lead, nickel, vanadium...etc.

Knowledge of the water and sediment content of crude oils is of great importance for operators and refiners in order to avoid deterioration of equipment (corrosion, erosion, deposits, plugging, etc.).

II.5.F. The salt content:

The salts in the crude come from a natural formation at the bottom of the deposit. The salinity of a well is related to a flow of water into the surface, visible or not) it evolves during the life of the well and the deposit and it varies according to the structural position of the well and the characteristics of the reservoir rock in the drained area. Generally speaking, we find MgCl_2 magnesium dichloride, CaCl_2 calcium dichloride, NaCl sodium chloride.

Salts are generally present in two forms:

- In crystal form ;
- Ous forms dissolved in fine water droplets dispersed in the crude.

The presence of these salts presents problems of tube plugging of heat exchangers and corrosion.

II.5.G. Asphalt:

Asphaltenes are so far poorly defined substances .

They do not correspond to a family of well-determined hydrocarbons, they are aromatic based, having an amorphous structure.

In the reservoir, the presence of polar functions of asphaltenes is likely to make the rock wettable with hydrocarbons, thus limiting production. They are considered emulsifying agents that promote water-oil emulsion. They are determined by extraction with a solvent (benzene, toluene or chloroform) which consists in precipitating the asphalt.

-The main hydrocarbon families.

II.5.G.1. Aliphatic hydrocarbons:

These are paraffinic hydrocarbons, olefins, and open-chain acetylene .

- **Saturated:**

The alkanes $\text{C}_n\text{H}_{2n+2}$ are either normal or branched (isomeric). Paraffinic oils contain about 50% paraffin.

- **Unsaturated:**

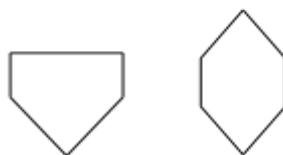
They do not exist in the crude oil, they are formed during the oil treatment by thermal cracking or thermocatalytic processes. These unsaturated are called olefins whose general formula is C_nH_{2n} for alkenes and $\text{C}_n\text{H}_{2n-2}$ for alkynes.

II.5.G.2. Cyclic hydrocarbons Generally :

The cycle consists of 05 or 06 carbon atoms.

Saturated hydrocarbons are naphthenic hydrocarbons having the formula C_nH_{2n} .

Ex: C_6H_{12} or C_5H_{10}



Cyclohexane cyclopentane

Figure II.4: Chemical structure of cyclohexane and cyclopentane.

They are divided into monocyclic, bicyclic and polycyclic naphthenics.

Unsaturated saturated hydrocarbons are aromatics with the chemical formula C_nH_{2n-6} (benzene, C_6H_6).



Figure II.5: Benzene chemical structure.

Aromatics occur in petroleum as BTX (Benzene, Toluene, Xylene), naphthalene, anthracene, pyrene, etc.

II.5.G.3. Mixed hydrocarbons:

The combination of cyclic and aliphatic hydrocarbons produces mixed molecules (cycle+chain). The properties of these mixed molecules depend on the importance of the cycle or chains in the structure.

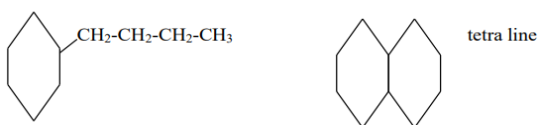


Figure II.6: Chemical structure Mixed hydrocarbons.

Note: The chemical composition of crude oil is given by the content of paraffin, olefin, naphthene and aromatic PONA in the petroleum fraction

II.6. The various compounds contained in the crude oil:

II.6.a) Sulphur compounds:

Almost all oils contain sulphur. The oil content increases with the increase in the boiling temperature of the petroleum fraction. These sulphide compounds are divided into 03 groups

- **The first group:**

Includes H_2S and $R-SH$ (mercaptans) which have acidic, corrosive and unpleasant properties .

- **The second group :**

Contains $R-S-R'$ and $R-S-R'$ disulfides that are cold neutral and unstable at high temperatures between 130 and 160°C to produce mercaptans and H_2S .

- **The third group:**

Contains heterocyclic compounds, namely thiophene (1) and thiophene (2), which are unstable at high temperatures in the range of 500 to 600°C to produce mercaptans and H_2S .



Figure II.7: Chemical structure Sulphide compounds.

Sulphide compounds are undesirable because they reduce the octane number of gasoline, acting on the effectiveness of the action of anti-knock additives, such as P.T.E (lead-tetraethyl).

These compounds also poison catalysts in catalytic processes.

II.6.b) Nitrogen compounds:

The nitrogen content varies from 0.02-2.5%, it increases with the increase of the boiling temperature of the fractions, it is found in the form of quinoline (1) and pyridine (2).

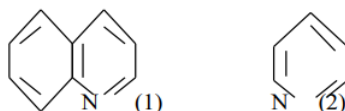


Figure II.8: Chemical structure Nitrogen compounds.

All nitrogen compounds are poisons for catalysts.

CHAPITRE II: CARACTERISATION PHYSICO-CHIMIQUE DU PETROLE BRUT DU CHAMP D'OURHOUD.

II.6.c) Oxygenated compounds:

In petroleum there is a small amount of oxygen, in naphthenic acids, phenols and gums

Ex: $C_nH_{2n-1}COOH$

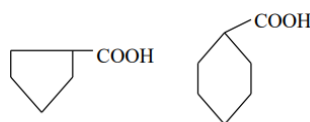


Figure II.9: Chemical structure Oxygen compounds.

II.6.d) Metal compounds:

They exist as salts dissolved in water mixed with crude oil. Metals are permanent poisons. For these compounds lead, As, P, V, Hg, etc.

II.7.Oil refining in Algeria:

As our country is a major oil reserve, it is obliged to build complexes to allow the treatment of this wealth to obtain consumer products and also those that will be used as raw material in other sectors.

The continuous process of a single refinery involves first cleaning up the crude oil, then distillation separation into white (distillation, light and medium) and black (heavy residues) products. Light products are converted into automotive gasoline.

Currently, the marketing of crude oil is governed by contracts binding on producers, transporters and refiners which set specifications for the oil offered for sale, in particular the salt and water content. The most common values are 40 to 60 mg/l for salt content and in the order of % for water. Refineries must reduce their units to the maximum salt content of 5mg/L before they start to prevent any source of technical problems that may affect production, such as fouling of the exchangers, corrosion of the equipment of the atmospheric distillation units, degradation of the quality of the residues, etc. etc .

The removal of salts and water is essential at all levels of crude oil treatment and this requires the installation of desalination units. In order to carry out a study on one of the techniques for removing water and salt, a one-month training course was carried out in an oil field located in the Berkine basin 200 km south of the town of Hassi Messaoud, namely the «Ourhoud field».

So the next part will be devoted to the description of this deposit.

CHAPITRE II: CARACTERISATION PHYSICO-CHIMIQUE DU PETROLE BRUT DU CHAMP D'OURHOUD.

The URH UD field is primarily for crude oil production. Production is carried out using different circuits called systems” from oil producing wells, via satellites and finally arriving at the CPF (Central Processing Facilities). The latter consists of several systems, with complementary roles.

The influencers, in the form of a mixture (crude-gas-water) entering the CPF, begin to undergo their first separations in the Slugcatcher, then continue to be separated gradually, through the different stomes, in order to reach a final stage of purity, characterised by a quality which gives the products their ability to be reused (gas and water) or shipped (crude oil). We note here that the injection of selective demulsifying chemicals, remains essential, in order to achieve very advanced separation rates and good water quality. The European Commission’s Green Paper on the Environment, Public Health and Consumer Protection.

CHAPITRE II: CARACTERISATION PHYSICO-CHIMIQUE DU PETROLE BRUT DU CHAMP D'OURHOUD.

CHAPTER III: ELECTROSTATIC DESALINATION OF CRUDE OIL

Introduction:

Crude oil often contains water, salts, suspended solids and traces of water-soluble metals. The salinity of the latter is limited to 40 mg/l and BSW (Basic Sediment and Water) is less than 1%, for this reason advanced techniques and continuous research on crude oil to remove salts and water contained in the crude, including the goal of saving processing facilities, and improving the selling price of the barrel. The first step is to remove these contaminants through desalination (dehydration) to reduce corrosion, clogging and fouling of facilities.

The role of the desalination unit is to remove mineral salts from crude oils by washing them with water. These salts are liable to cause corrosion and fouling in the crude oil treatment units. This desalination operation also allows to recover the sediments still present in the crude. The raw desalinated/ water separation is carried out in a large horizontal settling flask: the desalinator

The discovery of desalination of a crude oil in the presence of an electric field dates back to 1908 and COTTRELL, well known for this work on the electrical precipitation of aerosols. The first industrial applications of this refining process date from 1935 in the United States. In France, on the other hand, electrostatic desalinators did not appear in refineries until the 1960s. But today virtually all refineries are equipped with electrostatic desalinators.

III.1.Desalination:

Desalination is an essential operation in the oil industry, as it leads to the proper functioning of the downstream treatments. Indeed, poor desalination has direct consequences on the operation of crude oil treatment units, which can cause adverse effects on all installations such as:

- Fouling of heat exchangers and furnaces.
- Corrosion of column head circuits.
- Obtaining residues rich in salts.

With regard to the environment, the massive transfer of hydrocarbons into the waters of the desalinator leads to serious ecological problems, which require additional effort and cost to manage.

So the goal will be to eliminate:

-DESHYDRATION WATER

-Salt DESALINATION

For:

-Meet commercial specifications “BSW < 1% and Salinity < 40 mg.”

-Limit water transport in pipes (pressure losses, corrosion).

Objective and principle:

Crude oil and heavy residues may contain different amounts of organic compounds such as water-soluble salts, sand and other dry extracts, all of which are characterized as bottom deposits. The salt in the crude comes mainly in the form of salt crystals dissolved in suspension or dissolved in the water emulsion with the crude. These impurities, in particular salts, can result in fouling and corrosion of heat exchangers (crude oil preheats) and in particular the head distillate system of the crude distillation unit. So the objective will be to :

Eliminate:

" -Dehydration" water

The salts «Desalination-«

For :

-Meet commercial specifications “BSW < 1% and Salinity < 40 mg ”

-Limit load losses and corrosion in transport pipes.

III.2.Salts:

The water is dispersed in the crude in the form of thin water droplets whose dimensions are of the order of the micro. Emulsified water can vary in very large proportions from 40 to 50% water. The predominant salt in crude is sodium chloride (NaCl), accompanied by magnesium dechlorination ($MgCl_2$), calcium dechlorination ($CaCl_2$), and certain solid particles (SiO_2 , clay, resin, sand and sediment, etc.). These salts are present in the crude in two forms: crystals and emulsions.

In salt crudes, the salts considered are essentially chlorides with an approximate distribution: $MgCl_2$ (magnesium chloride) = 20%, $CaCl_2$ (calcium chloride) = 10%, NaCl (sodium chloride) = 70% .

III.2.1. Causes of salt formation:

The presence of salt-laden water in crude oil can have various causes :

III.2.1.a.Natural causes:

During its movement inside the pores of the formation, the oil is bound to the reservoir water, which causes an emulsion. This phenomenon may be negligible at the beginning of the exploitation of some wells, but it eventually manifests itself during the life of the oil field.

III.2.1.b.Accidental causes:

The emulsified water in the crude can also come from:

- From an area above the producing layer (in this case, it descends in the formation of casing cement cracking).
- Injection is performed to perform secondary or tertiary recovery.

III.2.1.c.Voluntary causes:

Fresh water washing on production facilities to dissolve salt deposits and in the crude for desalination.

III.2.2. Disadvantages of salts:

Salts have disadvantages in crude oil treatment units (stabilization), which are:

- Reduced production capacity due to reduced cross-section (fouling).
- Decrease in heat transfer coefficient in heat exchangers due to poor conductivity of salt deposits.
- Perforation and rupture of furnace and heat exchanger tubes (corrosion).
- Formation of hydroxides and acids by hydrolysis of salts.

III.3.General information on emulsion :

III.3.1. General definition of emulsion:

Crude salinity is related to the amount of water in the crude because salt is soluble in water and not in the crude. This water is represented as an emulsion .

An emulsion consists of two immiscible liquids (one is dispersed in fine droplets in the other) which are stabilized by emulsifying agents .

The small droplets constitute the internal or dispersed phase while the main phase is known as external or continuous, so we can distinguish two types of emulsion on the oil field:

Hydrophobic emulsion: water droplets in a concentrated medium of oil.

Hydrophilic emulsion: oil droplets in a concentrated water medium.

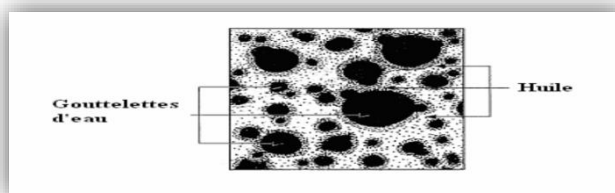


Figure III.1: General of an emulsion.

The emulsion encountered in the production of oil is generally of the type water in oil (hydrophobic) where the continuous phase is oil, and the disperse phase is water. There are three conditions that allowed the formation of such an emulsion:

- No miscibility of the two liquids.
- Presence of continuous emulsifying agents in the crude (asphaltenes, resins, organic acids, paraffins, oil-soluble and some finely divided solids such as iron, zinc and aluminum sulphates, calcium carbonates, clay silica and iron sulphide), the latter concentrate at the interface (water, oil) by forming a barrier around the drops of water thus preventing their coalescence and stabilising the emulsion.
- Sufficient energy to disperse water in the crude.

III.3.2. Stability of an emulsion:

The stability of an emulsion or its resistance to destruction depends on several factors:

III.3.2.a.Emulsifying agent:

This is the primary factor in the stability of an emulsion indeed, its absence does not lead to a stable emulsion, the activity of an emulsifying agent is defined by its speed of migration at the interface and by its emulsifying power .

III.3.2.b.Agitation:

The type and severity of the agitation determines the size of the water drops dispersed in the crude. The emulsion is more stable as the water droplets are smaller.

From this point of view, the determination of the particle size of the water drops can be a measure of the stability of an emulsion.

III.3.2.c.Oil viscosity:

The viscosity of the continuous phase plays a double role: on the one hand, the viscosity of the oil prevents the migration of the emulsifying agent to the interface and limits the formation of fine droplets by agitation. On the other hand, high viscosity is an

unfavourable factor when settling water droplets, generally speaking, the two opposite effects cancel each other out.

III.3.2.d.Moisture content in the emulsion:

When the percentage of water increases in an emulsion of the water-in-oil type, greater agitation is necessary to make the water emulsion.

Generally speaking, we would tend to say that emulsions with a high percentage of water are the least stable emulsions.

III.3.2.e.Age of the emulsion:

An emulsion decays a certain part of its water over time, the remaining emulsion containing the finest water bubbles, becomes more and more stable.

In addition, complex chemical reactions can stiffen the interfacial film and make coalescence more difficult, which is why it is necessary to treat the emulsions as soon as they are formed.

III.4. Desalination processes:

There are three main types of desalination:

- Chemical method.
- Mechanical method.
- Electrical method.

Each of these processes is designed to collect water droplets into large drops that can be deposited quickly at the bottom of the decanter.

The majority of the treatment units used both processes (chemical and electrical) at the same time to integrate stable emulsions.

III.4.1. Chemical method:

The chemical method is based on the introduction of a de-emulsifying agent (surfactant) into the crude oil at a temperature between 40°C and 150°C. The surfactant –active (stabilizing devices), having a very high surface tension, adsorbs to the surface of the water droplets while destroying the emulsions. Thus the disintegration of emulsions by means of chemicals can be obtained by :

The displacement by absorption of the active emulsifying agent by a product with a more powerful tensio-active effect and less solidity of the absorbing film .The formation of emulsions of opposite types (phase inversion) .

Dissolution of the absorbent film by its chemical reaction in the presence of the emulsifying agent introduced into the emulsion. The choice of demulsifiers depends on the nature of the oil, the quantity and composition of the aqueous phase, the mixing intensity, the temperature and the rate of settling... etc.

III.4.2. Mechanical process:

The three essential steps are:

III.4.2.a.Settling:

The operation of most crude oil processing equipment is based on the principle of settling (difference in density) to separate the water droplets from the oil, In addition, the drop motion of the water droplets through the oil is favored by friction related to This process is only effective for stable emulsions because of .the viscosity of the oil the difference between the specific weights of the emulsion compounds. Heat treatment of emulsions accelerates settling.

III.4.2.b.Centrifugation (spin-drying):

Low centrifuge throughput, as well as high costs on their farms, were the main reasons however, allows to achieve dehydration and for their limited uses, centrifugation almost complete desalination. For the process, 5-10% of water is mixed with petroleum prior to centrifugation and the mixture is heated to 80°C, stirred thoroughly .and then processed in centrifuges

III.4.2.c.Filtration:

The separation of oil water by filtration is based on selective wetting phenomena. To dehydrate the oil, poplar fill shavings and other sharp edges of shavings are used to collect fat drops flowing easily by gravity. The filtration columns are mainly used when the oil emulsions have already been disintegrated, but the droplets still remain The major drawback of the filtration process is the .suspended and do not deposit relatively rapid clogging of the filter by soil particles and often requires it to replace the lining.

III.4.3. Electrical process:

Even after the separators, the crude contains water and salts in the form of a very stable emulsion, the electrostatic desalinators bring in an efficient form the energy necessary for the destruction of these emulsions. Indeed, particles receive under the effect of a high voltage alternating electric field loads of opposite polarity. When the load reaches a sufficiently high potential, the dielectric envelope is pierced, and

consequently, the fine water droplets join together forming larger drops that are easily deposited at the bottom of the tank

The release of the gas in the tank is undesirable; during desalination, the evaporation of the light ones is avoided by raising the pressure in the apparatus thus keeping the gases in the dissolved state

Thus, a new emulsion of about 5% of fresh water is created in the crude; this new emulsion is destroyed again, causing also the salty water droplets present at the beginning

The removed water contains approximately fresh and salted water in the proportions of the emulsion mixture performed, four fundamental operations take place in the electric desalinator

The drops of water thus acquire a sufficient mass to fall gravity towards the bottom of the desalinator, it is the settling.

III.5.Electrostatic desalination mechanism:

The desalination of crude has three successive stages:

III.5.1. Diffusion of salts in washing water:

The washing, dissolution and dilution operation consists in passing the salts contained in the crude into the water phase. The washing water is used to dissolve the salt crystals contained in the crude, to ensure the best water/oil contact. The emulsion made must be quite fine, the size of which varies according to the washing rate used. The water/oil mixture is carried out through a mixing valve, which is adjusted so that the emulsion is as fine as possible.

III.5.1.a.Coalescence of water droplets:

The stable water/crude emulsion is strongly stabilized by polar molecules such as asphaltenes and finely divided solids.

These agents stabilize the emulsion, hence the need to use some demulsifier, the difficulty of coalescence will therefore depend on the quantity of natural emulsifier contained in the crude and also the presence of finely divided solids.

Two mechanisms cause coalescence:

- The forces of attraction of the droplets between them due to the polarity of the water molecules tending to orient.
- Agitation created by the electric field.

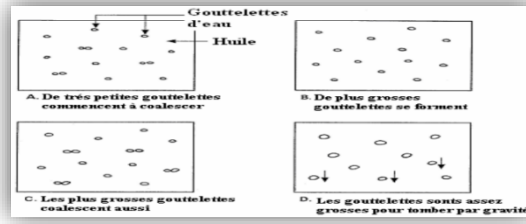


Figure III.2: Coalescence of water droplets.

The force of attraction between the droplets is given by the following formula Or:

$$F = K E^2 \frac{a^6}{d^4} \quad (III.1)$$

a: droplet radius

d: distance between droplet centres

E: electric field

k: the constant.

To increase the force of attraction, it is therefore useful to increase the electric field E .

Coalescence also depends on the rate of washing water injection, so the coalescence rate is given by the following formula:

$$V_C = K \frac{X^{4/3}}{\mu} \quad (III.2)$$

Where :

VC: Coalescence speed.

X: Wash water rate.

μ: Dynamic viscosity of crude oil.

It can be concluded that coalescence depends on :

- The electrical field.
- The rate of washing water injection.
- The desalination temperature .

III.5.1.b.Settling:

Under the effect of the electric field, the water droplets gather and give large droplets which, under the effect of their density greater than that of the crude, decant at the bottom of the desalinators, from where, the rate of settling is given by the Stokes formula.

$$V_d = \frac{1}{18} \cdot g \cdot \frac{(d_d - d_c)}{d_c} \cdot \frac{D^2}{9c} \quad (III.3)$$

Where :

g : acceleration of gravity

ρ_d : density of the dispersed phase (water)

ρ_c : density of the continuous phase (crude)

ν : kinematic viscosity of the continuous phase.

D : diameter of water droplets.

It is therefore of interest to improve decantation:

increase the size of the water droplets (by increasing the amount of water injected and using demulsifier).

Operate at the highest possible temperature to decrease the viscosity of the continuous phase.

In a practical way, desalinators are calculated for a viscosity of two centipoises and for an apparent settling time of 20 to 30 minutes.

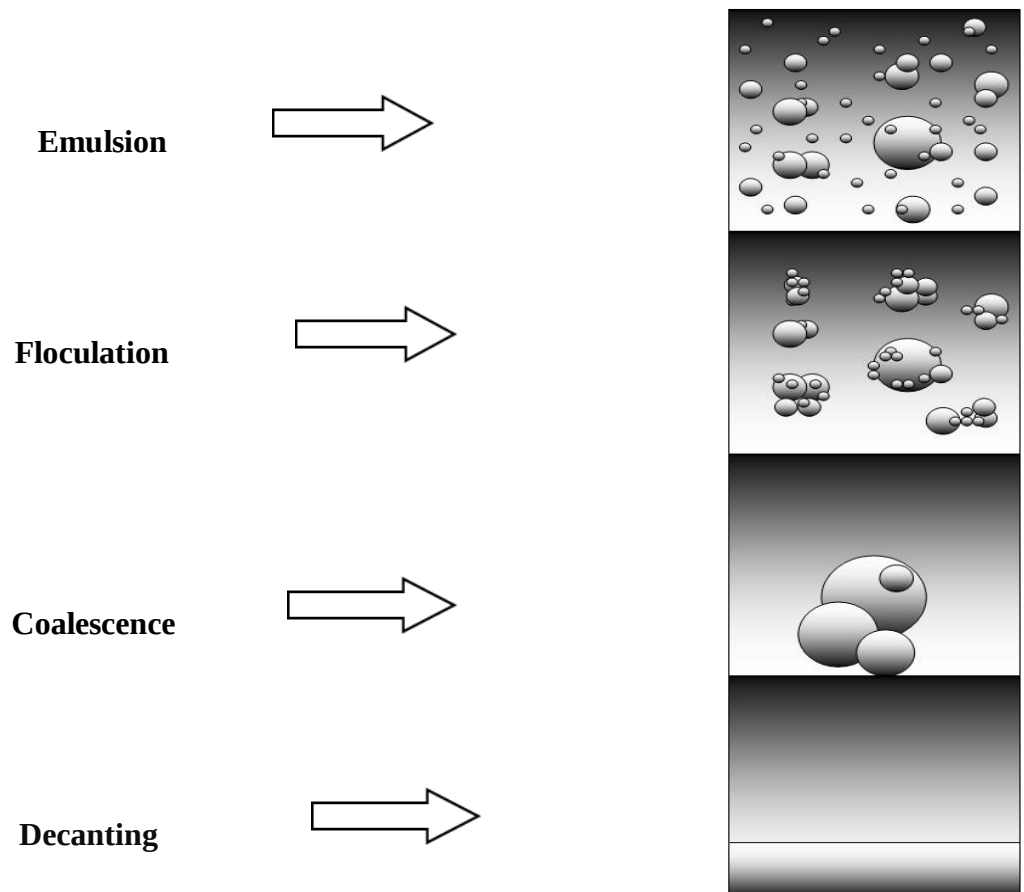


Figure III.3: Desalination principle.

III.5.2. Operating parameters and their influence:

III.5.2.a.Desalination temperature:

The temperature of the crude oil load is very important for the efficient operation of the desalter, the temperature varies between 70°C and 150°. A temperature lower than that specified reduce the desalination efficiency because of the increase in viscosity and consequently a difficulty of separation of water. Higher temperatures can also reduce desalination efficiency due to higher electrical conductivity of crude oil. It also intervenes at the rate of coalescence through the viscosity which is very sensitive to this parameter.

III.5.2.b.Wash water injection rate:

Washing water is used to wet salt crystals and dissolve them. The force of attraction between the droplets (coalescence) is greatly influenced by the washing rate and the temperature.

Excessive washing rates can cause:

- Water driven with desalinated oil (unit disturbance).
- Foaming inhibits desalination.

III.5.2.c.Operating pressure:

The pressure does not influence the salinity of the crude oil, but it can influence the operation of the desalinator.

The pressure in the desalter must be maintained at a sufficient value to prevent the vaporization of the crude. Vaporization causes hazardous conditions, irregular functioning and loss of effectiveness of desalination results .

In the event of a drop in pressure, hydrocarbon vapours will be saturated with water, thus more conductive than crude oil; this would cause excessive consumption of electrical power. The extra power will be converted into heat that will heat the crude more, and the vaporization will trigger the electrodes.

III.5.2.d.Pressure loss (P) at the mixing valve:

The load loss at the mixing valve measures the degree of mixing between the crude and the wash water, it allows the water to reach the crystals and dissolve them, creating an intimate mixture between the water and the crude.

The value of this load loss () is determined experimentally for each crude oil; it generally depends on the quality of the crude oil (heavy or light), an increase in the load loss tending to form a very fine dispersion, thus emulsions difficult to destroy.

Conversely, a low load loss leads to an incomplete washing, in a practical way, it varies between 0.2 and 2 bars, depending on the nature of the treated crude.

III.5.2.e. Influence of the electric field:

Water droplets are influenced by the electric field, they undergo a force of attraction according to the law of coalescence:

$$F = K E_o^2 \cdot \frac{a^6}{d^4} \quad (III.4)$$

Where:

a: droplet radius.

d: distance between the centres of the droplets.

E: electric field.

Water droplets in the electric field turn into induced dipole.

In other words two electric poles appear on the droplet which concentrate respectively the + and -charges.

The water droplets placed in a low frequency alternative field, the dipolar moments will instantly follow the variations of the field E_o and the force F will vary simultaneously without changing direction, to increase F , so it is better to increase the electric field, but without reaching critical tensions above which it is likely to deform the droplets to the point that they divide even more and cause the desalinator to activate.

Each droplet entering the electric field begins to vibrate at the frequency of the alternating electric current, this causes a collision of droplets which in turn form large drops of water by the fusion of several smaller, the large drops thus formed constitute a mass sufficient to cross the crude oil and settle at the bottom of the tank.

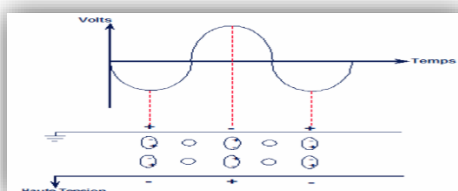


Figure III.4: Action of an alternative field.

III.5.2.f. Influence of the interface level:

The decanted water level forms the primary field of potential with the lowest electrode “Zero”. Any variation in water level disturbs the primary field that is regulated by law:

$$E_1 = \frac{E_o}{h} \quad (III.5)$$

E1: primary field.

Eo: voltage between electrodes.

h: distance between interface and bass electrode.

If the water level is too high, the electric field increases, the settling time decreases, and we will have water drives in the desalinated crude oil, therefore disturbance of the stabilization, if the water level is too low, the crude oil will not have sufficient washing time, hence decrease in desalination efficiency and crude oil drive, therefore, a constant level is maintained to have a good desalination, this is usually achieved by LCV (level control valve).

III.5.2.g. Residence time:

The residence time of the crude oil in the desalinators is given by the following relation:

Where:

TS: residence time or retention time.

V: volume of capacity (m3).

Q: Charge Volume Flow.

QThe residence time plays a major role in desalination, it directly influences coalescence and especially on the settling. $= Q_{raw} + Q_{water}$.

III.5.2.h. Influence of demulsifier:

The emulsion has great stability due to the formation of a protective layer around the water droplet. This protective layer consists of paraffins, gums, asphaltenes, clay and sand. Surfactants are used to break the protective film. They are usually injected upstream of the separators.

The injection rate varies from 5 to 50 ppm depending on the type of crude oil to be treated.

The required performance of a demulsifier is twofold:

Improve the quality of the oil-side separation.

Improve water side separation quality.

The demulsifiers encountered on the market under various brands act on emulsifiers by neutralisation. Four essential actions are required for demulsifier:

- Strong attraction through the water/oil interface.
- Flocculation.
- Coalescence.
- Anchorage of the solids.

The presence of these four actions causes the separation of water and oil. The demulsifier must be able to migrate quickly through the oil to the oil/water interface where it must combat the emulsifying agent that is more concentrated .

If the emulsifying agent is low, the flocculation forces may be sufficient to induce coalescence, which is not always the case, if necessary, the de-emulsifier must then neutralize the emulsifying agent and tear the interfacial film of the water droplets, which will cause coalescence.

The type of neutralizing action of the demulsifier depends on the nature of the emulsifier for example, paraffins and asphaltenes may be dissolved or altered, thus reducing the viscosity of their film and changing their wettability and dispersion in oil, it is rare that a single chemical compound alone can produce these actions, a mixture of several compounds is then used to allow a balanced action. We distinguish the ionic and non-ionic demulsifiers:

III.5.2.h.1. Ionic demulsifier:

The characteristics of the voltage - active are given by the organic ion which is the most important in volume, we distinguish three subgroups:

- Anionic products:

They possess one or more functional groups which can be ionized in solution only by providing an organic ion negatively charged, and a metal ion positively charged responsible for solubility.

The hydrophilic part is generally made up of sulphates and sulphonates, and the lipophilic part by hydrocarbons (petroleum sulphate, sulphonated resins, etc.).

- Cationic products:

The heated crude is pumped into the first-stage desalinator inlet piping, where it is conducted with recycled brine from the second-stage desalinator. The crude flow enters the first stage desalinator near the desalinator bottom. The flow is driven by perforated pipe distributions that extend the entire length of the desalinator for a uniform distribution of the crude oil in the coalescence zone.

The desalinated oil leaves the top of the desalinator by a single outlet line. Oil from the first stage desalinator feeds the second stage mixing valve, where it is combined with fresh water to dilute the salt concentration in the brine.

Fresh dilution water is injected into the oil stream upstream of the second-stage mixing valve before entering the desalinator.

III.6.1. Desalinator elements:

An electrostatic desalinator is typically equipped with the following internal parts:

III.6.2. Interior piping:

The desalination unit is equipped within several sets of pipes and each has its own function in the emulsion process.

III.6.2.a. Inlet piping "emulsion distributor":

Two horizontal manifolds are located at the bottom of the desalinator, each connecting to the inlet tubing of the distribution piping to which "tees" are connected, with one end open and pointing upward.

Along the distributor, one can notice the presence of a multitude of small holes that allow the emulsion to enter the main part of the desalter. The holes in the dispenser allow the liquid to enter the desalinator slowly and thus not to create a mixture with the liquids already in place in the desalinator.

III.6.2.b. Outlet pipes for desalinated crude:

A second horizontal manifold is located at the top of the balloon. This outlet manifold is not equipped with «tees» but in its upper part are drilled large holes through which the desalinated crude flows, this manifold is connected to the outlet tubing of the desalinator crude.

III.6.2.c. Water flow piping:

This pipe consists of a manifold attached to the bottom of the desalinator, its function is to evacuate the water accumulated at the bottom of the desalinator following the separation of the emulsion by the electric camp.

III.6.2.d. Steam piping:

This piping allows injection into the steam tank to degas the tank before starting or when stopping the unit before inspection.

III.6.3. The entrance diffuser:

The input diffuser is suitable with guide blades. The purpose of these blades is to straighten and produce a laminar flow in the emulsion when it enters the desalinator. The laminar flow is a smooth, stable flow that will not cause waves or ripples in the liquids that are already inside the desalinator, this in order to help the liquids to separate from the emulsion.

III.6.4. Electrodes:

Constitute the core of the desalination unit, have been specially designed to achieve maximum operating efficiency. There are three electrodes of steel rods.

The electrodes are powered by transformers. Each set of reactant transformers is connected to the electrodes inside the bag by the high voltage supply assembly. When the electrical current is in use, it passes from one electrode to the other so that the space between the electrodes becomes an electrostatic field.

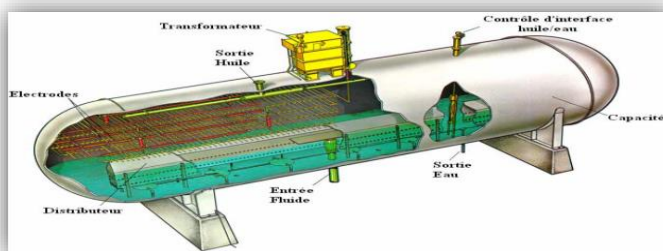


Figure III.6: Electrostatic desalinator electrodes.

III.6.5. Electrical instrumentation and connections:

The desalination unit is provided with a local explosion-proof electrical panel. It is equipped with:

- Cable presses and electrical supply terminals.

- Cable Presses and Starting Terminals for Connections between Switchboard and Transformer Assemblies.
- Cable presses and terminals of the connection with the low level switch.
- Remote control panel including:
 - Ammeter.
 - Voltmeter.
 - Pressure gauge.
 - Pilot lamp.
 - Push buttons.
 - Junction box.
- Instrumentation required for desalinator operation is:
 - Mixing valve.
 - Injection pump.
 - Transmitter and level controller.
 - Pressure transmitter.
 - Pressure gauge.
 - Safety valve.

III.6.6. Sludge washing operation:

The desalinator/coalescor system (10/20/30) VW-21-01/02 is equipped with a mud washing system. The mud washing system includes three sections of the wash manifold and sludge bowl to facilitate the movement of sand or the accumulation of solid from the bottom of the capacity.

The mud wash manifold is equipped with jet nozzles. The jet nozzles are located under the water interface and around the inner perimeter of the capacity.

Nozzles are oriented on the mud bowl.

When the sludge washing system is in operation, an emergency pump for the desalinator water circulation pumps (10/20/30) - PA-21-02/02, will be put into operation in parallel with the one that is in order to maintain the sufficient quantity of water to the nozzles.

III.7.Description of the CPF electrostatic desalinator:

The general characteristics of a desalinator are given in the table below:

Table III.1: General characteristics of an electrostatic desalinator.

Manufacturer NWL (NATCO OEM supplier).	
Primary	400volt AC, single phase, 50hertz.
Secondary	12/16.5/20/23/25 KV, DC half-wave, positive and negative .
Tertiary	AC de 100 V
Insulation class	Classe.A
Construction	fluid-filled outer coating.
Coating	hot-rolled steel wall sheet, stripped and Oil 7 or 10 thick, by ASTM A569.
Bottom	Hemispheric
Design pressure	31.0 bars
Maximum operating pressure	18.0 bars
Hydraulic test pressure	46.5bars.
Design temperature	110 C° .
Max operating temperature	80 C° .
Volume	77.8 m ³
Empty weight	50400Kg.
Size	300mmX10000mm.

III.8.Types of desalinator:

There are three types of desalinator:

- spherical desalinators.
- vertical desalinators.
- horizontal desalinators.

Desalination facilities generally consist of two floors. In the first stage 75 to 80% of water is removed and 95 to 98% of salt is also removed.

In the second stage 60 to 65% of remaining water and 98% of remaining salt are removed.

The number of floors depends on the volume and quality of the crude. This includes water content, salt content and emulsion resistance, and the type and productivity of the device.

In modern installations, horizontal cylindrical desalinators are used which have the following advantages:

- o Large electrode area and specific productivity.

- o The speed of oil in vertical motion is low (better water settling).
- o High pressure and high temperature operation.

Chapter IV: Calculation, Results and Discussions

CHAPTER IV: CALCULATION, RESULTS AND DISCUSSIONS.

Introduction

When a new crude oil deposit is discovered, a series of analyses are carried out that The aim is to evaluate the composition of the product and to fix the yields in certain fractions. This information will allow the refiner to predict the units to be used for processing this and their capabilities. The role of the Ourhoud Field Laboratory is to control quality analysis and perform a series of simplified crude oil analyses. Such an analysis allows the potential buyer should have a first idea of the essential qualities of oil and estimate value. Definitions of these characteristics are valid in terms of sampling is an important operation on which the results of the analyses. When taking a sample, it is very important to take a certain precautions; the product to be sampled, purging before sampling, avoid contamination of containersetc. These factors have a direct influence on the results of analyses. The analyses performed on the effluents for the calculation of material and salinity are shown below.

IV.1. Materials and methods:

IV.1.1. Crude oil analyses:

IV.1.1.1. Density:

Density is one of the most easily accessible quantities. It is determined by tests to determine the composition of the products to be studied. The expressed as the ratio of the density of a sample to the density of water. For petroleum products, it is expressed at 15°C, density value or density crude oil is determined using an aerometer according to NF T60- 101.

a) Principle:

This measurement is based on the aerometer and direct reading method at temperature of 15°C.

(b) Apparatus:

- Aerometer ALLA France.
- Digital thermometer with probe.
- Graduated test piece of 500.

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Figure IV.1: Aerometer.



Figure IV.2: Graduated Test Specimen.

c) Procedure:

- Take the sample for analysis and put it in a container (sample bottle) .
- Then pour the sample into a dry, clean 45° inclined specimen to avoid bubbles and minimize evaporative losses of volatile products .
- Immerse the suitable aerometer in the sample and subsequent thermometer and allow it to stabilize.
- Once the aerometer is stabilized, read directly to the aerometer and the displayed temperature.

When reading, we always add (0.5) to the value read to compensate for the vacuum left by the meniscus.

IV.1.1.2. Viscosity:

Viscosity is generally defined as a value characterizing the flow resistance of a liquid. In a real fluid, the contact forces are not perpendicular to the surface elements on which they are exerted. The viscosity is due to these frictions which are opposed to the sliding of the moving fluid layers on each other. It is defined by ASTM D 445.

a) Principle:

Kinematic viscosity is determined at 40°C. The flow time t of a volume of liquid is measured through a capillary tube. We show that the kinematic viscosity is proportional to the time t . If we know the constant of the device ($C = 0.01160$) provided by the manufacturer. It is expressed in centistoke (cSt).

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Figure IV.3: Viscometer.



Figure IV.4: Thermostat bath.

c) Procedure:

- Turn on the thermostat bath and let it set to a desired temperature .
- Pour approximately 25 ml of the raw sample into the viscometer inside the thermostatic bath .
- Using a pear, the sample was kept in the upper part limited by two gauge marks.
- Allow the sample to drain, and as soon as the level reached the upper line, the stopwatch was started .
- Once the last drop has passed through the lower gauge line, stop the stopwatch and record the flow time.

d) Expression of results:

$$\eta = C.t \quad (IV.1)$$

IV.1.1.3. Water and sediment content (BS&W):

Crude oils contain very small amounts of water and sediment, most of which is dissolved in water, with the remainder in the form of very fine crystals. The water and sediment content of crude oil is measured in accordance with ASTM D 96, which determines the volume of water and sediment separated from the crude oil by centrifugation.

a) Principle:

The test sample (raw) is 100 ml in a spinning top. Water and sediment are separated by centrifugation.

(b) Apparatus:

- KOKUSAN centrifuge (Japan).
- Centrifuge tubes.

Chapter IV: Calculation, Results and Discussions



Figure IV.5 : Tubes à centrifuger ASTM.

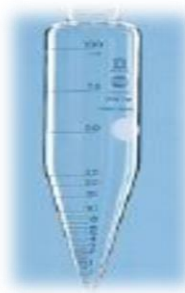


Figure IV.6 : Centrifugeuse.

c) Reagent:

- Sample to be analysed (crude oil) .
- Distilled water.

d) Procedure:

- In 100 ml ASTM tubes, insert 100 ml of crude oil for each tube .
- Fill another tube with distilled water .
- The 4 tubes were placed in the centrifuge in an opposite manner and allowed to centrifuge for 20 minutes at a speed of 1200 rpm .
- Once the centrifuge velocity begins to decrease, remove the sample from the centrifuge and record the volume of the deposit formed at the bottom of the tube.

e) Expression of Results:

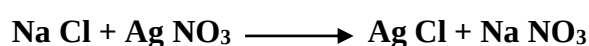
We do our reading directly on the ASTM centrifuge tube and the content will be given as a percentage.

IV.1.1.4. Salinity:

During drilling, a considerable amount of salt water is recovered first. As a result, oil always contains as low a level of salt as it is, but always present, which cannot be neglected at the risk of harming facilities. The results are expressed in mg of NaCl/ liter of crude or as a percentage. Salinity is determined according to the following standards: ASTM D 3230.

a) Principle:

The purpose of measuring salinity is the determination of chlorides in petroleum products, using the Mohr method which is based on the principle of salt neutralization (NaCl) by silver nitrate, according to the following reaction:



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(b) Apparatus and Reagents:

- A chloride ion meter.
- beakers.
- A 100 ml test piece.
- A magnetic stirrer.
- Silver nitrate (AgNO_3) to 0.05 N
- Demulsifier at 50 ppm.
- Potassium chromates (color indicator).

(c) Apparatus:



Figure IV.7: Salinity measurement assembly.



Organic phase (Crude oil)

Aqueous phase
(Water+Salt)

Figure IV.8: Dissociation of salt in crude.

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d) Procedure:

- Take 100 ml of crude in spinning tops, add 100 ml of the 50 ppm demulsifier for each of them, let them shake for 20 min, and after shaking let them settle .
- Take 20 ml of water from the bottom of each top and pour it into beakers, add 3 drops of potassium chromate (yellow) then put magnets inside .
- Dose with silver nitrate to 0.05 N until the yellow colour changes to a very low brownish hue.

e) Expression of results:

The chloride content will be given in milligrams/liter by the expression:

$$C (Cl) = V \times N \times A \times 1000 \times D / PE \quad (IV.2)$$

V: Volume in ml of the silver nitrate solution used.

N: Normality of silver nitrate solution .

A: Atomic mass of the chlorine ion 35.457 g/mol .

D: Dilution factor .

PE: Test sample volume used.

IV.1.2. Water testing:

In order to ensure the suitability of the water used for the washing of the crude oil before desalination, a series of analyses is carried out, and for a good follow-up, at each desalination stage a sample sample is checked and then analysed .

IV.1.2.1.pH:

Measuring the pH of a solution either before treatment or after gives us information about the acidity or alkalinity of the medium. If the pH is greater than 7, it is a basic solution, if it is less than 7, the solution is acidic, and if it is equal to 7, the solution is neutral .

a) Principle:

Measure the pH of the water by dipping the pH meter electrode into a 50 or 100 ml Erlenmeyer or beaker of this water. The result is displayed directly on the device. These measurements are made at water temperatures of 20 °C, which is a condition of pH meter operation.

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IV.1.2.2. Conductivity:

The conductivity of water allows the estimation of the chemical composition and the ion concentration (salts) of a solution.

a) Principle:

Conductivity measurement is based on the same principle as pH, using a conductivity meter at 20 °C.

(b) Apparatus and Reagents:

- KOKUSAN pH meter (Japan).
- DDK-TOA-Corporation CM-30G conductometer (Japan).
- Water to be analyzed.
- Beakers.
- Distilled water.



Figure IV.9: Conductometer (left). pH meter (right).

IV.1.2.3. Salinity:

The water contains chlorides in very close proportion, their contents increase during treatment, and at each exit of the desalination stage the water is extracted and analyzed.

a) Principle:

Chlorides are supplied by a solution called AgNO_3 , with a colored potassium chromate ($\text{K}_2\text{Cr}_2\text{O}_4$) indicator.

b) Procedure :

- Prepare solutions with the following dilutions :

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Table IV. 1: Dilutions performed for solutions.

Solution	Washing water	Water outlet 2 nd desalter	Outlet water 1 st desalter
Dilution factor	20	100	200

- Take 5 ml of the solutions.
- Add a few drops of a potassium chromate solution that is a colored indicator .
- Titrate with AgNO₃ solution (0.05 N) until a brick red color appears.

c) Expression of results:

The chloride content of the water will be given in mg/liter of crude, calculated by the expression.

$$N_1 * V_1 = N_2 * V_2 \quad (IV.3)$$

Measurements of the operating parameters of a unit constitute a very valuable set of information for a behavior study or analysis of a phenomenon. Generally, the method used in an experimental study is to carry out a series of experiments carried out according to a predetermined design. It is clear that this approach is very difficult to apply to the experimental study of an industrial production unit such as the one being studied here. The approach adopted in this study is therefore to exploit the data of the parameters recorded daily from January to May where there are large variations due to operating constraints.

Results and Discussions

IV.1.Data collection:

Every day we attended the sampling of the input/output of the two desalination stages as well as other points, and each time we were offered the opportunity we ourselves carried out analyses for the determination of the different physic-physical parameters samples taken at train 10.

IV.1.1. Physic-chemical properties of wash water (Miopliocene):

Table .IV.2: Wash water pH and conductivity analyses:

Sample	pH	Conductivity (ms/cm)
Inlet 1 st desalter	5.30	/
Exit 1 st desalter	5.77	11.56
Exit 2nd desalter	5.69	5.16
Output 2nd The stabilization column	6.24	/

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We noted from the conductivity values that the conductivity increases during processing, meaning that the salt content in the crude oil decreases. Because the conductivity varies according to the salinity, the more salts the water contains (ions: Na^+ , Cl^- , Mg^+ , Ca^{2+}) the more it is conductive of the electric current. The pH values, tells us about the acidity or alkalinity of the water used for the washing of the crude, we notice that during the treatment the pH decreases so the water becomes acid, which causes the increase of ions $[\text{H}_3\text{O}^+]$, which means an increase in the rate of salts in the discharge water at the outlet of the desalination stages.

IV.1.2. Crude oil viscosity analysis results at different temperatures:

Table .IV.3: Viscosity of crude oil at different temperatures.

DATE	T (°C)	20 °C	37.8 °C	40 °C
20/03/2023	9 (cSt)	4.13	2.75	2.75

Table.IV.4: Crude oil and water density.

DATE	Sample	Crude oil	Water
20/03/2023	density	0.8107	1.002

We noted from the viscosity and density values obtained that Ourhoud's crude is a light, therefore of good quality.

IV.1.3. BS&W analysis results and inlet/outlet salinities of the two desalters:

Salinity analyses and BS&W were taken for the period from (23/02/2023) to (23/03/2023), and the mean and represented in the table below.

Table.IV.5: Analysis of the BS&W and salinity of the desalination unit.

DATE	Input 1st desalter train 10		Exit 1st desalter train 10		Exit 2 Train 10 desalter	
	BS&W (%)	Salinity(mg/l)	BS&W (%)	Salinity(mg/l)	BS&W (%)	salinity(mg/l)
23/02/2023 23/03/2023	0.1356	64.8965	Traces	7.0689	Traces	2.3793

Based on the BS&W and salinity analyses, we noted a reduction in water quantity and sediment and a decrease in salinity after each desalination stage.

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IV.2. Calculation of raw-water flows at inlet 1/2nd desalter:

To make a material balance we took the flows for crude oil and water from the period from (23/02/2023) to (23/03/2023) we took their average and the results are represented in the table below.

Table.IV.6: Raw water flows of the desalination unit.

	Raw Flow Inlet 1 st Desalter Q_b (m ³ /h)	Quantity of water entering the 1 st Desalter Q_{wext} (m ³ /h)	Input oil flow rate 1 st Desalter Q_h (m ³ /h)	Wash water flow rate Q_w (m ³ /h)	Wash water rate X (%)
Mean	454.07	0.32	453.75	16.69	3.67

With :

Q_b value read on flow meter.

$$Q_{wext} = (BS\&We * Q_b)/100$$

$$Q_h = Q_b - Q_{wext}$$

Q_w value read on flow meter

$$X = Q_w * 100 / Q_b$$

IV.2.1. Material balance of the desalination unit:

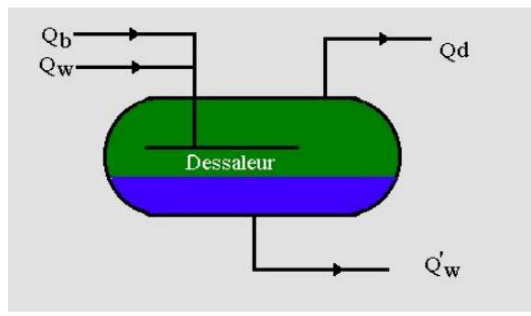


Figure IV.10: Desalting material balance.

With :

Q_b : Rate of crude to be desalinated.

Q_w : Flow of washing water.

Q_d : Flow rate of desalinated crude.

Q'_{w} : Drain water flow .

Q_{wext} : Water flow in desalinated crude.

$$Q_T = Q_b + Q_w.$$

$$Q_b + Q_w = Q_d + Q'_{w} \dots (1)$$

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According to the flow calculation table:

Table IV.7: Values of material flow rates of the desalination unit.

Flows	Q_b	Q_{west}	Q_h	Q_w
Values (m ³ /h)	454.07	0.32	453.75	16.69

Calculation of the quantity of desalinated crude:

$$Q_d = Q_b - Q_{west} + Q_d \cdot (BS \& Ws / 100)$$

$$Q_s = Q_b - Q_{west} / 1 - (BS \& Ws / 100)$$

$$Q_d = 453,8 \text{ m}^3/\text{h} \quad (\text{IV.4})$$

The quantity of purge water is given by:

$$Q'_w = Q_b + Q_w - Q_d = 454,07 + 16,69 - 453,8.$$

$$Q'_w = 16.96 \text{ m}^3/\text{h} \quad (\text{IV.5})$$

We have noticed according to the law of mass conservation that the quantity of purge water of the first desalter is greater than the quantity of wash water of the second desalter. This inequality due to the training of water droplets that are trapped in the crude with the washing water. The role of dilution water is to wash the crude, and this is done by migration of the saltiest water droplets in the crude to the less salty dilution water and for a better desalination several parameters that come into play (temperature, electric field, ...etc.) .

IV.2.2.Salinity balance of the desalination unit:

To make a salinity balance we took the results of salinity analyses and the flows for crude and water from the period from 20 March to 20 April 2023, we took their average and the results are represented in the table below.

Table.IV.8: Analyses of raw water salinity.

Water			Crude oil		
Salinity (mg/l)		Flow (m ³ /h)	Salinity (mg/l)		Flow (m ³ /h)
Entry 2 nd desalter	Exit 1 st desalter		Entry 1 st desalter	Exit 2 nd desalter	
1551.6	8411.8	16.69	232.23	8.76	454.07

According to the Mass Conservation Act:

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$$\sum \text{Incoming Flows} = \sum \text{Outgoing Flows}.$$

$$Q_b.S_{be} + Q_w.S_{we} = Q_w.S_{ws} + Q_b.S_{bs}$$

$$Q_b.S_{be} + Q_w.S_{we} = (454,07 \times 232,23 + 16,69 \times 1551,6) \cdot 10^{-3} = 131,34 \text{ kg/h.}$$

$$Q_w.S_{ws} + Q_b.S_{bs} = (454,07 \times 8,76 + 16,69 \times 8411,8) \cdot 10^{-3} = 144,37 \text{ kg.}$$

With:

S_{be} : crude salinity at the inlet (mg/l).

S_{bs} : output crude salinity (mg/l).

S_{ws} : salinity of wash water at inlet (mg/l).

S_{we} : salinity of wash water at outlet (mg/l).

We noted from our results that the value of the salinity balance for the wash water is close to that of the crude, and this difference is due to various errors such as :

- Manipulation errors: sampling, reading, accuracy, etc.
- Hardware errors: Hardware infidelity, instrumentation and regulation errors .

IV.2.3. Monitoring of salinity in the Central Processing Facilities (CPF) system :

In order to evaluate the effectiveness of our treatment process, salinity monitoring was carried out, the results of salinity analyses for the period 23 February to 23 March 2023 are presented in Table IV.8.

Table .IV.9: Follow up of analyses of the salinity of crude oil in the CPF.

Sample	CPF Entry	Output 1 st Separator	Exit 2 nd Separator	Entry 1 st desalter	Exit 1 st desalter	Exit 2 nd desalter
Salinity (mg/ l)	7956	3435.3	1345.7	232.23	24.64	8.76

Table IV.10: Monitoring of the salinity of wash water.

Sample	Salinity (mg/l)
Entry 2 nd desalter	1551.6
Exit 2 nd desalter	2583.2
Exit 1 st desalter	8411.8

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We have noticed from the results of analyses of the salinity of crude oil, that it decreases at the exit of each installation, on the other hand compared to the water of washing the salinity increases during the treatment, therefore the dilution water washes the crude and carries with it the salts contained in the crude.

IV.2.4. Calculation of system efficiency:

IV.2.4.1 Calculation of desalination unit efficiency:

The calculation of the mean salinity of the desalination unit, for the period from 23 February to 23 March 2023.

Calculation of the efficiency:

$$\text{Eff} = (\text{Se} - \text{Ss}) \times 100 / \text{Se} \quad (\text{IV.6})$$

The results are shown in Table IV.10.

Table IV.11: Calculation of the efficiency of the two desalters.

	1 st desalter			2 nd desalter			Total Efficiency EffT (%)
	Salinity (mg/l)		Efficiency Eff1 (%)	Salinity (mg/l)		Efficiency Eff1 (%)	
	Entry (Se)	Exit (SS)		Entry (Se)	Exit (SS)		
Medium	232.23	24.64	86.19	24.64	8.76	63.81	96.22

We noted from the desalter efficiency values that the bulk of the salt is removed in the first desalter, and the remainder is removed in the second desalter, because the charge at the entrance of the first desalter is saltier than that of the second desalter.

IV.2.4.2 Calculation of the total efficiency of the CPF:

We have done the analyses of the salinity of the crude at the inlet/outlet of the CPF in order to determine the total efficiency of the plant, the results are represented in the following

Table IV.12 :

Table IV.12: CPF salinity analyses.

Analysis	Entry CPF	Exit CPF	Efficiency (%)
Salinity (mg/l)	7956	4	99,94

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Ourhoud's CPF crude is of excellent quality, which means that the salts contained in the crude coming from the wells are almost completely eliminated with an efficiency of 99.94%, and at the exit a crude that meets the standards ready to ship .

IV.2.5. Calculation of the rate of settling of water droplets in the desalter:

According to the flow rate (Reynolds number) we have two laws for the calculation of the rate of settling which are given by the following formulae:

Table IV.13: Rate of settling as a function of flow rate.

Flow regime	Reynolds number.	Settling velocity
Laminar	$Re < 2000$	Law of Stocks: $V_d = \left(\frac{1}{18} \cdot g \cdot \frac{(d_d - d_c)}{d_c} \cdot \frac{D^2}{\vartheta} \right)$
Turbulent	$Re > 3000$	Newton's law: $V_d = \left(0,33 \cdot D \cdot g \cdot \frac{(d_d - d_c)}{d_c} \right)^{1/2}$

With:

D_d : Density of the dispersed phase (water).

D_c : Density of the contained phase (crude oil) .

G : Gravity acceleration in (m/s²).

V_d : Settling speed in (m/s) .

D : Diameter of the water particle in (m) .

ϑ : Kinematic viscosity of crude in (m²/s).

The particle diameter is determined from Table I.1.

For our case $X = 3.67$ %, and from table I.3 we find $D = 8.08 \cdot 10^{-5}$ m.

To perform these calculations, we proceed as follows :

The speed is fixed provisionally and after calculating the rate of settling, it is checked whether the calculated speed corresponds to the supposed speed.

So:

1) Assuming a turbulent diet.

•Determination of crude viscosity at 82°C

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This is impossible to determine at the 82°C temperature at the Ourhoud laboratory level.

The method used for determination of viscosity at 82°C consists of:

- Take viscosity at 20°C and 37.8°C at the Ourhoud laboratory that match

$\vartheta = 4,43 \text{ cSt à } 20^\circ\text{C}$ et $3,05 \text{ cSt à } 37,8^\circ\text{C}$.

Where the GROSS relation is used:

$$\log \vartheta_{t1}/\vartheta_{t2} = \log t1/t2 \quad (\text{IV.7})$$

The “R” coefficient is determined as:

$$\log \vartheta_{t1}/\vartheta_{t2} / \log t1/t2 \Rightarrow R = \log (4.43 / 3.05) / \log (37.8 / 20) = 0.5863.$$

Therefore, the viscosity of the crude at the desalination temperature will be:

$$\log \vartheta_{t1} / \vartheta_{t2} = R \log (t2 / t1).$$

$$\log \vartheta_2 = \log \vartheta_{t1} - R \log (\vartheta_{t2} / \vartheta_{t1})$$

$$\log \vartheta_{82} = \log(4.43 - 0.2794) \log(82 / 20)$$

$$\vartheta_{82} = 1.936 \text{ cSt (IV.8)}$$

•Density determination at 82°C:

The method used for determining the density at 82°C of oil consists of :

-determine by analysis the density of the continuous phase at 20°C temperature $d_{20}^4 = 0.808$.

- Density at any temperature is given by the following formula:

$$d_t^4 = d_{20}^4 - \alpha (t-20) \quad (\text{IV.9})$$

With

α : Coefficient characterizing the variation of density as a function of temperature.

$$\alpha = 0,001828 - 0,00132 (d_{20}^4) \quad (\text{IV.10})$$

The crude density is determined by:

$$\alpha = 0,001828 - 0,00132 (0,808).$$

$$\alpha = 7,61. 10^{-4}$$

$$d_{82}^4 = 0.808 - 7.61.10^{-4} (82 - 20) = 0.7608.$$

Same resonance for determination of water density at 82°.

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$$d^{20}_4 = 1,002$$

$$\alpha = 0,001828 - 0,00132(1,002)$$

$$\alpha = 5,05 \cdot 10^{-4}$$

-Water density will be equal to:

$$d^{82}_4 = 0,9706$$

The results are summarized in Table IV.13 below :

Table.IV.14: Viscosity and density of both phases at operating temperature.

Temperature (C°)	d_c	d_d	η (cSt)
82	0.7608	0.9706	1.936

Thus, the decanting rate according to equation (4) will be:

$$V_d = \left[0,33 \cdot 8,08 \cdot 10^{-5} \cdot 9,81 \cdot (970,6 - 760,8) / 760,8 \right]^{1/2} = 8,49 \cdot 10^{-3} \text{ m/s}$$

$$V_d = 8,49 \cdot 10^{-3} \text{ m/s}$$

Checking the flow rate:

$$Re = (V_d \cdot D) / \eta \quad (IV.11)$$

$$Re = (V_d \cdot D) / \eta = (8,49 \cdot 10^{-3} \cdot 8,08 \cdot 10^{-5}) / 1,936 \cdot 10^{-6} = 0,35$$

$Re < 3000 \rightarrow$ Diet is not turbulent.

2) Assuming the diet is a laminar diet .

Thus, the decanting rate according to equation (3) will be:

$$V_d = (1/18) \cdot 9,81 \cdot (970,6 - 760,8) (8,08 \cdot 10^{-5})^2 / (760,8 \times 1,936 \cdot 10^{-6}) = 5,06 \cdot 10^{-4} \text{ m/s}$$

$$V_d = 5,06 \cdot 10^{-4} \text{ m/s}$$

Checking the flow rate:

$$Re = (V_d \cdot D) / \eta.$$

$$Re = (V_d \cdot D) / \eta = (5,06 \cdot 10^{-4} \cdot 8,08 \cdot 10^{-5}) / 1,936 \cdot 10^{-6}$$

$$Re = 0,0211.$$

$Re < 2000 \rightarrow$ Laminar diet.

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Thus: The initial rate of decantation is the appropriate one.

IV.2.6. Calculation of the settling time of water droplets in the desalter:

The settling time can be calculated by the following formula:

$$T_d = L_1 / V_d \quad (IV.12)$$

Where:

T_d : settling time (mn) .

L_1 : distance between the low electrode and the interface ($L_1=0,86$ m).

V_d : settling speed (m/s). So:

$$T_d = 0,86 / 5,06 \cdot 10^{-4} = 28,32 \text{ mn}$$

$$T_d = 28,32 \text{ mn} \quad (IV.13)$$

To prevent the water from being drawn apart with the desalinated crude oil, the settling time must be greater than the residence time.

IV.2.7. Calculate the residence time:

Residence time is determined by the relationship:

$$T_s = V / Q_T \quad (IV.14)$$

Where:

T_s : residence time (mn) .

V : volume of desalter (m^3) .

Q_T : density flow of the charge (m^3/h).

$$Q_T = Q_b + Q_w$$

$$Q_T = 454,07 + 16,69 = 470,74 \text{ m}^3/h.$$

Calculation of desalter volume:

$$V = V_1 + V_2$$

With :

V : volume of desalter (m^3).

V_1 : volume of the cylindrical part of the desalter (m^3).

V_2 : volume of two hemispheres (m^3).

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Such as:

$$V_1 = \pi R^2 L \quad (IV.15)$$

$$V_2 = 4\pi R^2 h \quad (IV.16)$$

Hence:

$$V_1 = 70,65 \text{ m}^3 ; V_2 = 7,06 \text{ m}^3.$$

$$V = 77,71 \text{ m}^3 \quad (IV.17)$$

Thus:

$$T_S = 77,71 / 470,74 = 10,38 \text{ mn.}$$

$$T_S = 9.90 \text{ mn} \quad (IV.18)$$

According to the calculations we have found a settling time greater than the residence time, we can say from the results that there is no drag of water with the desalinated crude.

IV.2.8. Calculation of the electric characteristics of the desalter:

The electrical characteristics of the desalter allow us to estimate the functioning of the desalter. For the desalter to function properly, the electric field (E) between the electrodes must be lower than the critical field (EC).



Figure .IV.11: The electrodes inside the desalter.

IV.2.8.1. Calculation of the electric field between two electrodes:

$$E = U/L \quad (IV.19)$$

Where :

E: electric field between the electrodes (V/cm) .

U: current voltage (U = 20000 V).

L: distance between electrodes (L = 20 cm).

So:

$$E = 20000 / 20 = 1000 \text{ V/cm.}$$

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$$E = 1000 \text{ V/cm} \quad (\text{IV.20})$$

IV.2.8.2. Calcul du champ critique:

$$(\text{IV.21}) E_c = A \cdot \sqrt{\frac{2 \cdot \delta}{\varepsilon \cdot D}}$$

Where:

δ : Surface tension between water and oil in (g/cm²).

ε : Dielectric coefficient .

D: diameter of the water droplet in (cm).

A: coefficient of proportionality.

Is:

$$D = 8,24 \cdot 10^{-5} ; m = 8,24 \cdot 10^{-3} \text{ cm}; \varepsilon = 16 \text{ et } \delta = 15 \text{ g/cm}^2.$$

X = wash water rate (X = 3.67% vol).

According to curve.I.5 of (A = f (X)), we derive the value of the coefficient of proportionality (A).

So, for X = 3,67 % $\rightarrow$ A = 380.

So:

$$E_c = 380 \cdot \sqrt{\frac{2 \times 15}{16 \times 2,28 \cdot 10^{-3}}} = 5401,44 \text{ V/cm.}$$

$$E_c = 5401,44 \text{ V/cm.} \quad (\text{IV.22})$$

From the calculations we found that the electric field (E) between the electrodes is less than the critical field (EC). So our desalter works in an electrically suitable way.

IV.2.9. Calculation of theoretical and experimental efficiencies of the desalination unit:

The efficiency of the desalter and that of the desalination (theoretically estimated efficiency) are the parameters that condition the optimal yield of the desalter. These two terms can be expressed mathematically according to the different parameters involved in desalination.

$$A = \frac{Z \cdot (S_e + X S_w / 100)}{Y + X}. \quad (\text{IV.23})$$

Where :

A: Optimum theoretical salt content of the crude at the outlet of the desalter measured in mg/l.

Se: Salt content of the crude oil at the entrance to the desalter measured in (mg/l).

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Sw: Salt content of water injected in (mg/l).

Y: Water content of the crude oil entering the desalter .(%)

X: Amount of water injected relative to crude oil measured in .(%)

Z: Water content of the crude at the outlet of the desalter.(%)

The starting point is:

$$S_e = 232,23 \text{ mg/l.}$$

$$S_w = 1551,6 \text{ mg/l.}$$

$$X = 3,67\%.$$

$$Y = 0,07\%.$$

$$Z = 0,011 \text{ \%}.$$

$$A = (0,011 (232,23 + (3,67 * 1551,6) / 100) / 0,07 + 3,76 = 0,85 \text{ mg/l.}$$

The desalter efficiency shall be expressed as follows:

$$E_{ffT} = (S_e - S_s) \times 100 / S_e \quad (\text{IV.24})$$

Where:

EffT: Experimental effectiveness of the desalination unit .

Se: Salt content of the crude at the entrance of the desalter .

Ss: Salt content of the crude at the exit of the desalter .

Based on the desalter efficiency table:

$$E_{ffT} = (232,23 - 8,76) \cdot 100 / 232,23 = 96,22 \text{ \%}.$$

$$E_{ffT} = 96,22 \text{ \%}.$$

The theoretical effectiveness of desalination is given by the following formula:

$$E_p = (S_e - S_s) \times 100 / S_e - A \quad (\text{IV.25})$$

$$E_p = (232,23 - 8,76) / (232,23 - 0,85) = 96,59 \text{ \%}$$

$$E_p = 96,59 \text{ \%}.$$

We have noticed that the value of the experimental efficiency of the desalter is close to that of desalination estimated theoretically, so we can say that our desalter has a good functioning from an efficiency point of view.

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IV.2.10. Comparison between the design and the actual desalter:

Table. IV.15: Comparison of Current Desalter Design Values.

Current	Design	Heights
Crude oil:		
-Density (API).	54	43
-Input salt content (mg/l).	352,925	232,23
-Output salt content (mg/l).	10,6	8,76
-Feed rate (m3/h).	481,2	454,07
Water:		
-Rate of washing water (% vol).	5	3,67
-Amount of demulsifier (ppm).	10	0
Desalter:		
-Operating pressure (bar).	31	22
-Operating temperature (°C).	110	82
-Maximum load loss (p) (bar).	1.00	0,5
-Efficiency(%).	95	96

We noticed from the current efficiency value that our desalter has a good efficiency, it is close to 96% with less salinity than that recommended by the design, In addition, this efficiency is achieved without the injection of demulsifier at the entrance of the desalter.

IV.3. Desalter parameter improvement test:

We noted from the history of the Ourhoud salinity analyses that in 2003 the salinity was 3 ppm, and in 2013 it was 270 ppm, and that the water content increases with the aging of the deposit as shown in the table and figure below.

Table. IV.16: Percentage of water in the reservoir by year.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Water (%)	0,5	4,78	13.56	19.96	21.42	26.3	31.84	32.18	34.51	39.3	42.41

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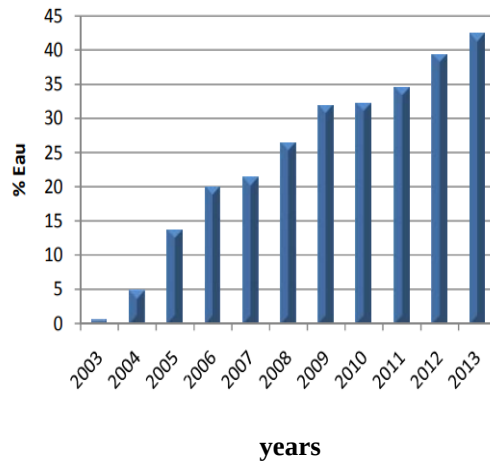


Figure.IV.12: Percentage of reservoir water change over time.

Based on the rate of the histogram, it was found that as the percentage of water in the reservoir continues to increase over the years, resulting in increased salinity in crude oil. Currently the desalter works in a suitable way and its efficiency is around 96%, but the problem is: will the desalter be able to continue in its approach with the current long-term parameters? For this purpose, a set of studies has been carried out on the parameters influencing the desalter in order to arrive at an effective and less costly remedy for a good functioning of the desalter.

IV.3.1. Increase in washing rate:

Based on the results obtained when we averaged the period from February 23 to March 23, 2023, we took values of efficiency and wash rates when the salinity at the inlet and the temperature are fixed. We obtained the values represented in the table below IV.16 .

Table.IV.17: Efficiency as a function of washing rate.

X (%)	3,016	3,483	3,569	3,594	3,6	3,681	3,633	3,696	4.024	4.106
E _{eff} (%)	90,55	90,55	90,46	91,42	92,18	92,59	94,69	94,73	94.81	96.40

From the table we see an increase in the desalter efficiency with the increase in the rate of washing water. So we can say that efficiency is improved with the increase in the rate of washing water, because it serves to dissolve the crystals of salts, and increase the force of attraction between the water droplets and the speed of coalescence and settling.

IV.3.2. Increasing the temperature of the desalter:

After consultation between the two departments, the operating department and the well department to limit well movements (opening/closing or adjustment on the production valve),

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on the day to perform the desalter performance test by increasing the desalination temperature, it was chosen to coordinate the conduct of the test on train 10 as the train on which the test will be conducted and the test temperature to be reached is 90°C.

The increase of the desalination temperature is achieved progressively by the increase of the setpoint of the temperature controller 20TIC010 which acts on the two valves 20TV010A and B without touching any other operating parameters either on the separation side or crude oil treatment. The increase in oven temperature was not necessary since the calories added to the heat was sufficient to stabilize the desired crude oil. The effect of temperature increase on the desalter was followed up by laboratory analyses and the results are shown in Table IV.17 below .

Table .IV.18: Analysis of salinity and BS&W input/output of desalination stages.

Date	1st desalter inlet		Entry 2 nd desalter		Exit 2 nd dessaleur	
	BS&W (%)	Salinity (mg/l)	BS&W (%)	Salinity (mg/l)	BS&W (%)	Salinity (mg/l)
23/03/2023	0.05	117	0.01	10	0	2

For the calculation of the residence time and the settling time we will need the material flows for the crude as well as for the washing water, and for this the results are represented in the following table:

IV.3.2. a) Summary table of material flow calculations:

Table. IV.19: Material flow rates at the entrance of desalters.

Date	Raw flow rate first desalter Q _b (m ³ /h)	Quantity of water input 1st desalter Q _{wext} (m ³ /h)	Input oil flow first desalter Q _h (m ³ /h)	Wash water flow rate Q _W (m ³ /h)	Wash water rate x(%)
23/03/2023	450	0.22	449.78	16	3.36

Table .IV.20: Material flows out of desalters.

Date	Output of desalinated crude oil Q _d (m ³ /h)	Quantity of purge water 2nd desalter Q _{w'} (m ³ /h)
23/03/2023	449.78	16.22

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IV.3.2. b) Calculation of the rate of settling :

For the calculation of the settling rate the viscosity values of crude oil and water at 90°C will be required, the results are shown in the following table:

Table .IV.21: Density and viscosity of both phases at 90°C.

Temperature (°C)	d_c	d_d	η (cSt)
90	0.7547	0.9666	1,834

According to the STOKES Formula we will have a speed equal to:

$$V_d = 1/18 \times 9,81 \times (966,6 - 754,7) \times (8,25 \times 10^{-5})^2 / (754,7 \times 1,834 \times 10^{-6})$$

$$V_d = 5,68 \times 10^{-4} \text{ m/s.}$$

Diet Check:

$$Re = V_d \cdot D/\eta = 5,68 \times 10^{-4} \times 8.25 \times 10^{-5} / 1,834 \times 10^{-6} = 0.025$$

$Re < 2000$ So the diet is laminar.

IV.3.2. c) Calculation of settling time:

$$T_d = L_1 / V_d$$

$$T_d = 0,86 / 5,68 \times 10^{-4}$$

$$T_d = 25,23 \text{ mn.}$$

IV.3.2. d) Calculation of desalination unit efficiency:

$$E_{ffT} = \frac{S_e - S_s}{S_e} \times 100$$

$$E_{ffT} = \frac{(117-2) \times 100}{117} = 98,29 \%$$

$$E_{ffT} = 98.29 \%$$

It should be noted that with the increase in temperature, the viscosity of the charge and its density decreases and both coalescence and settling speeds increase. In other words, the reduction of the forces opposed to the movement of the droplets having sufficient mass to descend by gravity towards the bottom of the desalter, dragging with them the salts, Hence the decrease in the salinity of the crude at the exit of the 2nd desalter, which reached 2 ppm, associated with other advantages:

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- Decrease in settling time from that calculated at 82°C .
- Improved desalter efficiency to 98.29%.
- No additional energy consumption for the oven .
- No consumption in addition to electricity for cooling from crude to storage .

Based on the results obtained, the desalter can be operated in the long term, with a yield higher than the current 96% yield.

General conclusion

General conclusion

The oil industry is a high-tech industry with expensive equipment and multidisciplinary skills. This is why it is necessary to preserve this equipment from the harmful effects of salts, such as corrosion, fouling of heat exchangers, loss of load in pipes, over-consumption of energy in the furnace, and a decrease in the quality of oil. It is with this in mind that we have contributed to the study of the desalination operation which is a very important stage of treatment because of its decisive role in the protection of the installations. Our study has provided answers to the questions raised in the problem raised during our internship in Ourhoud. From the analyses carried out on the dilution water it can be concluded that the water used for washing must be neutral and less salty than the crude oil for a better desalination of the crude oil. The amount of washing water at the entrance of the desalter is lower than that of the outlet, This inequality is due to the training of water droplets that are trapped in the crude oil with the washing water.

The qualitative evaluation of the desalination process, showed the conformity of ready-to-ship crude oil. Based on the calculations carried out, we found that the efficiency of the desalination unit of 96.22% is close to that theoretically estimated (96.59%), with an outlet salinity of 9 mg/l that meets specifications (< 40 mg/l). During this work we found that the residence time of the crude oil must be less than the settling time of the water droplets in the desalter, in order to avoid water being drawn into the desalinated oil; and that the electric field between the electrodes must be less than the critical field, for proper operation of one electric side. Based on the history of the deposit we opted for an improvement of the desalter parameters, to cope with the increase of water in the deposit over the years.

Based on calculations at the temperature (90°C) and the appropriate wash water rate, there is an increase in the settling rate due to:

- An increase in temperature that causes the viscosity of the contained phase to decrease, in other words a decrease in the forces opposing the displacement of droplets with sufficient mass to descend by gravity to the bottom of the desalter .
- Increasing the rate of wash water that increases the size of the water droplets, leading to an increase in the rate of settling .

General conclusion

In addition, the increase in the rate of settling decreases the transfer of salts dissolved in water with desalinated crude oil and consequently, decrease in salinity at the desalter inlet, which will then be able to stop the injection of the demulsifier at the Slugcatcher inlet, increase in desalination efficiency which reached 98.29% with an outlet salinity of 2 mg/l, and no overconsumption in addition to energy in the furnace and aero-refrigerators.

In perspective, we recommend a study on the installation of a pump that pushes more water flow for the washing of crude oil, and to overcome the pressure losses in the pipes, as well as a study on the installation of another water treatment unit, the increase in production water.

Appendix 1: Characterization of crude oil and dilution water by FTIR.

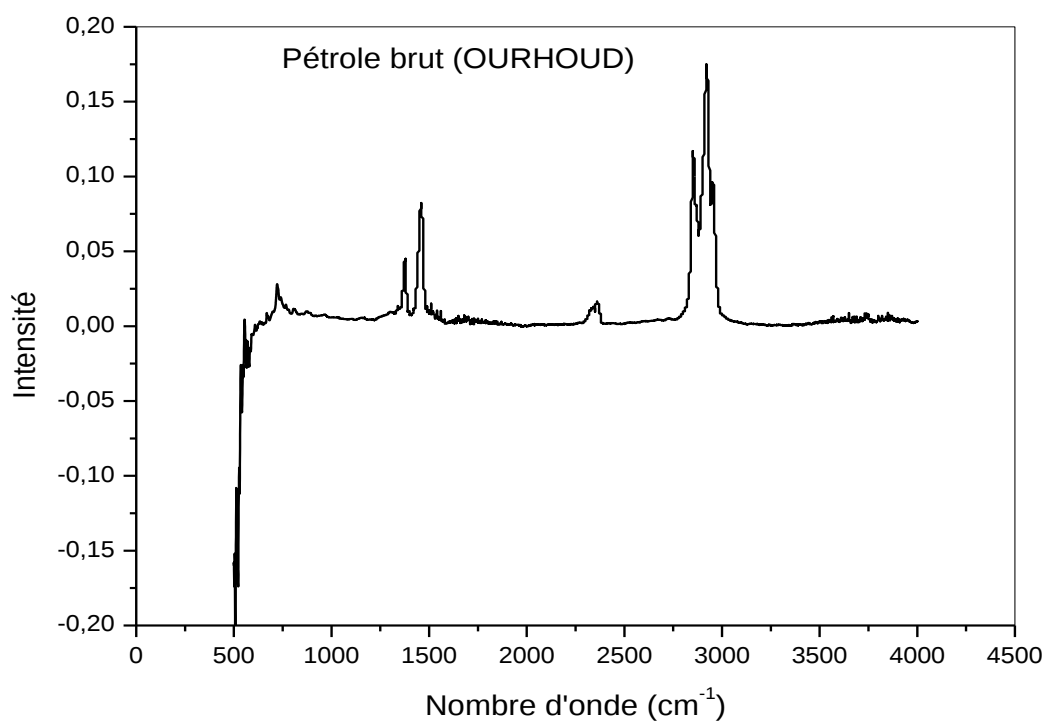


Figure A.1: Crude oil (OURHOUD) FTIR Analysis

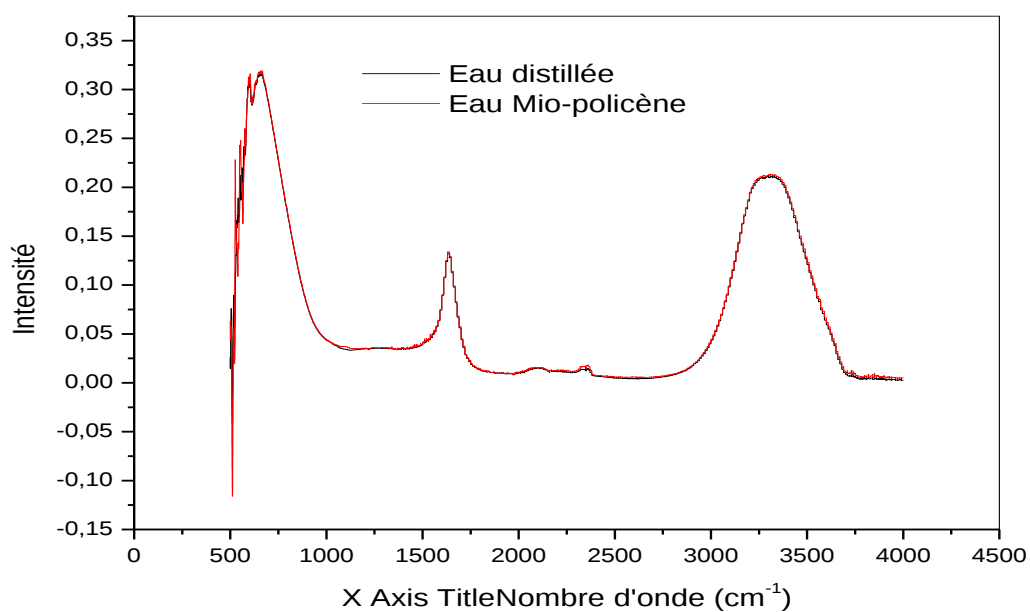


Figure A.2: FTIR of dilution water (Moi-policene), comparison with distilled water.

Appendix

Appendix 2: water, crude oil and demulsifier specifications.

Table 1. Mio-Policenene Water Analysis

Flow (m ³ /h)	3.5
Pressure (barg)	3.0
Calcium (mg/l)	277
Magnésium (mg/l)	111
Sodium (mg/l)	367
Chloride (mg/l)	669
Sulphate (mg/l)	828
Nitrate (mg/l)	23
Strontium (mg/l)	0.015
Barium (mg/l)	0.012
Bicarbonate (mg/l)	149
Iron (mg/l)	0.5
pH	7.8
TSS (mg/l)	< 1.0

This water also contains Sulfato-Reducing BSR bacteria: Up to 102 germs/ml

Table 2. Algerian crude oil specifications (OURHOUD) after desalting.

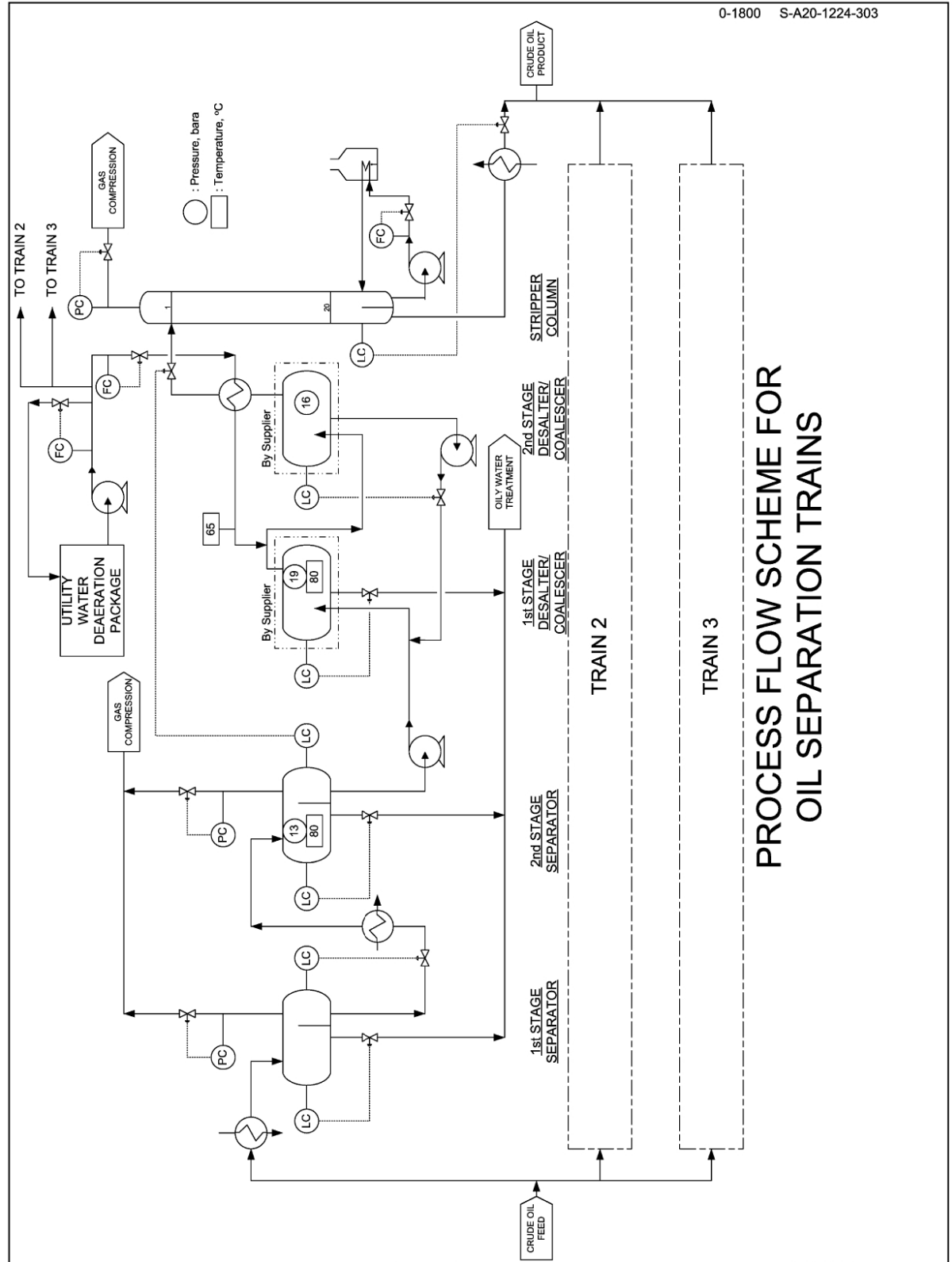
Parameter	Value
Density (g/cm ³) ASTM D1298	0.81
Viscosity at 37.8°C (Cst) ASTM D445	3.25
Gravity (°API) ASTM D1298	42.9
BS&W (vol. %) ASTM D96	0.05
RVP (psi) ASTM D323	8.88
Salt content (ppm) ASTM D6474	8.9
Total sulfur (% Wt) ASTM D4294	0.048
Total acid number (mg/Kg) ASTM D664	0.03
Asphaltene content (%Wt) ASTM D6560	0.06

Appendix

Table 3. Demulsifier specifications (NALCO - EC2016A).

PHYSICAL AND CHEMICAL PROPERTIES	
PHYSICAL STATE	Liquid
APPEARANCE	Clear Hazy Amber
ODOR	Aromatic
FLASH POINT :	10 °C PMCC
SPECIFIC GRAVITY	0.95 (15.5 °C)
SOLUBILITY IN WATER	Insoluble
VISCOSITY	88 cst (15 °C)
MELTING POINT ASTM D-97	-31.6 °C

Appendix 3: Process Flow Diagram of oil separation train (Train 10).



Appendix

Appendix4:

	Entrée 1er dessaleur train 10		Sortie 1er dessaleur train 10		Sortie 2eme dessaleur train 10	
Date	% Water	NaCl	% Water	NaCl	% Water	NaCl
2/23/23 4:00	0.1	56	TR	5		2
2/24/23 4:00	0.05	56	TR	8	TR	3
2/25/23 4:00	0.05	61	TR	7		2
2/26/23 4:00	0.1	64	0.05	10	TR	4
2/27/23 4:00	0.05	51	TR	5	TR	2
2/28/23 4:00	0.05	41	TR	3	TR	2
3/1/23 4:00	0.05	38	TR	4		2
3/2/23 4:00	0.05	85	TR	8	TR	2
3/3/23 4:00	0.05	36	TR	6	TR	2
3/4/23 4:00	0.05	63	TR	7	TR	2
3/5/23 4:00	0.1	78	TR	6	TR	2
3/6/23 4:00	0.1	78	TR	6	TR	2
3/7/23 4:00	0.05	58	TR	8	TR	2
3/8/23 4:00	0.1	79	TR	8	TR	2
3/9/23 4:00	0.05	71	TR	7	TR	3
3/10/23 4:00	0.1	97	TR	6	TR	2
3/11/23 4:00	0.1	86	0.05	14	TR	3
3/12/23 4:00	0.1	82	TR	8	TR	2
3/13/23 4:00	0.1	67	TR	5		2
3/14/23 4:00	0.1	79	TR	6	TR	2
3/15/23 4:00	0.05	67	TR	7	TR	2
3/16/23 4:00	0.05	58	TR	8	TR	3
3/17/23 4:00	0.05	66	TR	9	TR	3
3/18/23 4:00	0.05	61	TR	8	TR	3
3/19/23 4:00	0.05	57	TR	7		3
3/20/23 4:00	0.05	46		8		3
3/21/23 4:00	0.05	55	TR	6	TR	2
3/22/23 4:00	0.1	68	0.05	9	TR	3
3/23/23 4:00	0.05	78	0.05	6	TR	2

Appendix

Appendix5: PHYSICO-CHEMICAL CHARACTERISTICS BRUT FROM OURHOUD

CHARACTERISTICS	RESULTS
Density at 15°C	0.8112
°API	42.8
Kinematic viscosity in cSt at: 20.0 °C /68 °F 37.8 °C/100°F	4.43 3.05
Reid vapor pressure, Kg/cm2	0.70
Water content by extraction, %vol	Traces
Water and sediment content, BSW, %vol	Traces
Sulfur content, wt%	0.0511
Pour point, °C	-24
Flash point, closed cup, °C	< 15
Characterization factor, KUOP	12.25
Molecular weight g/mole	213
Superior calorific value, Kcal/Kg	11060