SHKAR QAIS SEDEEQ ALHABIB

OPTIMIZATION OF THE PRESSURE PROFILE FOR CENTRAL PROCESSING FACILITY USING PROMAX SOFTWARE

MASTER THESIS

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NEAR EAST UNIVERSITY

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DEPARTMENT OF PETROLEUM AND NATURAL GAS ENGINEERING

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Approval

We certify that we have read the thesis submitted by SHKAR QAIS SEDEEQ ALHABIB titled **"OPTIMIZATION OF THE PRESSURE PROFILE FOR CENTRAL PROCESSING FACILITY USING PROMAX SOFTWARE"** and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Applied Sciences.

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Declaration

I hereby declare that all information, documents, analysis, and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of the Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

SHKAR QAIS SEDEEQ ALHABIB

…../…../2023

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SHKAR QAIS SEDEEQ ALHABIB

Abstract

Optimization of the Pressure Profile for Central Processing Facility Using ProMax Software

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Pressure profile optimization of central processing facility (CPF) is a major tool to enhance the conditions and the properties of the crude oil to be exported. Crude oil treatment starts at CPF from in initial separation then continues through dehydration /emulsion treatment then if crude oil contains high salt content the feed stream should go through desalting process as well and final process is stabilization and sweetening to reduce both H_2S and raid vapor pressure (RVP) to allowable level, stabilization and sweetening is a dual process that take place at CPF which are responsible to control the levels of toxic gases which is main H_2S and light components to control RVP, stabilization and sweetening will take place only if the type of crude oil is a sour crude oil otherwise normal separation is enough for crude oil treatment, separating out H_2S from crude oil is vital because H_2S is main responsible for damaging equipment by causing a rapid and strong corrosion, at the same time H_2S is very toxic gas and cause a serious hazard for human, optimization is the main way to achieve correct stabilization and sweetening by improving pressure profile of the operating equipment , high sophisticated Promax simulator is used to perform modeling and simulation of different cases of pressure profile optimization using crude oil composition and feed operating parameters. The equation of state that used is Ping-Robinson equation to calculate required parameters. The results presented in this thesis for different cases of simulation show that the results of Case 1 are the best showing that the H_2S and RVP are at desirable levels at our plant.

Keywords: Pressure profile, optimization, central processing facility, Promax simulator, Ping-Robinson equation.

Özet

Yüzey Proses Tesisinde Basınc Profilinin ProMax Yazılmı ile Optimizasyonu

Shkar Qais Sedeeq Alhabib

M.Sc., Petrol ve Doğal Gaz Mühendisliği Bölümü
Ocak 2023, 94 sayfa

Merkezi İşleme Tesisi'nin basınç profili optimizasyonu, ihraç edilen ham petrolün koşullarını ve özelliklerini geliştirmek için önemli bir araçtır. Ham petrol arıtımı, CPF'de ilk ayırmadan başlar, daha sonra dehidrasyon / emülsiyon işleminden geçer, daha sonra ham petrol yüksek tuz içeriği içeriyorsa, besleme akışı da tuzdan arındırma işleminden geçmelidir ve son işlem, hem H_2S hem de RVP'yi izin verilen seviyeye düşürmek için stabilizasyon ve tatlandırmadır, stabilizasyon ve tatlandırma, CPF'de başlıça H_2S olan toksik gazların seviyelerini ve RVP'yi kontrol etmek için hafif bileşenlerin seviyelerini kontrol etmekten sorumlu olan ikili bir işlemdir, stabilizasyon ve tatlandırma sadece ham petrol türü ekşi bir ham petrol ise gerçekleşecektir, aksi takdirde ham petrol muamelesi için normal ayırma yeterlidir, H_2S'yi ham petrolden ayırmak hayati önem taşır, çünkü H_2S hızlı ve güçlü bir korozyona neden olarak ekipmanların zarar görmesinden ana sorumludur, aynı zamanda H_2S çok zehirli bir gazdır ve insan için ciddi bir tehlikeye neden olur, optimizasyon, işletme ekipmanının basınç profilini iyileştirerek doğru stabilizasyon ve tatlandırma elde etmenin ana yoludur, Yüksek sofistike Promax simülatörü, ham petrol bileşimi ve besleme çalışma parametrelerini kullanarak farklı basınç profili optimizasyonu durumlarının modellenmesini ve simülasyonunu gerçekleştirmek için kullanılır. Bu tezde farklı simülasyon durumları için sunulan sonuçlar, durum 1'in sonuçlarının fabrikamızda H_2S ve RVP'nin arzu edilen seviyelerde olduğunu gösteren en iyi sonuçlar olduğunu göstermektedir.

Anahtar Kelimeler: Basınç profili, optimizasyonu, merkezi işleme tesisi, Promax simülatörü, Ping-Robinson denklemleri.

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List of Abbreviations

API	American Petroleum Institute
ATM	Atmospheric
Bar	Metric system
Barg	Metric system gauge
BS&W	Basic Sediment and Water
C°	Degree Celsius
CO_2	Carbon dioxide
CCR	Central Control Room
CPF	Central Processing Facility
CRO	Control Room Operator
DSS	Distributed Control System
ESP	Electrical Submersible Pump
ESDV	Emergency Shut Down Valve
HP	High Pressure
H_2S	Hydrogen Sulfide
LCV	Level Control Valve
LP	Low Pressure
PCV	Pressure Control Valve
Psia	pound per square inch
PTB	Pounds of salt per thousand barrels of crude oil
RVP	Rate Vapor Pressure
SCF	Standard cubic foot

CHAPTER I

Introduction

Generally, oil wells produce a mixture of three phase oil, gas, water, and some small impurities such as sand. This mixture cannot be stored or exported because it is neither safe nor economical to transfer crude oil to refineries for refining or transferring the gas to consumers directly and without treatment.

Each unit in the refinery has its specifications and the feed to refinery should match the design specifications. Since oil wells produce toxic gas to protect the environment and the people from this toxic gas, we have to dispose of water produced with oil or toxic gases (H_2S) in economical and safe ways. To achieve the above target the well mixture should be properly processed in the field to obtain a product that is saleable in the market.

The function of oil and gas treatment plants is to separate gas and water from oil in economic and safe ways**.** Well mixture is collected from all wells in a large diameter manifold after that Well mixture is transferred to the plant for treatment purpose, initially Well mixture is heated up by passing through furnace to reduce viscosity and helping in releasing gases from oil (Arnold, and Stewart 2008).

After furnace Well mixture is sending to a mechanical separator/desalter/stabilizer to separate the gas and water in order to obtain a de gassed desalted and stabilized crude oil. Stabilized oil is sent to the storage tanks for export. While gas is being sent to the gas processing unit, as for the water it is injected again to the reservoir through Injection or disposal wells either for reservoir pressure maintenance or for disposal.

In general, each phase, oil, water, or gas requires special and additional processes to obtain a useful and saleable product**.** for the oil that contains a large quantity of water and salt this oil should pass through dehydration and desalting units for removing emulsion and excessive salt content.

If the oil contains large quantities of toxic gases (H_2S) and volatile substances, then stabilization and sweetening units will be necessary to remove high H_2S. The Gas separated from oil is transferred to the gas treatment plants for gas de-hydration and gas sweetening and finally sweet gas is compressed and sent to customers using such as power generation (Arnold, and Stewart 2008).

In normal daily operation oil samples are collected from different points in the plant, especially inlet and outlet feed. Samples will be analyzed in the laboratory to ensure the quality of the operations. Most important tests are BSW, API, salt content, H2S content and RVP, table 1 shows crude oil export specifications.

CPF is abbreviation of central processing facility that works to collect, treat, store, and export crude oil.

CPF consists of processing package (heater, heat exchanger, reboiler, stabilizer, pumps, storage tanks, flare package, export system) and utility package (utility water, air compressor, nitrogen generator, power generation).

All these units and equipment work together to achieve one objective which is processing well stream into some marketable products.

All the operations are controlled through Central control room (CCR) which is operated by DCS system, all the parameters such as pressure, temperature and flowrate are connected to the system through sensors and the controller inside DCS will take action depend on the pre-determined set points to keep the plant run in safe and smooth mode to get the required products (Arnold, and Stewart 2008).

Table 1.1: Crude oil export specifications

Specification	**Untreated**	**Treated**	**Measure unit**
H_2S content	>3000	<50	ppm
RVP	>10	<10	psi
Salt content	>10	<10	Ptb
BSW	>0.5	<0.5	%Volum

Hydrocarbons

Compounds having only carbon and hydrogen atoms.

Liquid Phase

Matter that is free flowing has volume but no shape. Liquid takes the shape of the container into which it is poured (Arnold, and Stewart 2008).

Crude

Crude oil contains hundreds of different compounds from the lightest Hydrocarbon Methane to heaviest asphaltic compounds and impurities like water, H_2S etc, The weight of a hydrocarbon depends on the number of Carbon atoms in one molecule of the compound (Arnold, and Stewart 2008).

- **Sour Crude:** It is a type of Crude with high concentration of H_2S.
- **Sweet Crude:** It is a type of Crude with very low concentration of H_2S.
- **Wet Crude:** Crude with large amount of water.
- **Dry Crude:** Crude with little or no water.
- **Light Crude:** Greater concentration of lighter HC and lesser concentration of heavier HC.
- **Heavy Crude:** Greater concentration of heavier Hydrocarbons and lesser concentration of lighter hydrocarbons.

  Figure 1 shows crude oil processing diagram.

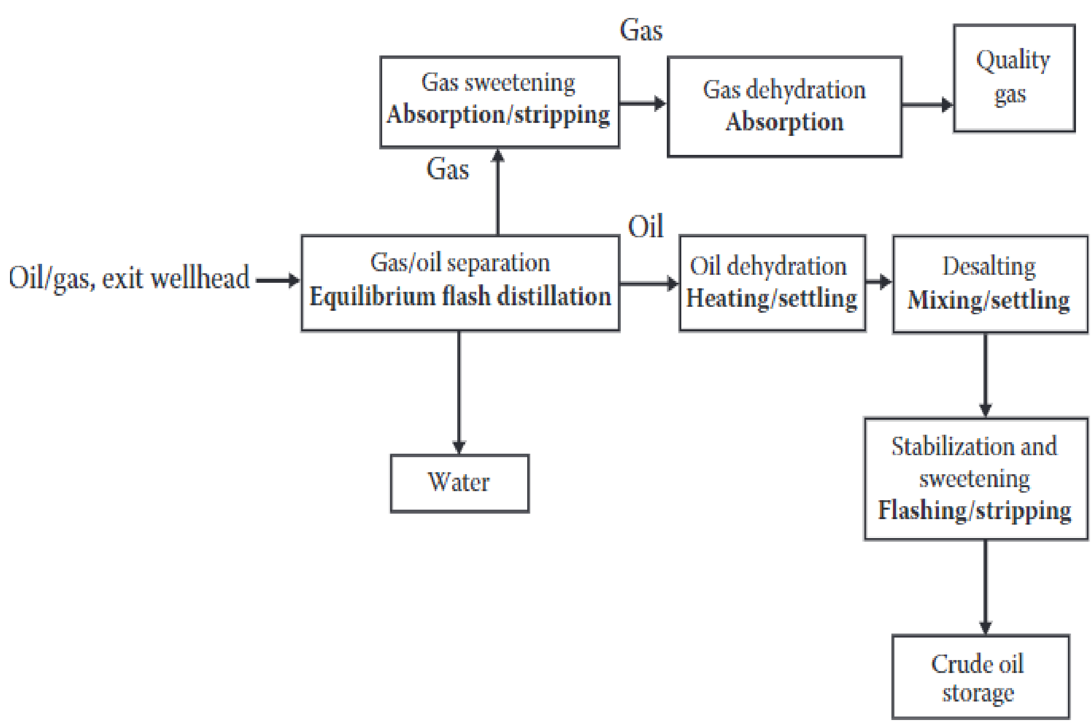


Figure 1.1: Crude oil processing diagram (Taqa, 2022).

Pressure profile optimization is the process of finding the best working pressure of the plant and to achieve this, crude oil is often sent and processed in a Crude Stabilization and Sweetening Unit To meet the H_2S or RVP crude sales specifications.

The selection of the best and correct process for stabilization and sweetening of crude oil is a critical aspect of overall central processing facility design.

The economic goal of Pressure profile optimization is to maximize recovery of stock tank oil while reaching vapor pressure and H2S desirable levels.

At present, there are several technologies available for crude oil stabilization and sweetening which include: stripping by nitrogen, column with a reboiler and sweet gas stripping.

Sometimes a combination of two technologies can also be used together at same time to provide the optimum result.

Problem Statement

CPF was designed to process 30000 bbl./day of crude oil but by expanding the field and drilling more wells the company attempts to increase daily production rate. This step brings a challenging task to the company to find a way to process more than 30000 bbl./day in the same processing plant with some changes in the plant. here it becomes must optimize the pressure profile to be able for processing more oil without any issues and safely to maintain the integrity of the plant.

Work Objective

Main objective of this work is to build a simulation model in Promax simulator to using the inlet oil composition and operating parameters of the plant equipment to play with operating pressure for different vessel at CPF to optimize pressure profile of the plant to achieve the following:

- **Crude oil stabilization**: Reduce H_2S to allowable level for storage purpose.
- **Crude oil sweetening**: Reduce RVP to allowable level for corrosion and safety purpose.

CHAPTER II

Literature Review

Crude Oil Processing

Separation of the well stream into individual phases is the first stage of crude oil treatment that takes place at the CPF. Separation needs three factors to be obtained which are difference in fluids density, immiscible fluids and retention time. The equipment used in this process called separator which is a mechanical vessel consist of several sections and parts to release gas and separate out water from crude oil in optimum range to maximize crude oil recovery. Free water is separated in conventional method by difference in density and gravity force (Lieberman, 2022).

If the water comes in the emulsion form, it is not easy to separate it and it should be passed through more processing stages which are:

- Heating the fluids to decrease the viscosity.
- Injecting chemicals to assist in the separation.
- Using electrical aids for coalescing process of the water drops.

Separators can be classified into main three classifications:

- By Mechanical Shape: Vertical, Horizontal.
- By phases: Two phases (gas and liquid), Three Phases (oil, gas, and water).
- By working pressure: Low pressure (10psi -225psi), Medium Pressure (230psi-700psi). High Pressure(750psi-1500psi).

There are many factors that affect the quality of the separation and the most important are:

- Working pressure.
- Working temperature.
- Retention time.
- Fluids composition.

For better understanding the separation process we have to know about the main three groups of compounds that create the crude oil as the following:

- Light component's: methane C1 and ethane C2.
- Medium component's: propane, butane, pentane, and hexane.
- Heavy component's: this group remains with crude oil which is heptane C7.

Our goal from the separation is to achieve the following points:

- Separate light gases from crude oil like C1 and C2.
- Increase the recovery efficiency of medium components.
- Keep heavy components in the crude oil (liquid phase).

To obtain above some of the medium components will escape with gas phase and to decrease this loss of precious medium component's and increase liquid recovery we have to use the following separation:

- Differential or enhanced separation.
- Flash equilibrium separation.

If the crude oil has the following physical properties, then it will consider a sweet crude oil and will go for storage and export after initial separation otherwise the crude oil will go for wet crude oil treatment and stabilization and sweetening to reduce the physical properties to economical range (Lieberman, 2022).

Physical properties are the following:

- BSW less than 0.5%.
- H_2S less than 500 ppm.
- Salt content less than 10 Ptb.
- RVP less than 10 Psi.

Retention Time

To ensure that the mixture of well stream has been reached to equilibrium there should be sufficient time for this mixture to stay in the separator to allow gas to be released and water to get separated (Lieberman, 2022).
retention time can be calculated from below equation:

$$\text{Retention time} = \frac{\text{separator volume}}{\text{flowrate in the separator}} \qquad (2.1)$$

From field experiments it has been discovered that the retention time is between 30 second and 3 minutes except if there is high foam or high CO_2 in this case retention time should be increased (Lieberman, 2022).

Table 2 shows the typical retention time for different types of crude oil:

Table 2.1: Retention time for different types of crude oil.

API (degree)	**Retention time (Minutes)**
35 +	0.5 -1
30	2
25	3
20 +	4+

Pressure Profile for the Separation

Usually, the well stream comes to the surface with high pressure from the reservoir which contains high quantity of dissolved gas. This high pressure should be reduced in stages and gradually to avoid losing light precious components with gas and obtain a stable oil (Lieberman, 2022).

- In the Figure below 2.1 we can find out the following points:
- Well effluent has 70 barg which reduced to 10.5 barg in first separation stage by releasing excessive gases.
- Then in second stage the pressure reduced from 10.5 brag to 3.5 brag by releasing another amount of gases without losing light components.
- Final stage which brought the pressure to 0.8 brag for exporting.

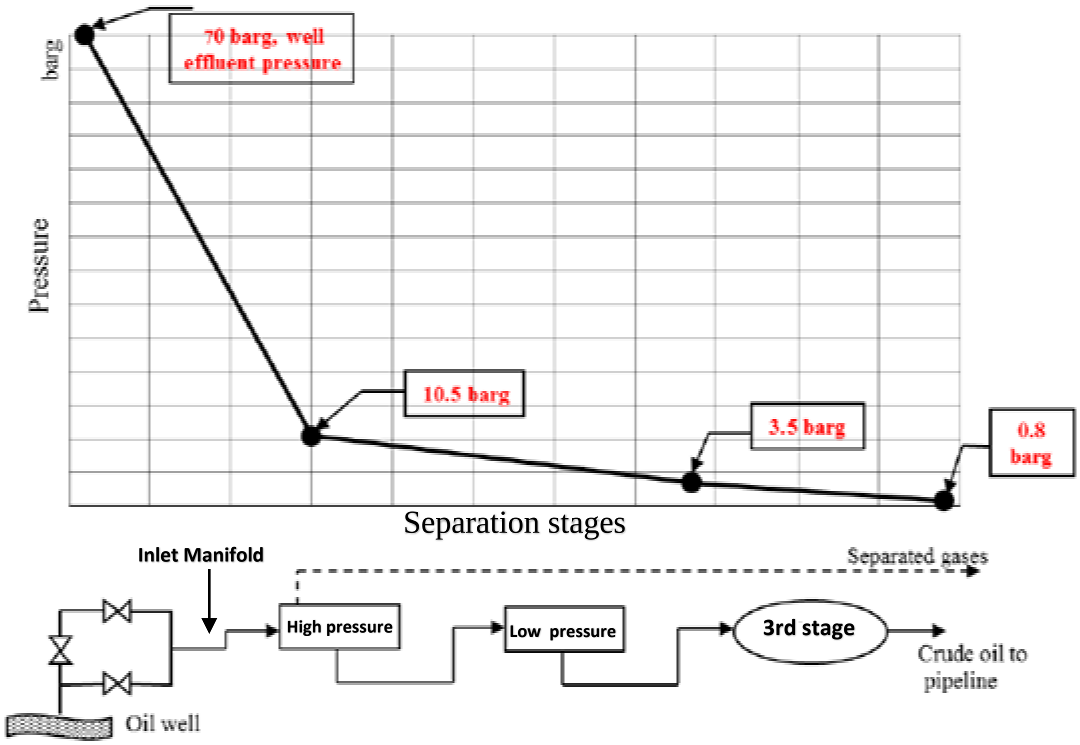


Figure 2.1: Pressure profile for the typical separation unit at CPF (Taqa, 2022).

Working Principle of a Horizontal Three-Phase Separator

The well streams from all wells are combined in one line called inlet manifold header which has a large diameter that collects the fluids from all wells and transfer to separator. Separators work on the principle that the three fluids have different densities, which allow them to segregate when moving slowly in the vessel. Gas on top, water on the bottom and oil in the middle of the vessel (Lieberman, 2022).

In the Figure 2.2 showing separation takes place inside the separator in the following steps:

- Fluids enter the separator and hit the inlet deflector with high pressure and high speed, here the deflector change the speed and direction of the fluids cause liquid drops to fall to the bottom due to the gravity and gas to the top of the vessel.
- Fluids will continue to move in the vessel slowly to allow more gas to be separated and at the same time separate water from oil by gravity and bouncy force.
- Water will accumulate at the bottom and can't overflow over the weir where it exists from the water outlet at the middle of the vessel.

- Oil is accumulating over water overflowing over the weir to oil section then finally exists from oil outlet to the next stage of separation.
- Gas at the top of the separator will go through mist extractor to remove any drops of oil that escaped with gas phase then exits from gas outlet to the header, Figure 2.2 shows three phase separator (Lieberman, 2022).

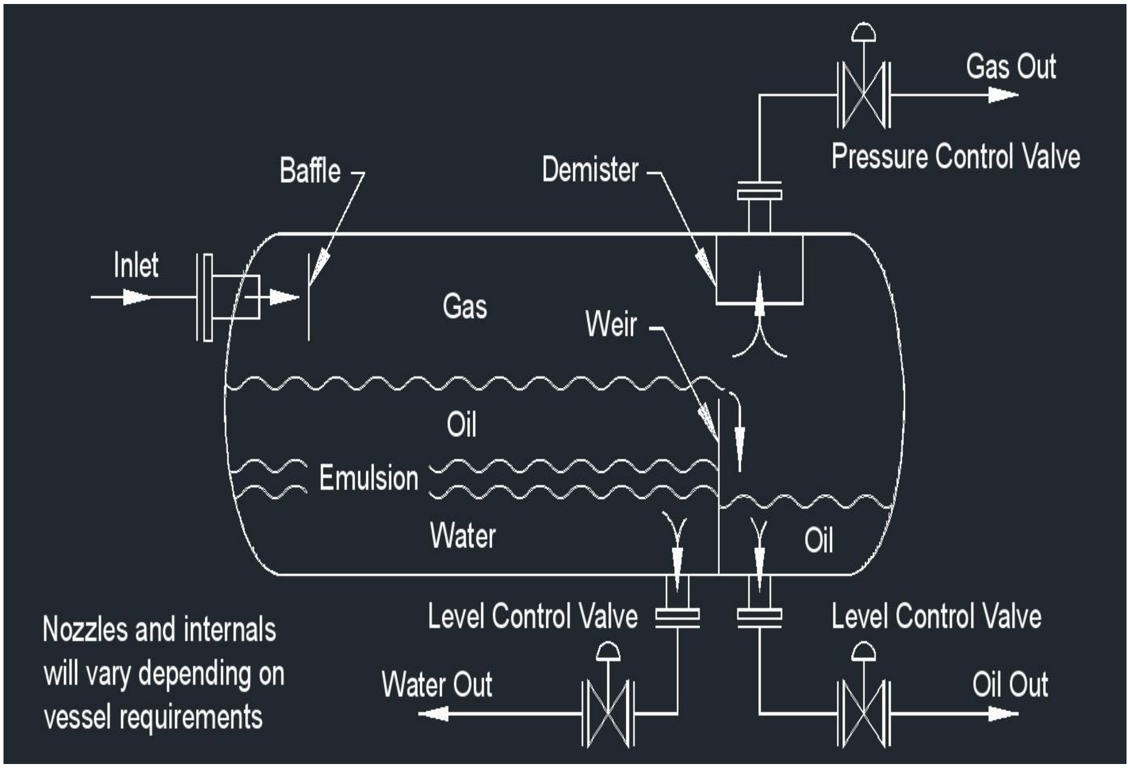


Figure 2.2: Three phase separator (Didactic, 2019).

Enhancing Separation Process

There are three main factors that can be adjusted to improve the quality of the separation:

- **Temperature**: As the temperature increases, the amount of gas that separates increases and the amount of oil that can be obtained decreases.
- **Pressure**: The higher the pressure, the greater the amount of oil that can be obtained and the less gas separated because there will be more dissolved gas remained in the crude oil this means more light components will not escape with gas phase and will stay with liquid phase.
- **Stages**: More stages increase the efficiency of separation and decrease the losses (Didactic, 2019).

Water Types with Oil

- **Free water**: It is the water separated from the oil in short time only by gravity without any other assist (Didactic, 2019).
- **Emulsified water**: It is the water that disperse in the oil as droplets and Surrounded by a thin layer of oil due to attractive force between water and oil Molecules and can't be separate by conventional methods. Special technique such as using chemicals might be needed (Didactic, 2019).
- **Soluble water**: It is the water that soluble in oil and can't be separated. It has a small ratio, less than 0.001 by weight ratio (Didactic, 2019).

Conditions for the formation of emulsions

- Immiscible fluids.
- The mixture was subjected to enough mixing to disperse one in the other.
- Emulsifying agent to be present.

Factors that maintain the stability of emulsions

- Viscosity degree.
- The difference in density between oil and water.
- Intermolecular tensile forces.
- The size of water molecules.
- The degree of salinity of the water.
- Ratio between water volume and oil volume.

Emulsion Types

- **Water in oil (hydrophobic)**: It is the common type of emulsion, here water (Discontinuous phase) as small drops surrounded by thin film of oil are dispersed in Continuous oil phase.
- **Oil in water (hydrophilic)**: Small oil drops are dispersed in water (Continuous phase). This type of ratio will increase with increasing age of the production especially when there is water injection.

- **Mixed Emulsion:** It is a mixture of type one and type two and is the most complicated type of emulsion to be treated. To process this type of emulsion and convert it to individual phases we may need more units and equipment to reach the target, Figure 2.3 shows emulsion types (Didactic, 2019).

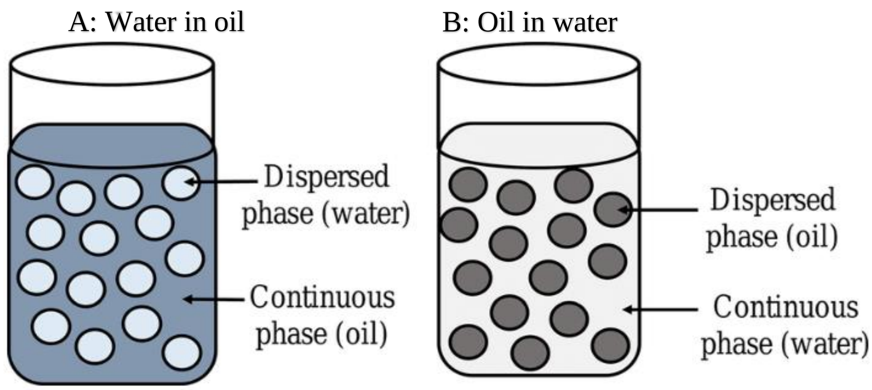


Figure 2.3: Emulsion types (Didactic, 2019).

Emulsion treatment methods

There are three main ways to separate water from oil when there is emulsion:

- **Heating**: Heating reduces the viscosity of the oil and reduces the tensile forces between the oil molecules and water droplets.

There are two types of heating treatment processes:

- **Direct**: By passing the oil inside a path which is heated by burning hot gas and fuel around.
- **Indirect**: By using water to transfer heat from a fuel burner.
- **Chemical treatment**: Through using some chemical additives to break the bonds between oil and water molecules (Didactic, 2019).
- **Electrical aids**: This is done by passing an electric current inside the mixture in the vessel so that the oil is separated from the water. This is called electrostatic separation (Didactic, 2019).
- **Settling:** After demulsification process drops of water get higher in weight by coalescing together. Then these drops start to settle due to gravity if there is sufficient time (Didactic, 2019).

Stock Law

Stock law is the main equation that describes the process of separation and how to control and adjust the factors for improving the separation and increasing recovery factor of oil (Didactic, 2019).

$$v = \frac{D^2\ (\mathrm{d_{water}} - \mathrm{d_{oil}})g}{18\ \mu} \tag{2.2}$$

- $\boldsymbol{v}$ = Velocity of drop settling.
- **D**= Diameter of drop.
- $\boldsymbol{\mu}$ = Viscosity.
- **g** = Acceleration due to gravity, 9.81 m/s².
- $(\mathbf{d_{water}} - \mathbf{d_{oil}})$ = Difference in density between water and oil (Didactic, 2019).

In the above equation we can find out that there are two methods for enhancing separation process:

- Decreasing viscosity by heating.
- Increasing the diameter of the drops by coalescing process.

Density

The difference in density is one of the most important factors that determine the speed at which water droplets settle from continuous phase of oil. The greater the difference between the two densities, the less stable the emulsion will be, and the speed of settling and stability of water droplets increase (Didactic, 2019).

Size of the drops

The size of the drop also affects the speed of its settling, as the larger it is, the faster it settles in the continuous phase. drop size of the emulsion depends mainly on the degree of blending to which the emulsion is exposed before processing, where the flow through pumps, throttle valves, other valves or some other surface equipment reduces the size of water droplets (Didactic, 2019).

Viscosity

As for the viscosity, it plays an essential role in this process. As viscosity increases, the speed of movement of water droplets will decrease, resulting in a reduction in coalescence and cause difficulty of processing (Maria and Lona, 2018).

Emulsifying agent

In the absence of any emulsifying agent, the surface tension between oil and water will increase and facilitates the coalescence of water droplets. When there is an emulsifying agent, the surface tension will be reduced, and lead to a reduction in the coalescence between water droplets (Maria and Lona, 2018).

The above factors determine the stability of the emulsion, that some emulsions may takes weeks or months to separate if left alone in a tank and untreated, some unstable emulsions may take minutes to separate (Maria and Lona, 2018).

Best way that the designer can do is to avoid emulsion is to reduce flow velocity, reduce changes and sudden narrowing's in the direction of the flow (Didactic, 2019).

Three stages of processing emulsions:

- **Emulsion breakage**: Involves tearing and breaking the thin film surrounded the water droplets. This process needs assistance by heat and emulsifying breaker (Didactic, 2019).
- **Droplets coalescence**: It involves the union of water droplets which become free after breaking emulsion, forming large droplets, Coalescence is a strong function of time. The more the time there will be more coalescence of drops. This step is done by using electrostatic treater (Didactic, 2019).
- **Settling due to gravity:** large drops formed due to coalescence will start to settle in the bottom of vessel due to the huge weight by gravity (Didactic, 2019).

These steps must be in the correct order and the specific step of the process is the one that depends mainly on the length of time (Didactic, 2019).

Crude Oil Desalting

The process of removing water-soluble salts from oil stream is called oil desalting, Salts are spread in crude oil in the form of brine, mostly this salt is sodium chloride. The percentage of salts varies according to the type of oil in some reservoir the salt content is high while in some reservoir the salt content is increasing with increasing the age of the reservoir with production. and it has been found that a thousand barrels of oil may contain from 1 up to 260 lb from salts as average, water and salt are found naturally together in geological deposits, Salts dissolve in the water and the water is exist as emulsion in the oil (James, 2022).

- Produces hydrogen chloride, which accelerates corrosion of equipment.
- Contribute to the mechanical clogging of furnace tubes, heat exchanger, and lines by deposition which causes to reduce heat transfer coefficient and pressure drop.
- This leads to maintenance issues, which can result in downtime and loss of productivity (James, 2022).

Nearly all crude oil types contain entrained water, which always contains dissolved salts, specifically NaCl. The majority of the produced salt water is removed by initial separation and the emulsion treatment. However, a small amount of entrained water remains in the crude oil and this amount of salt should be removed by electrostatic desalter (James, 2022).

Reasons behind doing desalting are:

- To prevent corrosion.
- To reduce fouling.
- To reduce cleaning frequency.
- To maintain unit capacity.
- To save energy.

Types of desalter

Here a settling time is given to the crude oil and brine to allow the salt and water to settle down under gravity force to the bottom of the desalter and then discharge it such as draining water from tanks, this type of desalter is suitable for crude has low ratio of salt (James, 2022).

Chemical desalter

In these desalter chemicals is added to crude oil in order to remove salt and water by reducing surface tension for making removal of salt and water easily, this type of desalter is suitable for crude low ratio of salt content (James, 2022).

Electrostatic desalter

It is a type of desalter that utilizes chemicals along with electric field for desalting process. Demulsifier used as chemical while electrodes connected to step up transformer used for electric field generation (James, 2022).

Removed of salt with electrical field:

A transformer is located on the top of the desalter generating high electrical field inside the vessel which pass to grid of electrodes of carbon–steel (James, 2022).

Alternating current is used, and direct current can be used, but it will be one of the factors that cause corrosion, and it is also more expensive than alternating current (James, 2022).

The oil/water emulsion when it flows through these electrodes inside the Desalter becomes charged with an electric charge So the charged water droplets will begin to attract and repel with other droplets, leading to collide and forming a large water droplet which are easy to separate by gravity due to their weight and this the process can be achieved by interacting (water in the oil emulsion) to High Voltage electric field (James, 2022).

When a no-conducting liquid (oil) contains another conductive liquid (water). If mixture is exposed to an electrostatic field where the water droplets will combine with each other by one of the following three physical phenomena (James, 2022).

- These droplets become polarized and tend to line themselves with the electrostatic field lines and because of the moment the positive and negative drops collide with each other which facilitate their coalescence.

- The droplets are attracted towards the grid because of the electric field and because of the moment small droplets vibrate to a greater distance than large droplets, resulting in coalescence.
- The electric field leads to the weakening and thus breaking of the emulsion layer where the drop lengthens horizontally and vertically due to the increased surface tension between the drops of oil and emulsion water.

Washing Water Ratio

The purpose of washing crude oil with fresh water is to remove salts from crude oil. Addition of fresh water will reduce the concentration of salt in the brine, which helps to extract large quantities of salts found in crude oil, usually the mixing process between washing water and emulsion occurs in a globe valve to get a good mixing and it must be noted that high drop in pressure may lead to emulsification of washing water (James, 2022).

The use of an insufficient amount of washing water leads to a reduction (of the process of removing salts) due to the lack of water needed to dissolve salts (James, 2022).

The use of too much washing water leads to an increase in the amount of high amperage current. Excessive Current or occurrence of short circuit between the poles where the increase of water lead to the creation of leakage voltages with the occurrence of (carryover) of water with oil outlet from desalter also reduces oil residence time inside the desalter (James, 2022).

Mixing valve

The mixing degree of oil and washing water is a function of the pressure difference through the mixing valve. The optimum pressure drop for this valve is that 1.5 bar for light oil and 0.5 bar for heavy oil James, G. (2022).

Desalting steps

From Figure 2.4 we can explain how to remove salt desalter:

- Crude oil mix with fresh water and chemical is added as well before entering to the vessel to form emulsion.
- Emulsion enters the desalter and start to flow into first section which is called heating section to increase the emulsion temperature to decrease the viscosity and release

some gases from the solution. heating section is provided by burners working on diesel or gas.

- A portion of water will separate from the emulsion and settle down to the bottom of desalter then discharge through water outlet (James, 2022).
- The remained emulsion will overflow the weir which is located between heating section and bucket section (second section).
- The main function of bucket section is to keep coalescing section always full of liquid.
- There is a gas equalizer to equalize the pressure between heating section and bucket section in order to keep enough force to push liquid to coalescing section from bucket section.
- Emulsion from bucket section will go to coalescing section from bottom through a spreader to allow water drops settle down uniformly and send oil up (James, 2022).
- In the coalescing section, emulsion will come contact with electrodes which handle high electrical field causing collision between water drops to form bigger drops to be settled easier.
- Water from bottom of coalescing section will discharge and oil will go out from top of the desalter through collector.
- Coalescing section should be full always to avoid accumulating gas in the top of vessel because maybe cause explosion with present of transformer.
- Water level should not reach electrodes because it will cause shortage and trip the transformer.

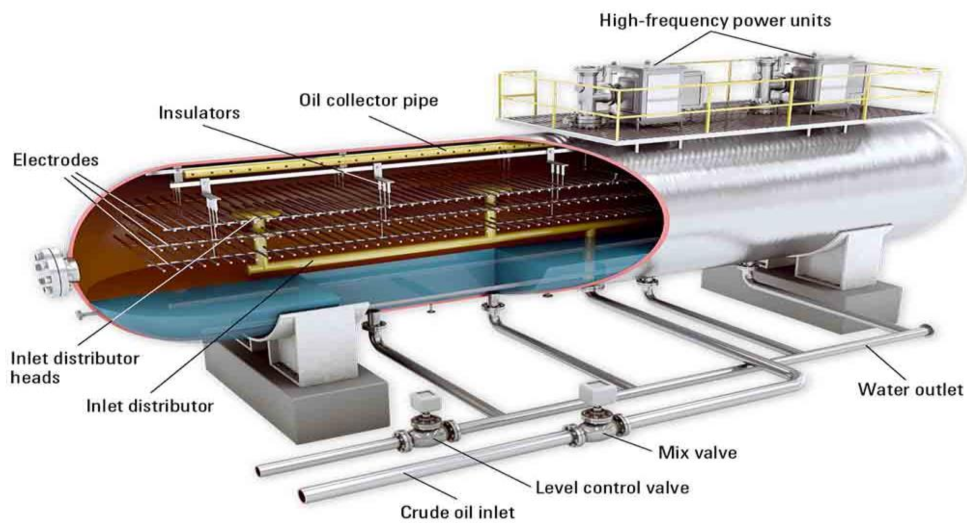


Figure 2.4: Desalter (James, 2022).

Desalting efficiency

Desalting efficiency can be calculated from following equation:

$$SE = \frac{(Si - So) * 100}{Si} \tag{2.3}$$

Where:

SE = salt removal efficiency %.

Si = salt content of raw crude oil in PTB.

So = salt content of desalted crude oil in PTB.

PTB = pounds per thousand barrels.

Desalting efficiency should be between 90 – 95 %.

Si and so can be obtained by taking sample from inlet and out of the desalter and analyze in the lab (James, 2022).

Dehydration efficiency

Dehydration efficiency can be calculated from following equation:

$$\text{Dehydration efficiency} = \frac{Ww+Wi-Wo}{Ww+Wi} \text{ X}100\% \qquad (2.4)$$

Where: Ww = wash water rate.

Wi = water coming in with the crude oil.

Wo = water leaving with the crude oil.

Dehydration efficiencies ranging from 95 - 98%.

Wi and Wo can be obtained by taking sample from inlet and out of the desalter and analyzed in the lab (James, 2022).

Effect of the operating parameters

- **Water - crude interface level**: This level should be always constant because any changes in this level will change electrical field and perturbs the coalescing process (James, 2022).
- **Desalting temperature**: Heating effect on viscosity which means effecting on the coalescing process of the drops so heavy oil require higher temperature (James, 2022).
- **Wash water ratio**: Heavy oil requires more wash water to increase electrical coalescence (James, 2022).
- **Pressure drops in mixing valve:** High pressure drop will form fine stable emulsion and better washing. but if this pressure drop is excessive then the result will be opposite, and it will be difficult to break the emulsion (James, 2022).
- Type of the demulsifier: Demulsifier is important because it assists in the process of breaking emulsion and drops coalescing. levels are ranging between 3 ppm and 10 ppm of oil used (James, 2022).

In Table 2.1 shows desalting troubleshooting.

Table 2.2: Desalting troubleshooting.

Problem	Causes	Solution
A high salt content in the desalted crude oil.	Feed salt content high.	Increase the wash water rate.
	Wash water injection low.	Reduce crude oil flowrate.
	Crude oil flowrate exceeds the design flow rate.	Increase the mixing valve pressure drop.
	Insufficent mixing of the crude oil and wash water.	Increase the mixing valve pressure drop.
	Interface level too low.	Increase the interface level.
Oil in the desalter effluent water.	Wide emulsion band at the interface.	Inject a chemical or dump the emulsion.
	Excessive crude oil wash water mixing.	Reduce the mixing valve pressure drop.
	Crude oil temperature too low.	Check for any waste in the wash water source.
High water carries over in desalted crude oil.	Wash water flowrate too high.	Reduce the wash water flowrate and commence or increase chemical.
	Excessive formation water in the crude oil.	

Stabilization and Sweetening of Crude Oil

Once well mixture de-gassed, de-hydrated and de-salted it will be pumped to stored for exporting. However, if this crude still contains any dissolved gases that belong to the light or the intermediate hydrocarbon groups, these gases including hydrogen sulfide should be removed before storing. This process aims to reduce RVP and H_2S to desirable levels which described as a dual process of both stabilizing and sweetening the crude oil (Maria and Lona, 2018).

The stabilization process removes the light components in the solution (C1, C2, and C3) without losing precious components, Stabilizers maximize production of valuable hydrocarbon liquids, while making the liquids safe for storage and transport, as well as reduce the atmospheric emissions of volatile hydrocarbons (Maria and Lona, 2018).

Vapor pressure is exerted by light hydrocarbons, such as methane, ethane, propane, and butane, changing from liquid to gas as the pressure on the crude is lowered. If a sufficient amount of these light hydrocarbons is removed, the vapor pressure becomes satisfactory for shipment at approximately atmospheric pressure (Maria and Lona, 2018).

The process makes a cut between the lightest liquid component (pentane) and the heaviest gas which is (butane), butanes increase the vapor pressure of crude oil which cause increasing RVP so controlling butanes can largely control the RVP of the stabilized crude oil (Maria and Lona, 2018).

During the stabilization operation, methane, ethane, propane and most of the butanes are removed from the liquid phase, the finished product from the bottom of the column is composed mainly of pentanes and heavier hydrocarbons, with small amounts of butane (Maria and Lona, 2018).

The bottom product from stabilization tower is liquid free of all gaseous components able to be stored safely at atmospheric pressure (Maria and Lona, 2018).

Dalton's Law

Law of Partial Pressures, states that the total pressure exerted by a mixture of gases is equal to the sum of the partial pressures of the gases in the mixture.

$$P_{Total}=P1+P2+P3+P4 \quad (2.4)$$

- If P1 dropped, then P total will drop and cause releasing of more components in the tank.

Crude oil after separation and emulsion treatment contains a large percentage of methane and ethane, which will flash to gas state in the storage tank, this drops the partial pressure of all other components in the tank and increases their tendency to flash to vapors, Stabilization is the process of increasing the amount of intermediate (C 3 to C 5) and heavy (C 6+) components in the liquid phase (Maria and Lona, 2018).

In this dual process adjusting the pentanes and lighter fractions remained in the oil can change the crude oil API which influencing the economic value of the crude oil if too much light component's escaped with gas and decrease API which cause decreasing its market value (Maria and Lona, 2018).

Remaining gases with liquid will cause the following:

- Excessive loss of precious compounds as a result of the evaporation process carried out during the transport and storage of oil.
- Occurrence of gas gaps in the pipelines, which leads to pumping problems and reducing the volumetric capacity of the pipelines.

Methods of stabilization and sweetening

Stripping by nitrogen

Stripping by N_2 is one method used in the CPF to remove H_2S and reduce RVP and called the cold stripping because no reboiler will be used at the bottom of the stripper for heating purpose. Nitrogen is an inert gas that prevents the flammable gases from igniting and thus eliminates the risk of explosion. Once the H_2S has been stripped from the crude oil in the stripper, it is usually flared (Maria and Lona, 2018).

In this method a complete nitrogen generation package should be available at site to generate sufficient amount of nitrogen for stripping purpose. controlling the flowrate of nitrogen is critical for injecting required amount of nitrogen into the tower to reach equilibrium with crude to reduce H_2S and RVP to desirable level (Maria and Lona, 2018).

Equilibrium stage will reached when the amount of injected inert gas is enough to reduce both H_2S and RVP (Maria and Lona, 2018).

This process can be simply described as follows assuming basic sediment and water BS&W is zero percentage:

- Un-stabilized crude will enter the stripping tower from the top and flows down to the bottom of the tower trough trays inside the tower.
- Inert gas which N_2 is injected from the bottom of the tower and flows up to the top of the stripper through trays inside the tower.
- N_2 and crude oil will come in contact and stripping of H_2S, and light components will take place by N_2.
- N_2 has ability to absorb H_2S and other light component's present in the crude oil and take them out of the stripping tower through gas line at the top of tower either to flaring or gas treatment plant.
- Stabilized crude oil will discharge from bottom of the tower to storage tanks.

Disadvantage of stripping by nitrogen method are:

- It is difficult to control light component's which cause losing some of light components with gas.
- Can't remove H_2S properly like other methods.

Stripping by hot vapor of crude oil

The reboiled trayed stabilization is the most effective system for stabilization and sweetening of sour crude oils. Stabilization column is equipped with a re-boiler connected at the bottom of the tower to generate hot vapor for stripping, this method is like stripping by sweet gas in operational but using crude vapor instead of sweet gas, this vapor is very effective because it has energy momentum due to elevated temperature (Maria and Lona, 2018).

Because hydrogen sulfide has a vapor pressure higher than propane, it is relatively easy to drive hydrogen sulfide from the oil, Conversely, the trayed stabilizer provides enough vapor/liquid contact that little pentanes plus are lost to the overhead (Maria and Lona, 2018).

This operation of stripping by hot vapor of crude oil can be summarized in few steps as showing in the Figure 2.5.

- Raw feed is entering 3 phase separators, gas released to gas line, water discharged to water treatment unit and oil is pumped to splitter.
- Oil in the splitter is divided into two streams, one stream will be 20% of the flow and go to the top of the tower bypassing heat exchanger, and second stream will be 80% of the flow and go to the heat exchanger for increasing the temperature (Maria and Lona, 2018).
- The stream of 20% is responsible to generate a cold zone at the top of tower for condensing of the light components.
- preheated crude then flows from heat exchanger to tower.
- The crude flows downwards through trays and comes in contact with heated vapor flowing up from bottom reboiler section.
- The warm preheated crude condenses heavier ends in vapor and allows only lighter end to flow out through the top of the column. In the process, crude also gets heated up and loses light ends to the vapor stream.
- The crude then flows to the reboiler where it gets heated by exchanging heat with the heating source passing through reboiler tubes. The heating results in separation of volatile hydrocarbons and H_2S from crude oil making crude stable and sweet.
- When light component's and H_2S reached cold zone, light component's will condensate to liquid and join liquid phase fall down to the bottom of column.
- While H_2S does not get condensed, and it will go out with gases through top of the tower.
- The stabilized crude leaves the column from the bottom and gets cooled in the crude heat exchanger before flowing to storage tanks.
- If there are any water drops remained with crude oil, it will separate and discharge to water draw off vessel.

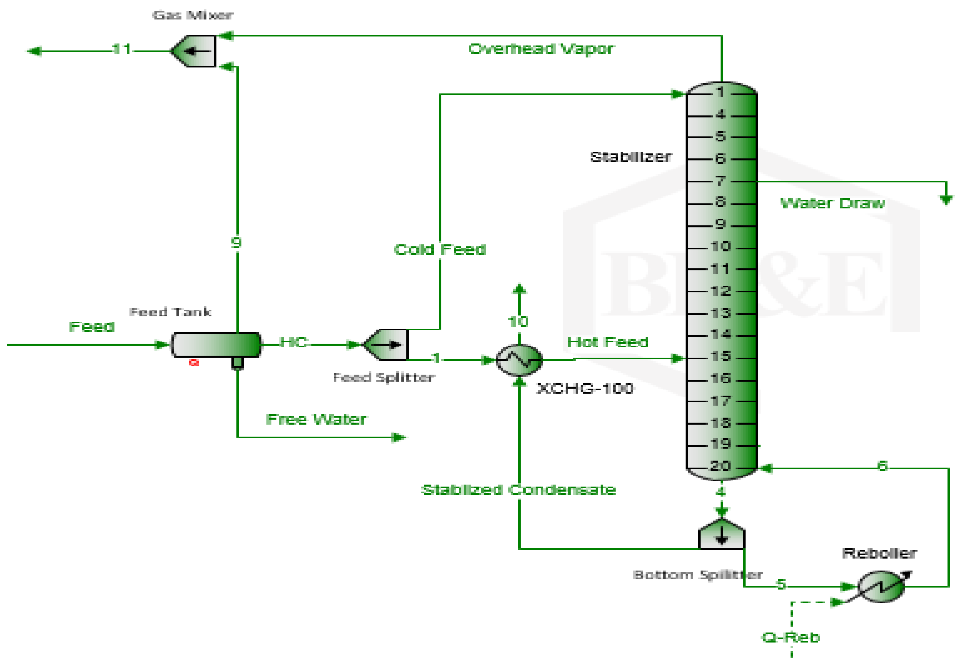


Figure 2.5: Stripping by hot vapor of crude oil (ProMax Software, 2022).

Heating source

The heating source for reboiled column is heater which responsible for heating up a special type of oil to a high temperature. The warm oil will go to the tube side of the reboiler while the crude oil will be in shell side for heat transferring (Maria and Lona, 2018).

Stripping by sweet gas

High temperature in reboiler is causing many problems such as salt deposits but most common one is reboilered fouling, this problem because a poor reboiler performance, so to overcome this issue there is an option to injecting sweet gas and reduces the duty on reboiler to achieve same result of previous method with fewer loads on reboiler (Maria and Lona, 2018).

A simulation model by a computer simulator has been generated and different cases has been reviewed to show the effect of the sweet gas injection flowrate which was giving different results with different injection rate and at the end it is clear that higher injection rate is giving lower H_2S and RVP levels (Maria and Lona, 2018).

Plant Equipment

Processing of crude oil is a complex process and need different equipment to achieve the target. Each equipment works to support other to do the process successfully such as heater increase the temperature of crude oil to help the separator in the separation (Taqa, 2022).

There are many different designs of wet oil treatment plants, but the difference Among them is not essential, but rather a difference resulting from a certain philosophy of the company for designing the processing system. This or that, but in the end, it does not differ in the basic parameters and conditions for treatment and in the basic principles defined by the Stoke Law, or the basics of the treatment Emulsions (Taqa, 2022).

The most common equipment used in the plants are:

- slug catcher.
- Three phase separators.
- Heat exchanger.
- Heater.
- Reboiler.
- Desalter.
- Stabilization column.
- Oil skimmer.
- Storage tank.
- Pump.
- Flare.

Each one of the above equipment will be explained in the more details as following:

Slug catcher

The slug catcher is a 2-phase separator which separates out any associated gas that is flashed from the incoming liquid (crude and water) mixture from oil manifold (wells) depend on gravity force difference in the densities (Taqa, 2022).

The first benefit of slug catcher is to separate free gas from (total liquid stream) and the second benefit is to change the flow regime from turbulent flow to laminar flow specially in the mountain area, because the equipment after slug catcher need laminar flow to control the liquid level in vessel (Taqa, 2022).

Slug catcher is the initial processing vessel in the production facility, therefore it should be operated properly to keep entire facility stable, Figure 2.6 shows slug catcher and three phase separators (Taqa, 2022).

Slug catchers consist of:

- **Mechanical vessel:** To hold the fluids.
- **Inlet diverter:** To decrease the fluids velocity entering to vessel and doing initial separation of gas from liquid (oil and water).
- **Gas outlet: to** release separated gas to flare.
- **Liquid (oil and water) outlet:** To drain the liquid from the vessel to next equipment's.
- **PSV and BDV:** To release excessive gas (pressure) if the pressure of the vessel increased more than the limit to protect the vessel and all plant.
- **Mist extractor:** To remove the oil drops from gas at the gas outlet.
- **Pressure control valve:** To control the pressure of the vessel.
- **Level control valve:** To control the level of liquid in the vessel.
- **Instruments:** To send the pressure, temperature, level to CCR for monitoring and controlling.

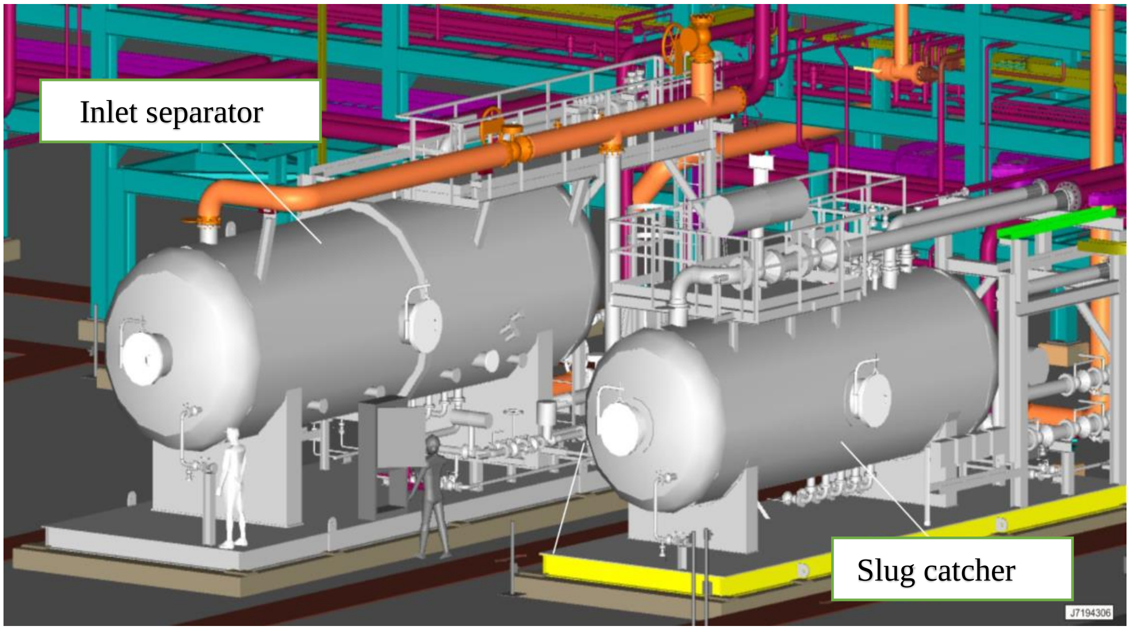


Figure 2.6: Slug catcher and three phase separators (Taqa, 2022).

Three phase separators

It is a mechanical vessel used to separate produced fluids from the wells into three phase oil, water, and gas. Separator utilizes the force of gravity to separate oil-gas mixtures. The lightest one is gas which rises to the top and leave separator from gas line, the heaviest one which is water falls down to the bottom of separator and accumulate before the weir and drain out from water outlet, oil will be in the middle and accumulate after the weir and then leave the separator from oil outlet, The internal components and instrumentations of. Three phase separator is almost same as two phase separator but there is a weir in the 3 phase separator to separate water from oil (Taqa, 2022).

Heat Exchanger

Is an equipment used to exchange the heat between two fluids of different temperature, here the fluids separated from each other by a sold wall and will not mix anyway, the fluids either heated or cooled. Example for this crude oil comes from well is cold and steam is hot, heat will be transferred from hot steam to cold crude oil. Most used type of heat exchanger is shell and tube, which consist of a series of tubes inside a vessel called shell, one fluid will be inside tubes and the second fluid will be in the shell such as crude oil is in tube and steam is in shell side as showing in Figure 2.7 (Taqa, 2022).

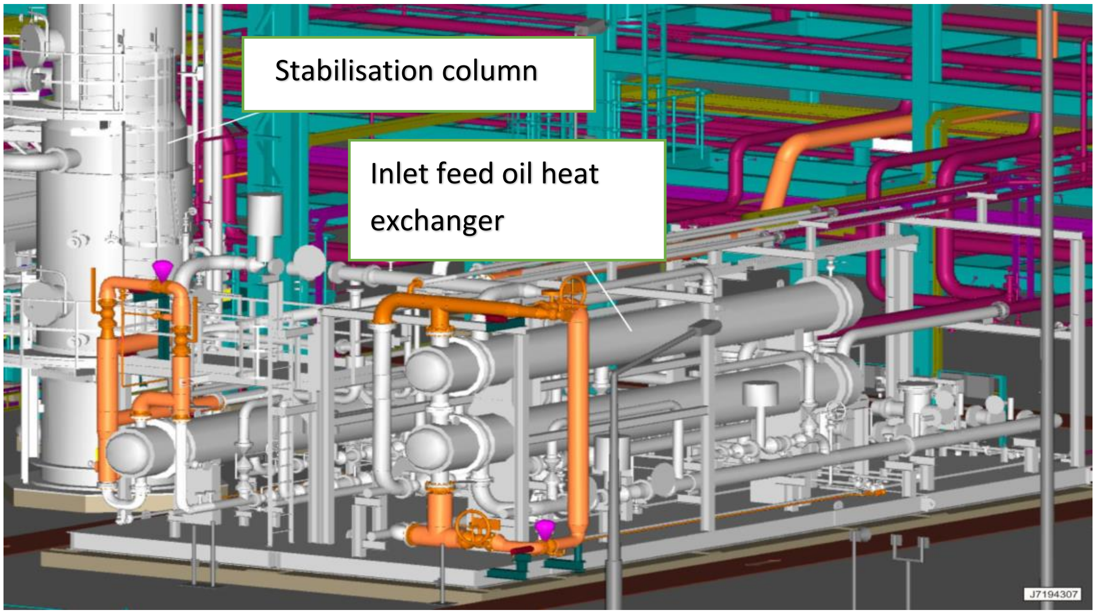


Figure 2.7: Shell and tube heat exchangers (Taqa, 2022).

Heater

It is an equipment used to heat up the crude oil either directly or indirectly. Heater is working by fuel either gas or diesel under controlled burner, Figure 2.8 hot oil fired heater (Taqa, 2022).

Indirect heater

Here the heater is heating up a special type of oil (not crude oil) then this hot oil will go to give the heat to crude oil to a reboiler (Taqa, 2022).

Main components of indirect heater:

- **Burner:** here the fuel (gas or diesel) burned to generate the flame (heat) we need.
- **Pilot:** to ignite the burner where we start the heater.
- **Fuel line:** this line will supply the fuel diesel or gas to the burner.
- **Blower:** it's like a fan used to clean inside the heater before start.

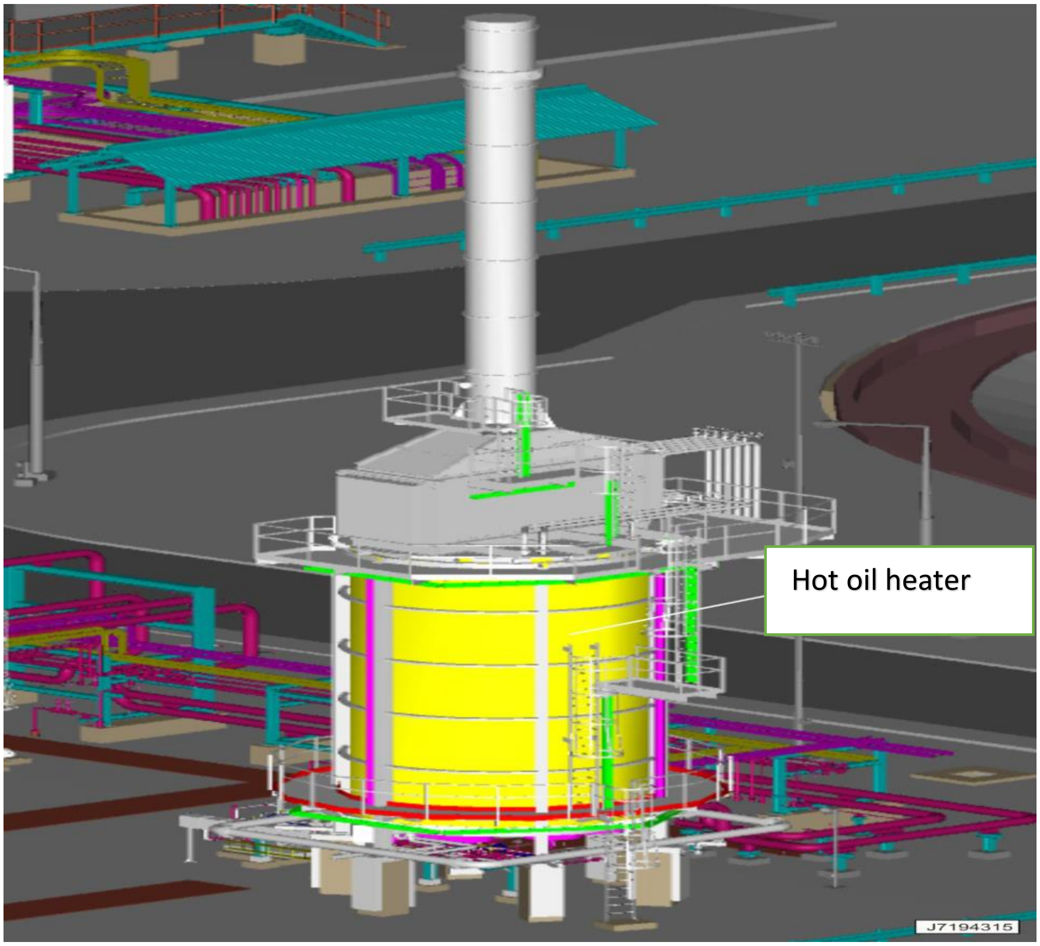


Figure 2.8: Hot oil-fired heater (Taqa, 2022).

Kettle Re-boiler

It is a type of heat exchanger used to provide the heat to the bottom of the stabilization column (stabilizer), which consist of bundle of tube (U-shape) inside the shell and there is also a weir, hot oil comes from indirect fired heater and enter the tube while crude oil is coming from stabilizer and enter the shell side to exchange the heat, Figure 2.9 showing stabilization column reboiler (Taqa, 2022).

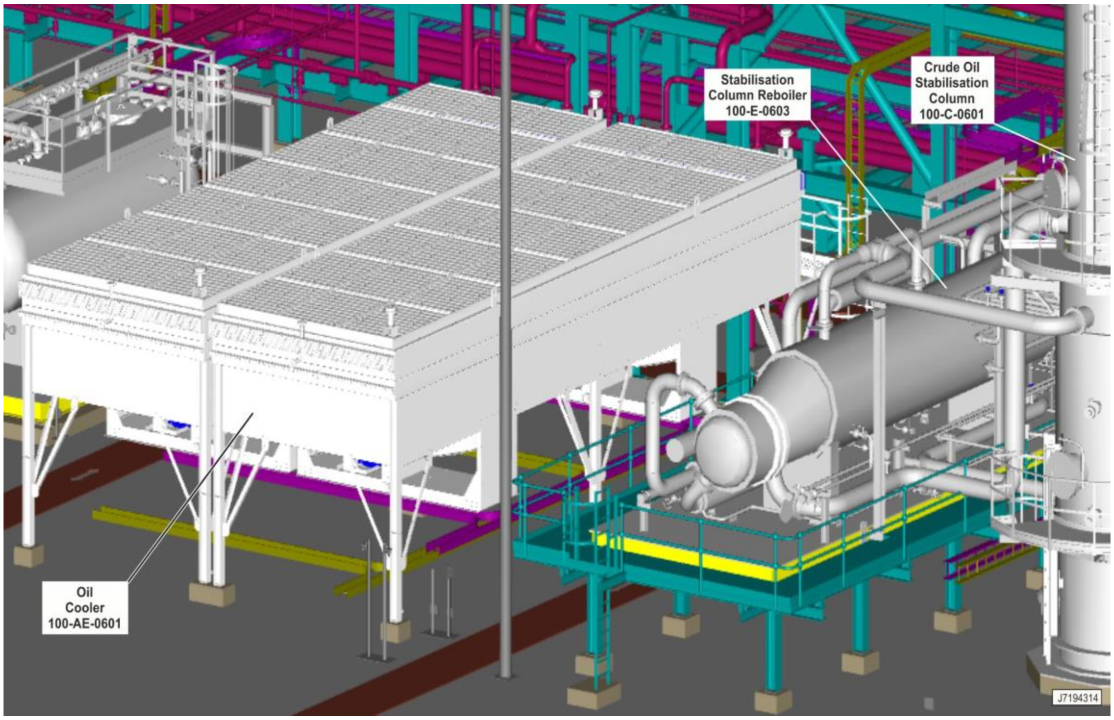


Figure 2.9: Stabilization column reboiler (Taqa, 2022).

Desalter

It is called electrostatic separator which separator salt and water from crude oil by principle adding wash water and chemical along with electric field. Demulsifier is used as chemical while electrodes connected to transforms to generate electrical field, Figure 2.10 showing desalters package system (Taqa, 2022).

Desalter consist of the following:

1. **Transformer:** To generate electrical field inside the Desalter**.**
2. **Wash water:** To mix with crude oil to decrease the concentration of salt in the crude oil.
3. **Mixing valve:** To control the flow or ratio of wash water.
4. **Chemical Injection point:** To inject the Demulsifier to crude oil.

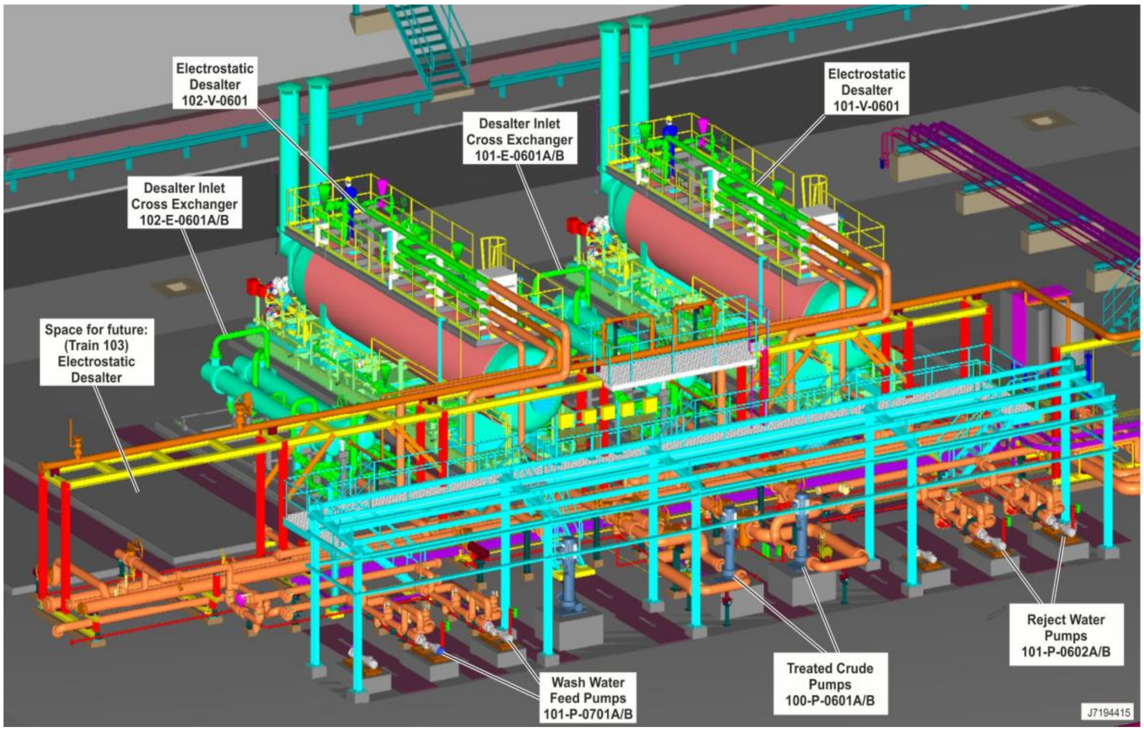


Figure 2.10: Desalters package system (Taqa, 2022).

Stabilization column (Stabilizer)

It is a tower used to do dual purpose operation. first is to stabilize the crude oil by reducing the vapor pressure (RVP) to maximum allowable value, and second is sweeten the crude oil by reducing the H_2S content to maximum allowable value. There are trays inside the tower either bubble cups tray type or valve tray type. A water draw vessel will be connected to the side of tower to remove the remained water drops from oil and also there is a PSV to protect the tower from excessive pressure (Taqa, 2022).

Stabilization column works by three methods:

1. Circulation of hot stream from reboiler connected to the bottom of the tower.
2. Injection inert gas nitrogen to the bottom of the tower.
3. Injection of sweet gas (low H_2S) to the bottom of the tower.

Oil Skimmer

It is a three-phase separator used to separate any drops of oil from produced water and also separate any gas remained with produced water. Same as slug catcher and three phase separator, oil skimmer has PSV and instrumentation to operate the vessel properly and safely, Figure 2.11 showing oil skimmer (Taqa, 2022).

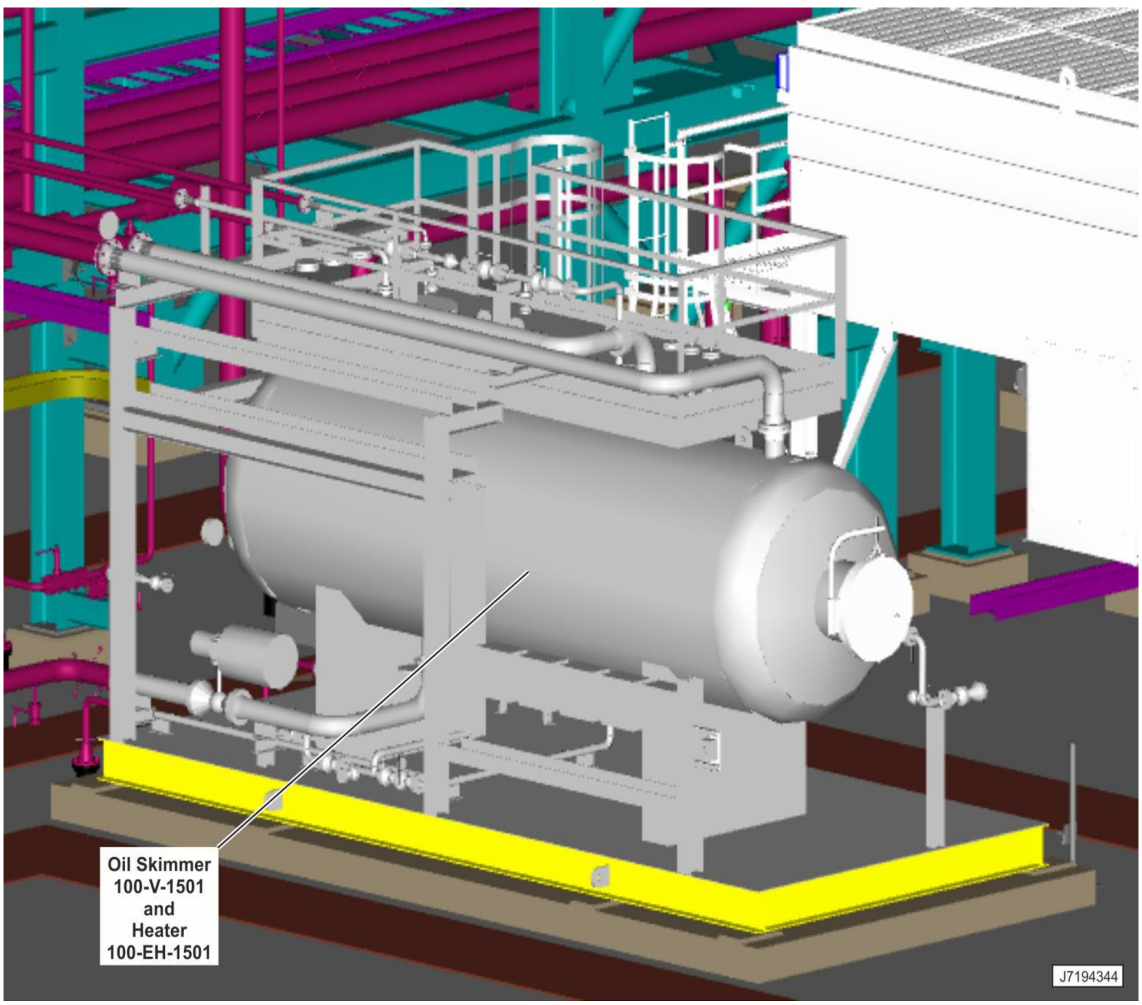


Figure 2.11: Oil skimmer (Taqa, 2022).

Storage Tank

It is a big vessel used to store the liquids (oil and water) and its capacity is dependent on the production rate of the field. The kind of fluid we want to store will determine the type of storage tank. There are two types of storage tank, fixed roof and floating roof, Figure 2.12 showing oil storage tank (Taqa, 2022).

Storage tank generally consist of the following:

1. **Inlet:** Oil or water enter the tanks from this point.
2. **Outlet**: Oil goes to export pumps, water goes to injection pumps.
3. **Foam box**: To spread the foam on the tank in case of fire or explosion.
4. **Ladder**: To enable workers to go to top of the tank.
5. **Drain**: To drain out the oil or water for maintenance.
6. **Blanket gas**: To supply inert gas (nitrogen) to maintain the pressure in the tank at desired level.
7. **Manway**: To enter to the tank for maintenance.

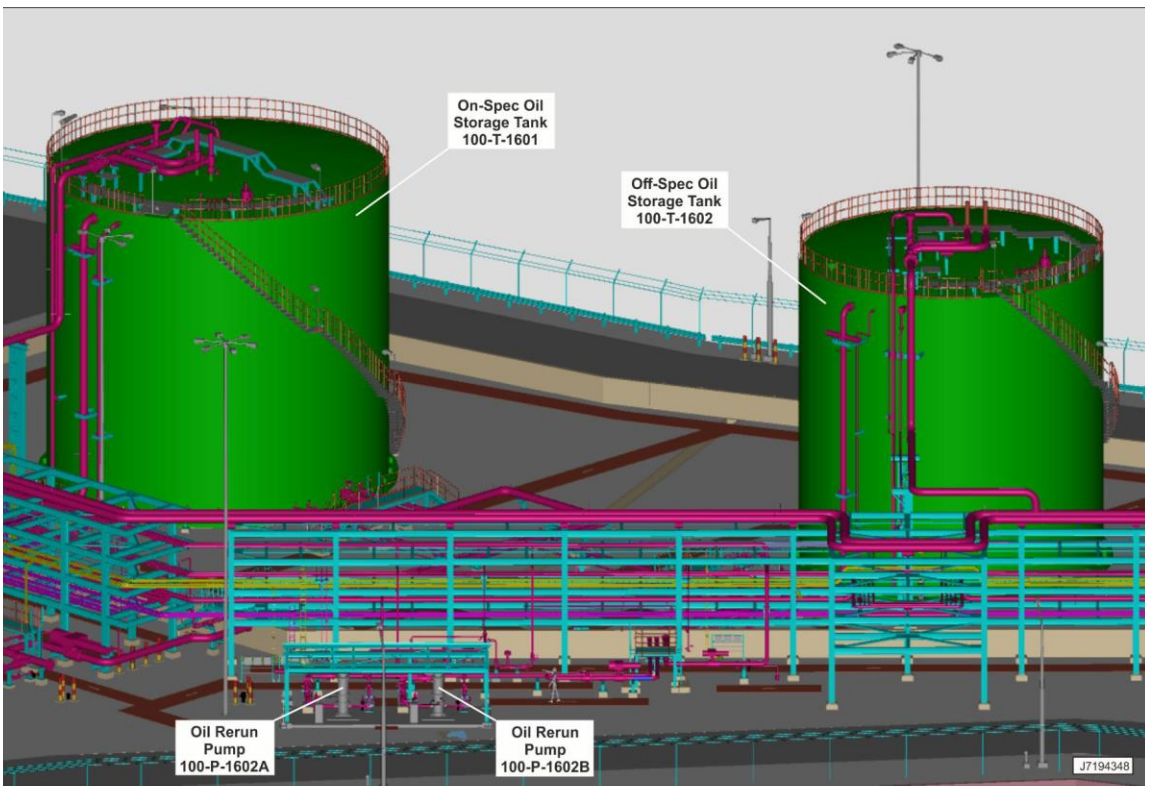


Figure 2.12: Oil storage tank (Taqa, 2022).

Pump

It is machines that are used to move oil or water from one place to another through flowlines by mechanical action such as pushing oil from CPF to export point. there are Two main types of pumps, Figure 2.13 showing centrifuge pumps (Taqa, 2022).

- **Centrifuge pumps:** This type operate on the principle of centrifugal force which used for moving high volume of liquid (high flowrate and low pressure), this pump consist of (Taqa, 2022).

1. **Motor:** Which works electrical and connected to impeller through a shift, as the motor works, it will cause the impeller to rotate as well to push the oil (Taqa, 2022).
2. **Impeller:** It's main part of pump and its function Is to move the liquid, impeller is inside the fixed part Diffuser (Taqa, 2022).
3. **Diffuser:** It is a stationary part, the impeller is moving inside the diffuser to push the liquid (Taqa, 2022).

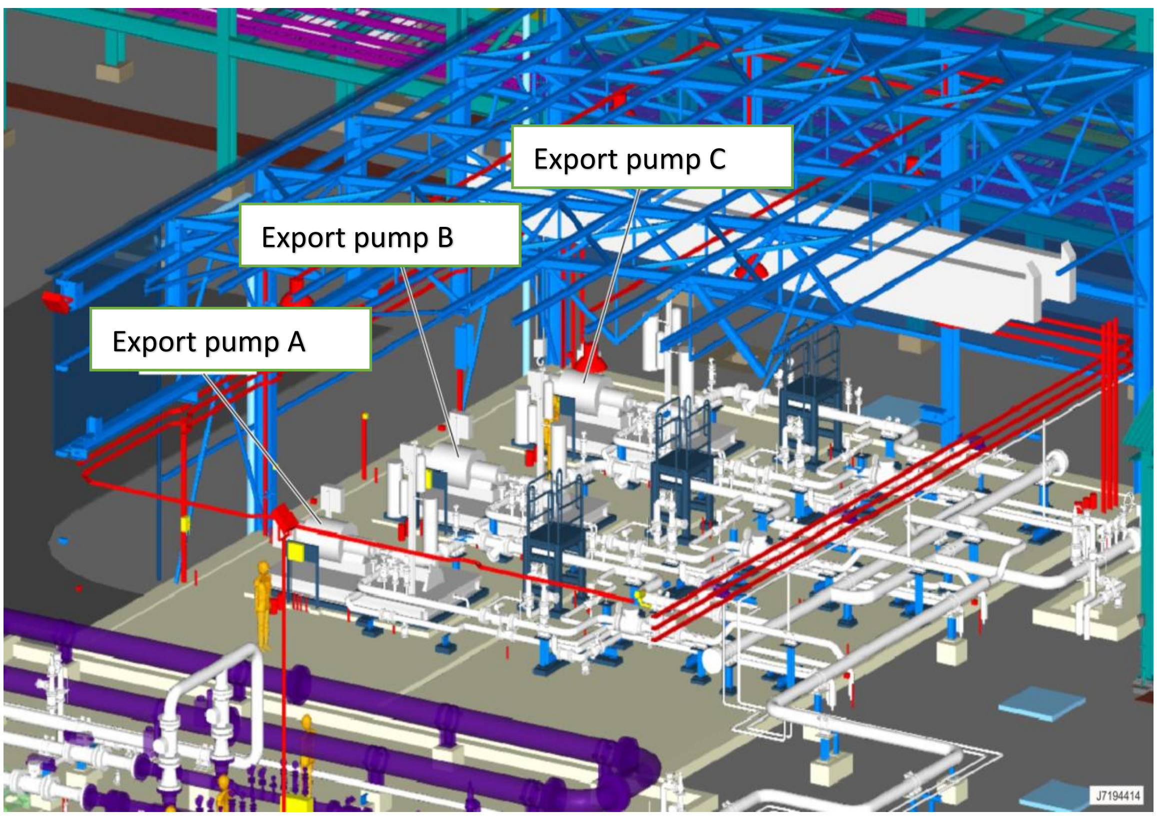


Figure 2.13: Centrifuge pumps (Taqa, 2022).

- **Positive Displacement Pumps:** This type of pumps used to inject a liquid with high pressure (low volume, high pressure) such as injecting Demulsifier into Flowline in high pressure and low volume (Taqa, 2022).

Flare

It is like as symbol of the CPF everywhere, this equipment allows us to burn the separated gases (toxic gas) from oil in a safe manner and under controlled condition, flare is designed only to burn gases, not allow any way to burn oil, there is two types of flare at the plant, Figure 2.14 showing high pressure and low pressure flares (Taqa, 2022).

- **High pressure flare (ATM)**: This flare is responsible for burring the gases coming from high pressure vessels such as 1st and 2nd stage separator or Desalter or stabilizer.
- **Low pressure flare (LP)**: This flare is to burn the low pressure vessel such as vent of storage tanks.

Flare consists of the following:

1. **Pilot:** It is responsible to prepare a fire for the flare to burn the gas when it comes from FKOD (pilot works by propane gas).
2. Flame arrestor: it's like a mesh and works to prevent back fire from flare to gas line.
3. **FKOD:** It is a vessel, and its function to remove any drops of oil with gas before sending the gas to flare, this is to prevent carry over or flare smoking which is caused by burning oil in the flare.
4. **Blower:** It is a fan, installed at the bottom of flare and its job is to push continuously air upward to prevent any gas to come down.
5. **Ignition package:** This package is responsible to start up the pilot.

In Figure 2.15 showing high pressure and low pressure flares system.

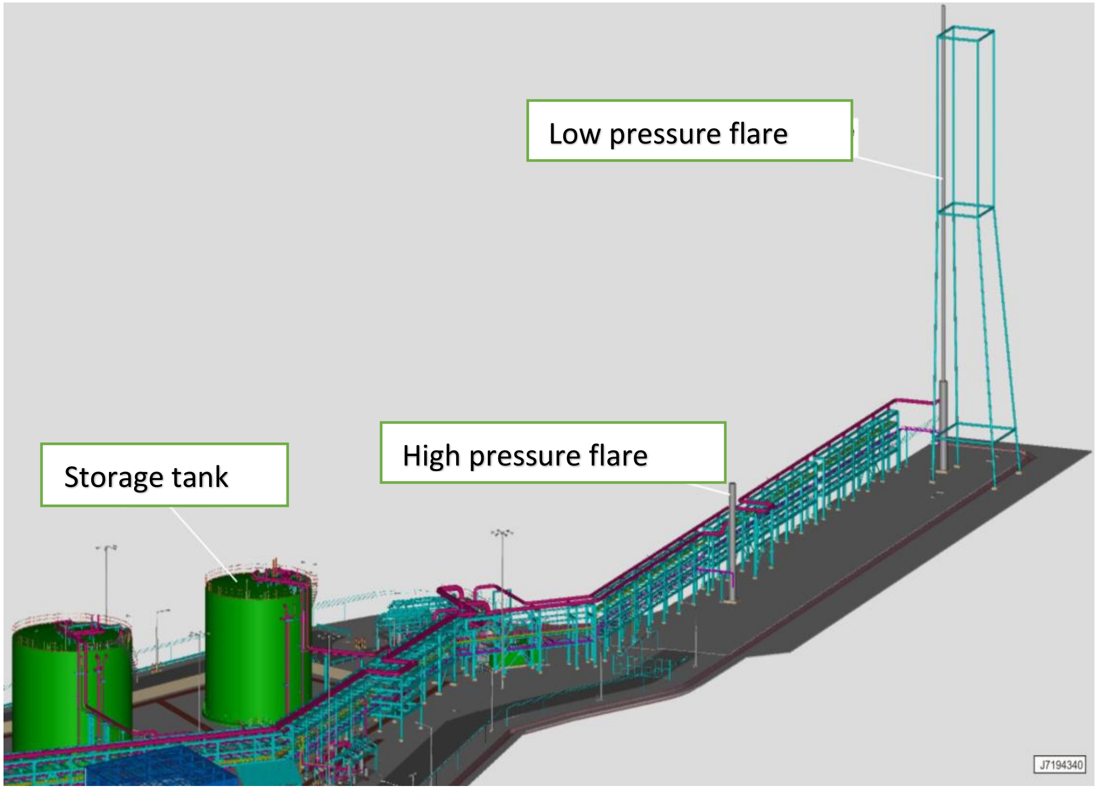


Figure 2.14: High pressure and low pressure flares (Taqa, 2022).

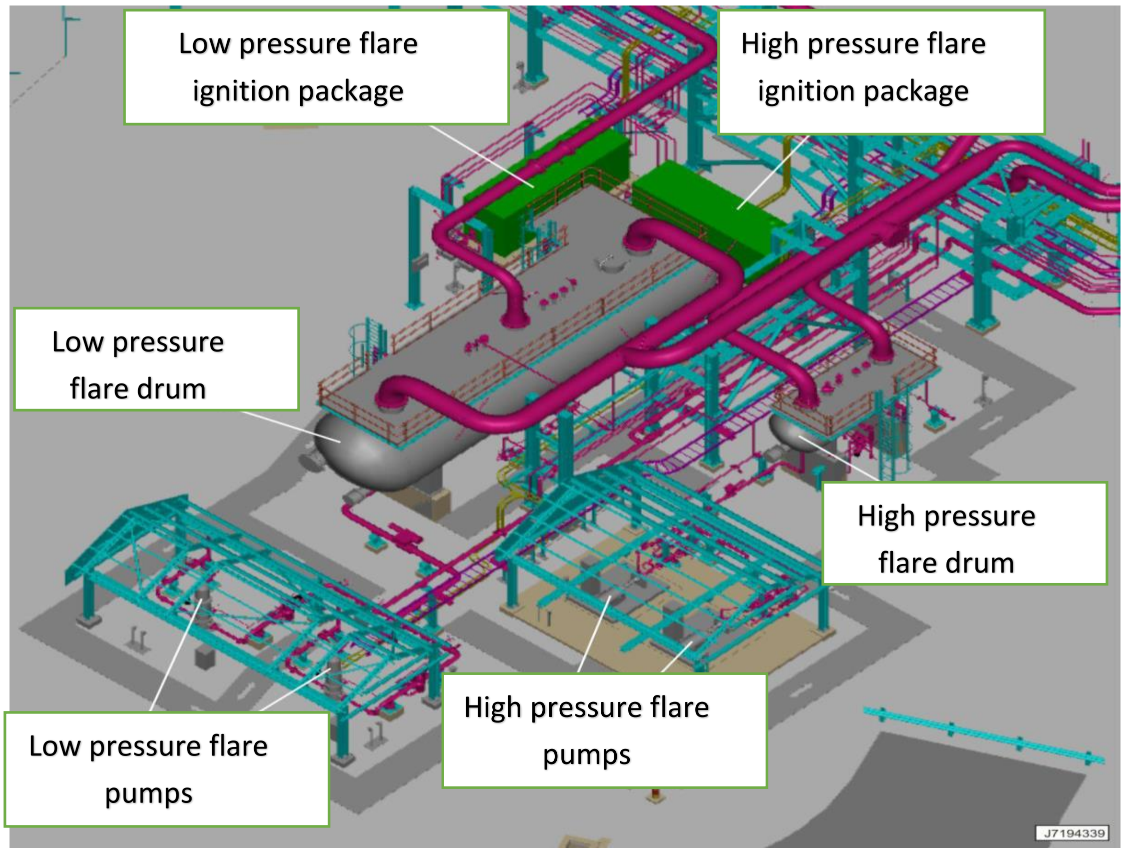


Figure 2.15: High pressure and low pressure flares system.

Crude Oil Treatment Problems

Development of modern designs for the separation system should take into the account operation problems and provide the suitable solutions. High efficiency level controls and pressure controls have been added to this system to minimize operation problems as much as possible (Taqa, 2022).

Most of the operation problems are due to the malfunction of these controls or bad operation.

Most common operation problems are:

- Carryover
- Foaming
- Gas blowby

Liquid carryover

Typically, flare stack is designed to burn gases only which produce blue smoke from gas combustion during normal operation. In case oil carried over to flare a black smoke is generated due to burning heavy hydrocarbons (Taqa, 2022).

During normal operation each phase is discharged from its outlet but if any abnormal situation takes place and the levels inside three phase separators have been disturbed, there is a chance of escaping some quantity of oil phase with gas phase through gas line and cause a phenomenon called oil carryover to flare (Taqa, 2022).

Carryover reasons

Most common reasons that cause oil carryover to flare are:

- High liquid level inside the separator.
- closing oil outlet valve mistakenly, or a technical problem in it.
- Damage to vessel internal parts.
- Foaming phenomenon.
- Improper design.

- Liquid outlet plugged.
- Inlet flowrates exceed the design rate for the vessel.

Failure of malfunction of pressure control valve, this will decrease the separator pressure causing oil level to increase then escaping with gas (Taqa, 2022).

Carryover remedies

Solution for carryover problem is to install an emergency shutdown valve (ESDV) at the inlet of the separator. Whenever the liquid level reaches high high, ESDV will close the inlet flow in worst case, in case that carryover just started, control room operator (CRO) should take action quickly and adjust the liquid level to bring back the operation to normal without any shutdown time loss, routine check and maintenance should take for the control valves and sensors to establish their integrity (Taqa, 2022).

Foaming

Foaming is another challenge that the operator faces during processing crude oil. Impurities appearance in crude is the major cause of foaming and CO_2 can be considered as main reason to have a foamy crude, foam is not presenting any issue in the separator if internal parts of separator can ensure sufficient time for foam breaking (Taqa, 2022).

Three major problems of foaming crude in separator are as follow:

- Mechanical control cannot reach the best performance because the control valves deal with three phases not two phases.
- Foam will fill most space in the separator and reduce space for liquid.
- Gas outlet or liquid outlet may carry out foamy crude.

Foam is a bubble of gas surrounded by a thin layer of oil and pressure drop and temperature determine the amount of foam (Taqa, 2022).

Breaking foam

Increasing temperature has two effects on foamy crude:

- Increase the temperature causes reducing the viscosity and allow gas bubble to escape from oil layer.
- Temperature increase will increase the amount of gas, which evolves from the oil.

Anti-foam injecting

Antifoam is injected to the main flow inlet of CPF to break out foamy oil (Taqa, 2022).

Gas blowby

Gas blowby is undesirable operation scenario for separation system that handling gas and liquids. gas blowby occurs when free gas escaped with liquid phase through liquid outlet when this vessel is drained completely which allow gas to flow freely to downstream vessel this may cause over pressure in the downstream vessel and lead to a very dangerous situation (Taqa, 2022).

Main reasons for occurring gas blowby are:

- Vessel level reaches low.
- Vortex breaker failure.
- Level controller failure.

Normally separator is equipped with liquid control valve (LCV) at the liquid outlet. LCV maintains a certain level in the vessel as per set point in normal operation. liquid is discharging from separator from bottom through LCV and gas is releasing from top of separator through pressure control valve (PCV),vortex breaker is installed at the outlet of liquid and its function to break any gas bubbles come with oil, if by any reason, LCV at the liquid outlet fails, there is a possibility to drain level to downstream vessel .in this scenario if high pressure gas has a free access to downstream vessel without any controlling loop will cause overpressure and other possible damage depending on the type of the downstream vessel, when LCV fails and low low level is reached, the control system should try to adjust the situation and normalize, if normalizing not take place and to avoid more dropping in the liquid level, emergency shutdown valve (ESDV) at the liquid outlet should be activated to close the liquid outlet, Pressure relieve valve should be installed at downstream to release excessive gas pressure against gas blowby (Taqa, 2022).

Chemicals additives

Chemicals additives are chemical substances are injected to different location and processes for enhancing the separation or protecting equipment's. Most used chemicals in the field are described below with a brief explanation:

- **Demulsifier**: Used to break emulsions to facilitate separation between oil and water.
- **Corrosion inhibitor**: Used to prevent corrosion in the equipment's such as separator or ESP in bottom of well.
- **Scale inhibitor**: Used to prevent the deposition of scales and debris in the pumps and lines.
- **Anti-foam**: Used to reduce the foaming in the vessels such as separator.
- **Oxygen scavenger**: Used to mitigate corrosion problems in desalting system due to existing high amount of wash water.
- **H_2S scavenger**: Used to remove H_2S from the crude oil.
- **Glycol:** Used in water path indirect heater because it's good heat transfer capability and it is low freezing point when mixed with water.

These can cause fires, explosions, corrosion, and hazardous reactions if not handled safely which may cause cancer (Taqa, 2022).

- **Flammable:** Can cause fires easily.
- **Toxic**: Harmful for both contact with skin or inhalation.
- **Corrosive**: Burns the skin if they contact with it.
- **Irritant**: Can damage eyes or skin in case of contact with them.
- **Harmful to environment**: Can be harmful if its vapor released to environment.
- **Explosive**: Can make explosion.

Heating Source

Once the crude oil is brought to surface, it needs to be heated to make it suitable for handling .in addition this crude contains water, gas and some impurities that have to be separated. In case of heavy oil which is too thick and viscous it's tough to pump it easily therefore heating this heavy crude will reduce the viscosity and ease its flow.

Special methods have been developed for this purpose in cost effective manner and as per safety regulations. Normally there are three main techniques for heating available at oil and gas field:

- **Hot oil system**: Heating a special type of organic or synthetic thermal oils.
- **Water path system**: Heating a water.

CHAPTER III

Methodology

Thesis Plan

For this thesis to be done, the thesis has taken five stages and can be summarized below:

First Stage: Literature Review

In this stage the required document has been reviewed including, books and field documents which allow me to understand more about the theoretical and scientifically background of crude oil processing and pressure optimization.

Second Stage: Collection of Required Input Data

For building the plant model in order to run simulation and calculate required parameters the following data has been collected and validated:

- Crude oil compositions
- Operating parameters such as flowrate, pressure, and temperature
- Equipment data such as vessel capacity

Third Stage: Modeling and Simulation

After collection all required data the plant model was used and required adjustments were implemented to obtain a corrected model to achieve the goal of the project.

Fourth Stage: Execution of Simulation and Results

Once the plant model has been built and corrected, several cases were run, and the results were collected.

Fifth Stage: Analyzing the Results and Discussion

Results of the modeling were presented and analyzed to select the best result and show the reasons for why other results are not suitable.

Peng-Robinson Equation

Peng-Robinson equation is one of the most used equations of state in the oil and gas industry for calculating thermodynamic properties of different hydrocarbon systems pure fluids and mixture fluids. Peng-Robinson equation requires minimal data so it can provide algebraic simplicity and generality in the simulation field, for determining pure fluid system properties. Data required in this case is only the critical pressure and critical temperature, for non-ideal mixture system binary interaction parameters are required in addition to calculate and determine the properties of this system. The Peng-Robinson equation can be utilized to do the calculations for multi-component liquid-vapor phase equilibrium if the binary interaction parameters are known, Peng-Robinson equation of state has been used in the simulation modeling in ProMax simulator to do this thesis because that Peng-Robinson equation provides accurate and reasonable estimation of liquid and vapor phase densities .as a result it can be established that the equation of state Peng-Robinson can be utilized to calculate vapor pressure of pure fluids system and mixture fluid mixture systems. (Klein and Nelis, 2011).

The Peng-Robinson equation is:

$$P = \frac{RT}{v-b} - \frac{a(T)}{v(v+b)+b(v-b)} \quad (3.1)$$

P = Is the pressure.

T = Is the absolute temperature.

v = Is specific volume.

a(T) = Is a fluid-specific constant that depends on temperature.

b **=** Is a fluid-specific constant.

R= Constant

Promax Simulator

Promax software is the product of Bryan Research and Engineering developed and sold by Bryan Research and Engineering which is a chemical process simulator used to design , optimize and troubleshooting of different types of plants in oil and gas industry. ProMax software uses Microsoft Visio as the graphical user interface in for plant modeling and enabling to model huge amount of any process in the oil and gas industry, Promax simulator requires crude oil composition and operating parameters such as flowrate, pressure, and temperature to model the plant and do the required calculations.

Process Description

Based on the model has been built in the ProMax software the following process flow diagram is obtained:

The Atrush processing facility built in the first phase is known as PF-1 and processes crude oil from four artificially lifted wells by separating out any water and flaring all the sour gas. It was built on four terraces carved out of the mountain with the main processing facilities high up on Terrace 2 (Taqa, 2021).

All Atrush wells have down hole electric submersible pumps installed which lift the fluids to surface and push them through the PF-1 plant. Future planned wells currently under development are CK-7 and CK-10 on Chamanke E pad which will be routed back via two new flexible flowlines to the CPF Inlet Facilities on Terrace 4, Terrace 3 contains the main control room, the main electrical switchroom, instrument air, nitrogen, utility water, foam water and power generation. Power is provided via two Solar Taurus 70 dual fuel machines running on diesel and a diesel emergency generator (EDG), Normally only one main generator is required to meet the site electrical load (Taqa, 2021).

Three wells (AT-4, CK-5 and CK-8) are on Chamanke A drill pad about 3km from PF-1 and so are commingled and sent via a buried flowline to PF-1, the other well AT-2 is on Terrace 1 within PF-1 and has a short flowline to the production manifold where it joins fluids from Chamanke A, Multi-phase flowmeters are provided at Chamanke A and at the PF-1 production and test manifolds to allow well testing, a variety of chemical injection skids are installed at the wellheads and at the inlet manifold to allow corrosion inhibitor and other chemicals to be injected at specified rates

All fluids are routed from the production manifold to the two-phase slug catcher where some gas comes out of solution due to the pressure drop and is flared, then the fluids flow to the three phase inlet separator having first passed through a heat exchanger to warm them up and improve separation, free water is removed in the Inlet separator (none currently present) and passes to the oil skimmer for recovery of any entrained oil and then flows to the produced water storage tank for eventual disposal, further gas comes out of solution in both the inlet separator and the oil skimmer vessels and is flared via the low pressure flare system LP (Taqa, 2021).

The oil flows from the inlet separator through another crude oil heat exchanger, to warm up it further, to Tray 8 of the crude oil stabilization column, where water and any remaining gas is boiled off using a reboiler, which is heated via a hot oil recirculation loop. Another cold stream from the inlet separator bypasses the crude oil exchanger and enters the column at Tray 1, stripping liquids from the rising gas vapor, this oil stabilization process reduces the sour gas (H_2S) content to less than 20ppm to enable us to maximize export oil value, Vapor from the top of the column is routed to the low pressure flare system LP but column operating pressure can also be maintained by nitrogen blanketing when gas deficient (Taqa, 2021).

Dry stabilized oil exits the bottom of the column and passes through the other side of the above mentioned two heat exchangers to cool down again against incoming well fluids. It is then pumped by the stabilized crude pumps, sampled its temperature trimmed by an oil cooler/heater (as required) and routed to the on-spec storage tank if the required export oil specification is met. Should the oil export specification not be achieved then this fluid is diverted to the off-spec storage tank where it is stored and later recycled back to the inlet separator using the re-run pumps for reprocessing (Taqa, 2021).

CHAPTER IV

Case Studies

Simulation Case Study Normal Operating Plant

Pressure of the following pressure vessels are being adjusted and optimized:

- Slug catcher
- Inlet separator
- Stabilization column

Table 4.1: Normal operating pressure vessels.

Vessel	Pressure
Slug catcher	8.5 bar
Inlet separator	5.5 bar
Stabilization column	2.6 bar

Analyzing of daily samples of exported crude oil at CPF laboratory show that the hydrogen sulfide (H_2S) is 7 ppm as average, while the result of reid vapor pressure (RVP) is 2.5 psi as average. Depending on the above laboratory analyzing results of hydrogen sulfide (H_2S) and reid vapor pressure (RVP) we can adjust the simulation model to get the best result for the optimization of the pressure profile of the plant.

Table 4.2: Lab results for normal operating plant.

H_2S	RVP
5.5 ppm	2.55 psi

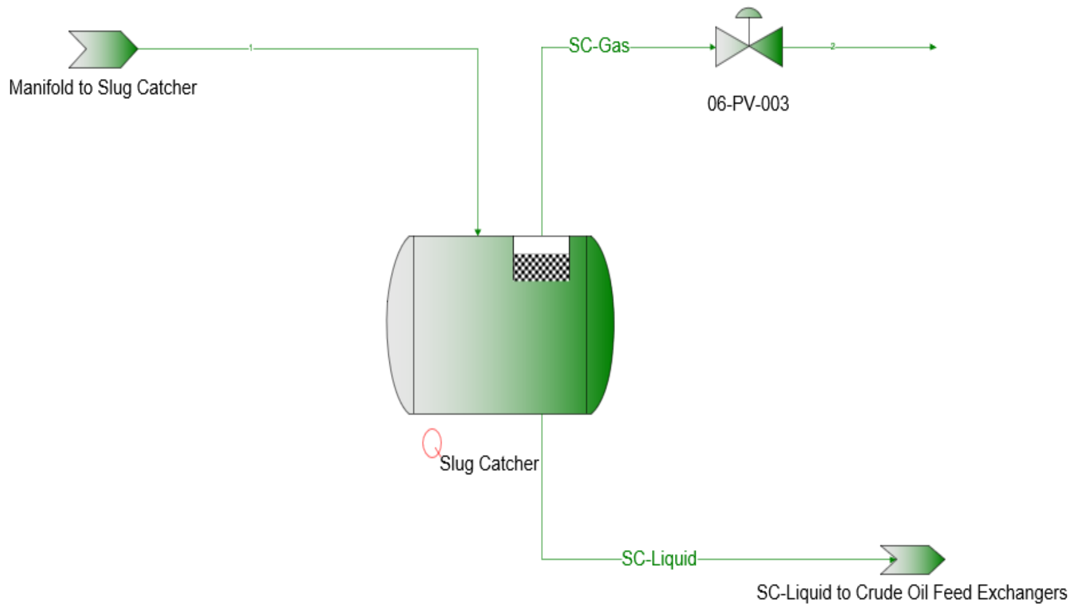


Figure 4.1: Slug catcher vessel.

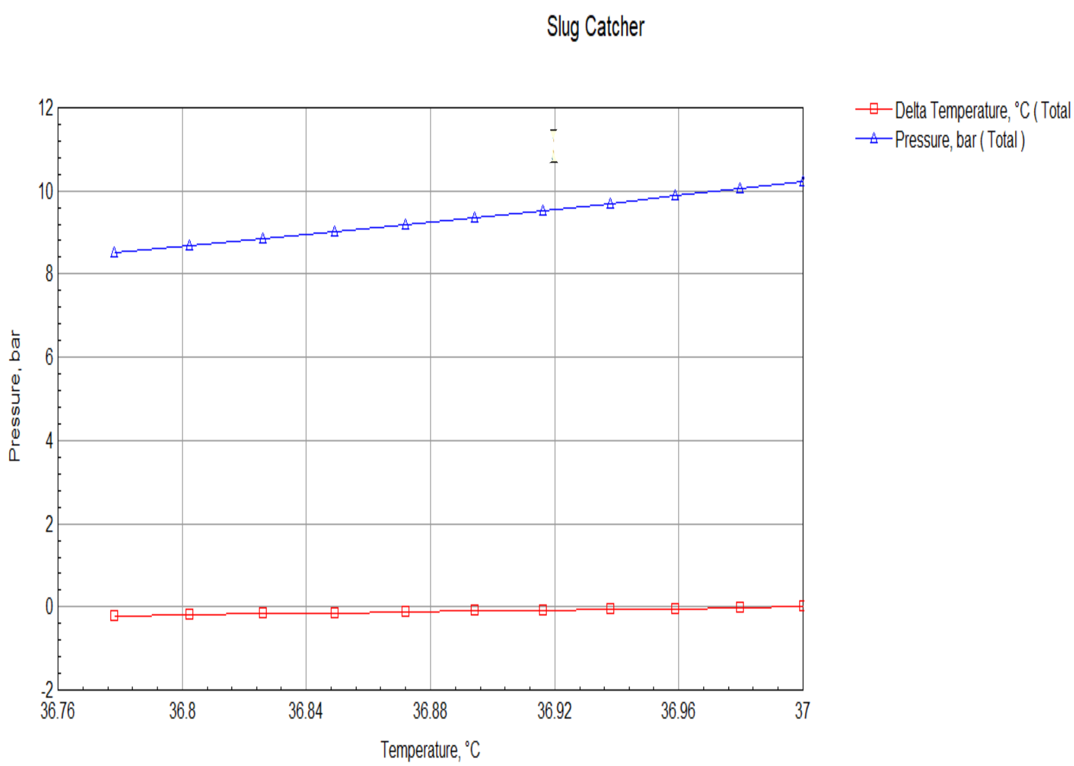


Figure 4.2: Slug catcher pressure and temperature.

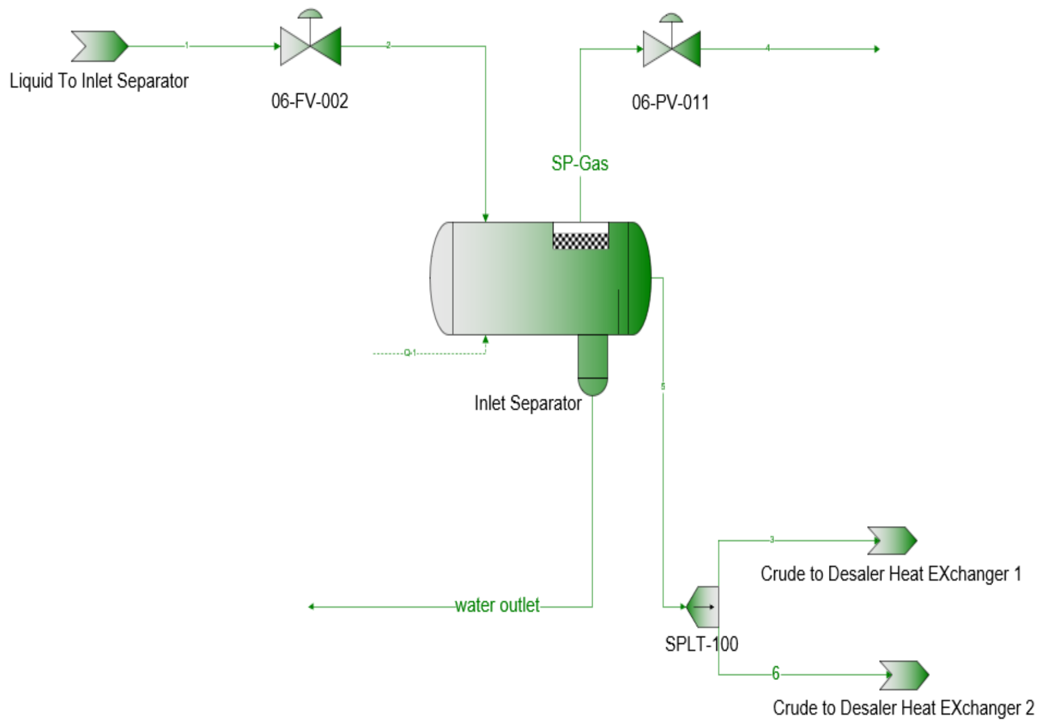


Figure 4.3: Inlet separator.

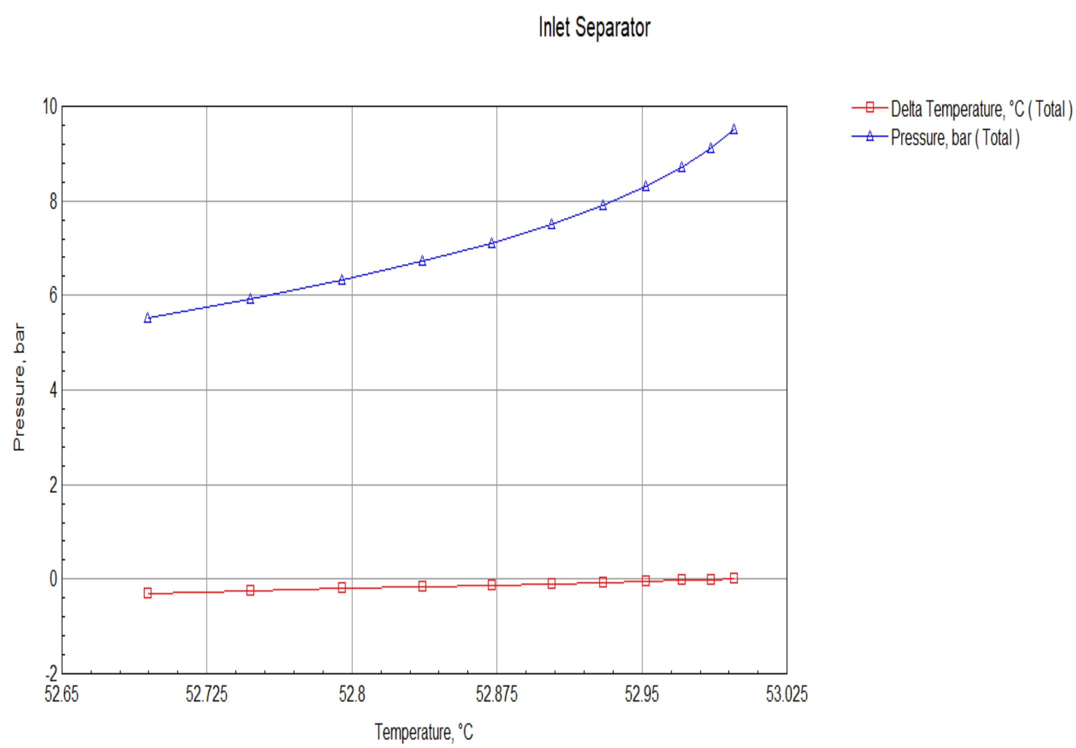


Figure 4.4: Inlet Separator pressure and temperature.

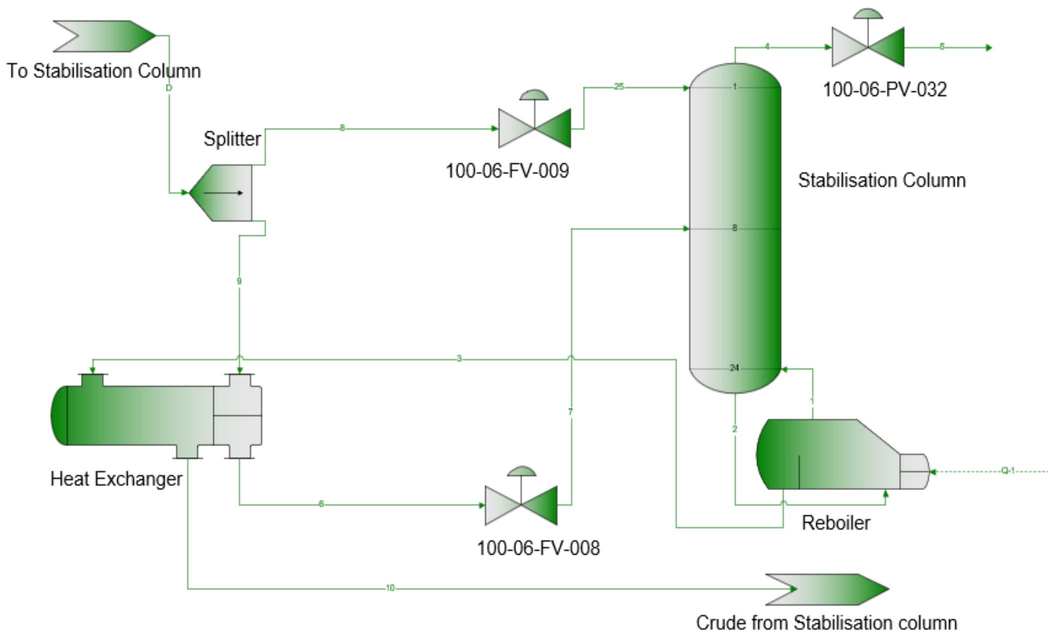


Figure 4.5: Stabilization column.

Pressure Change	0.2	bar
Bottoms Head	0	bar
Pressures from Hardware	☐	

Stage	Show Stage	3 Phases	Pressure	Temperature		Molar Flow		
				Vapor	Liquid	Vapor	Light Liquid	Heavy Liquid
			bar	°C		kmol/h		
4	☐	☐	2.62609	50.5825	49.905	38.1074	112.115	
5	☐	☐	2.63478	51.6074	51.003	41.184	114.731	
6	☐	☐	2.64348	52.5528	51.9382	43.7999	116.898	
7	☐	☐	2.65217	53.5653	52.7726	45.9669	118.686	
8	☑	☐	2.66087	54.9544	54.1905	47.755	153.843	
9	☐	☐	2.66957	56.0656	55.3043	48.2262	157.328	
10	☐	☐	2.67826	57.0769	56.3315	51.7113	160.485	
11	☐	☐	2.68696	58.093	57.3145	54.8675	163.409	
12	☐	☐	2.69565	59.1796	58.3156	57.7921	166.272	
13	☐	☐	2.70435	60.4054	59.4053	60.6545	169.271	
14	☐	☐	2.71304	61.8335	60.6544	63.6537	172.61	
15	☐	☐	2.72174	63.5142	62.1255	66.9926	176.472	
16	☐	☐	2.73043	65.4777	63.8626	70.8544	180.986	
17	☐	☐	2.73913	67.7373	65.8773	75.3691	186.179	
18	☐	☐	2.74783	70.3183	68.4349	80.5615	192.816	
19	☐	☐	2.75652	73.2351	71.1884	87.1992	199.902	
20	☐	☐	2.76522	76.4251	73.9968	94.2853	206.698	

Figure 4.6: Stabilization column pressure.

In the Figure 4.6 we can observe clearly that the temperature and pressure at the bottom of the stabilization column is higher than temperature and pressure at the top of the tower. The reason is that vapor is coming from the reboiler and entering stabilization column from the bottom to remove H_2S from the crude oil and take it out from the stabilization column throw the gas line.

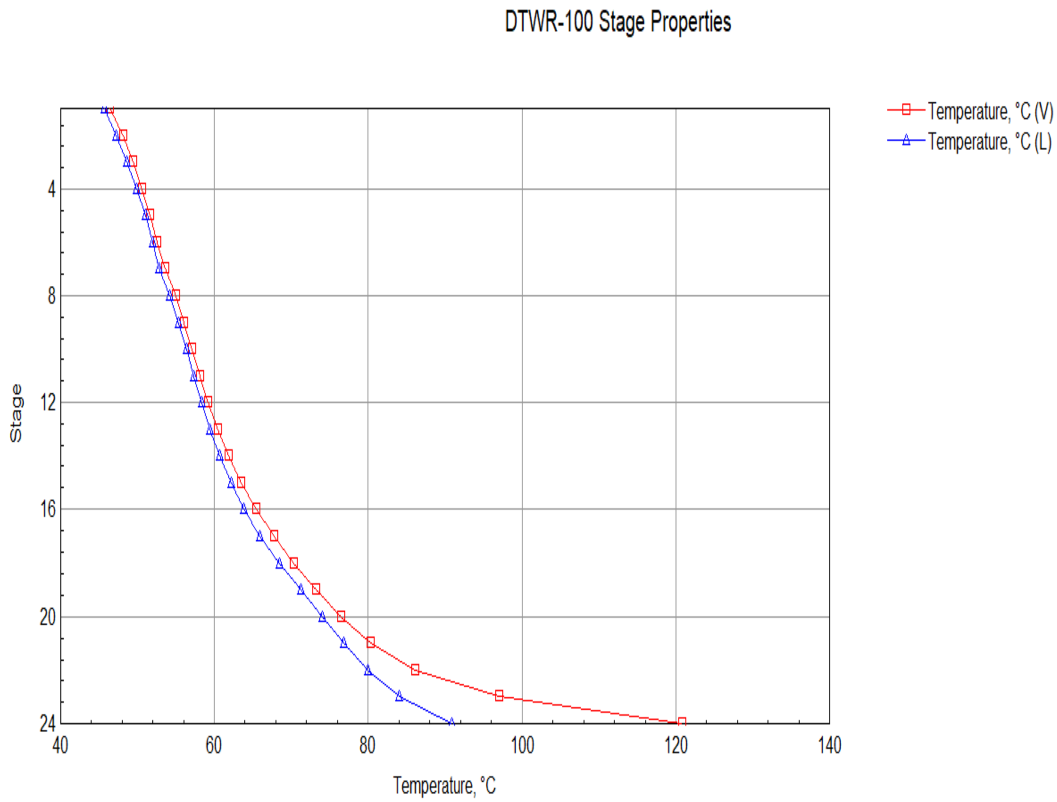


Figure 4.7: Stabilization column temperature.

In the Figure 4.7 there are two curves one of them temperature without reboiler vapor and second curve is temperature with reboiler vapor. In both curves the temperature is increasing from the top of the tower gradually stage by stage until the bottom of the tower which is stage 24, in the last stage the temperature is maximum.

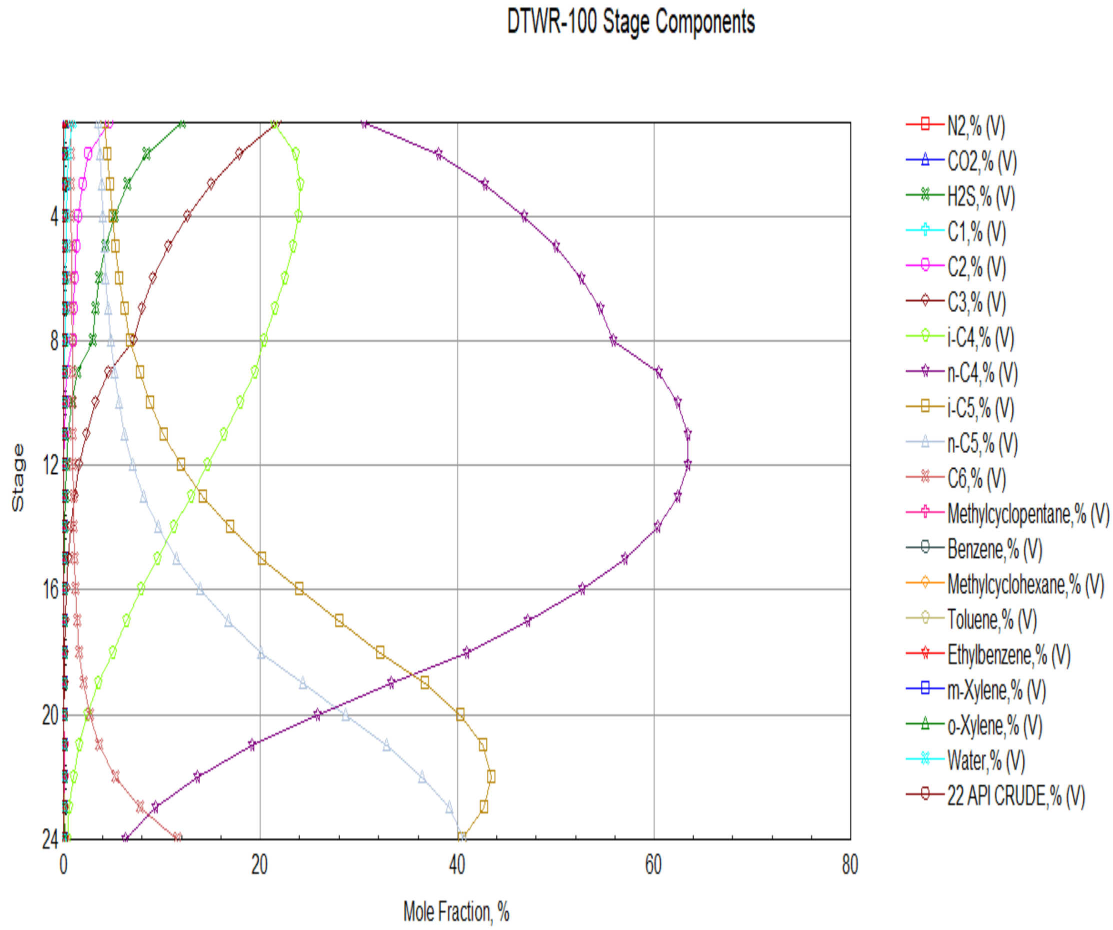


Figure 4.8: Stabilization column components.

Figure 4.8 describe the enthalpy of the components of fluids in the stabilization column with stages. For example, the enthalpy curve of H_2S is showing that H_2S is minimum at the bottom of the tower because of the vapor is removing H_2S and pushing to the top of the tower which is maximum H_2S.

Simulation Case Study One

Pressure of the following pressure vessel is being adjusted and optimized:

- Slug catcher pressure increased 1 bar.
- Inlet separator pressure increased 0.5 bar.
- Stabilization column pressure increased 0.05 bar.

Table 4.3: Change in Vessels Pressure.

Vessel	**Pressure**
Slug catcher	9.5 bar
Inlet separator	6 bar
Stabilization column	2.65 bar

Simulation results for case study one show that the hydrogen sulfide (H_2S) is 8 ppm as average, while the result of reid vapor pressure (RVP) is 2.55 psi as average.

Table 4.4: Simulation results for case study one.

H_2S	**RVP**
5.5 ppm	2.55 psi

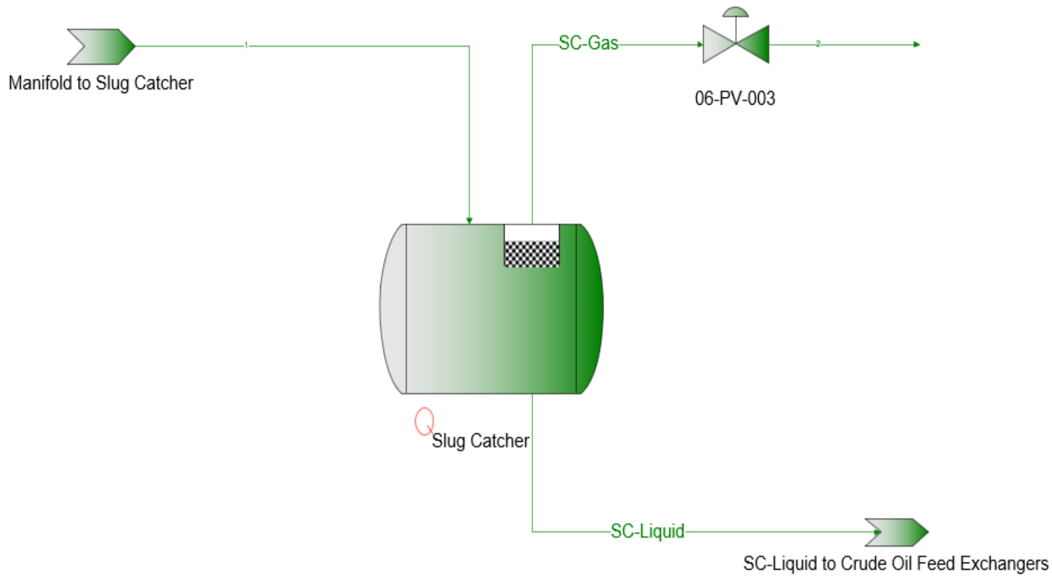


Figure 4.9: Slug catcher.

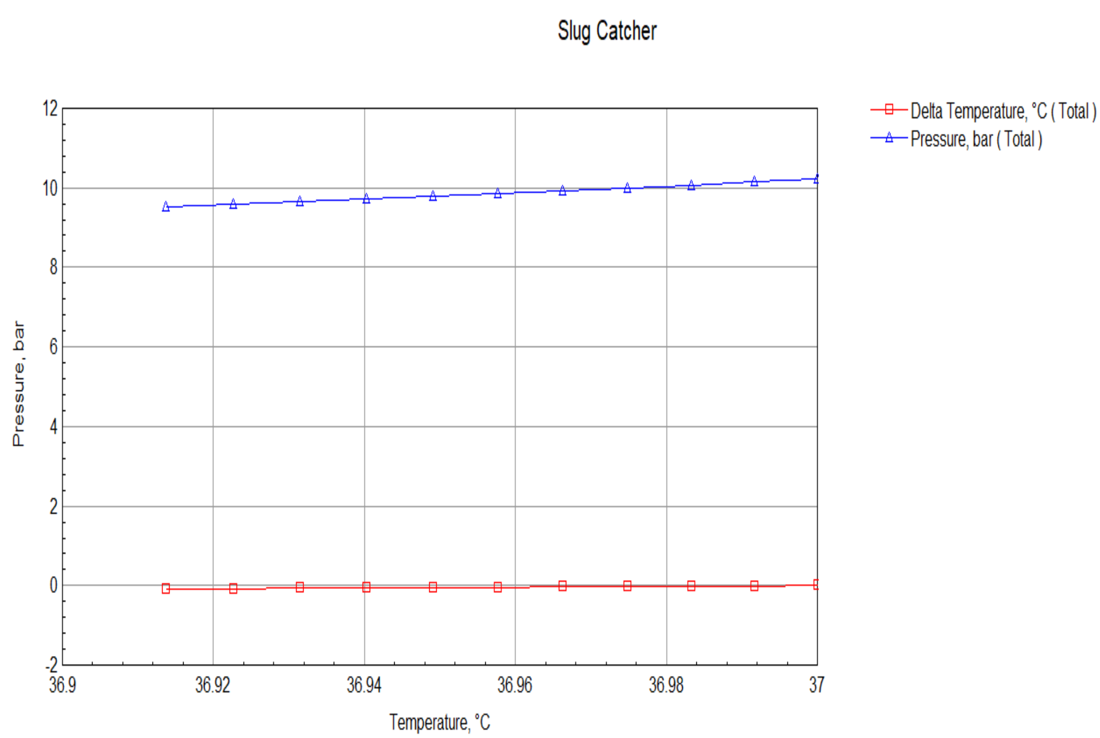


Figure 4.10: Slug catcher pressure and temperature.

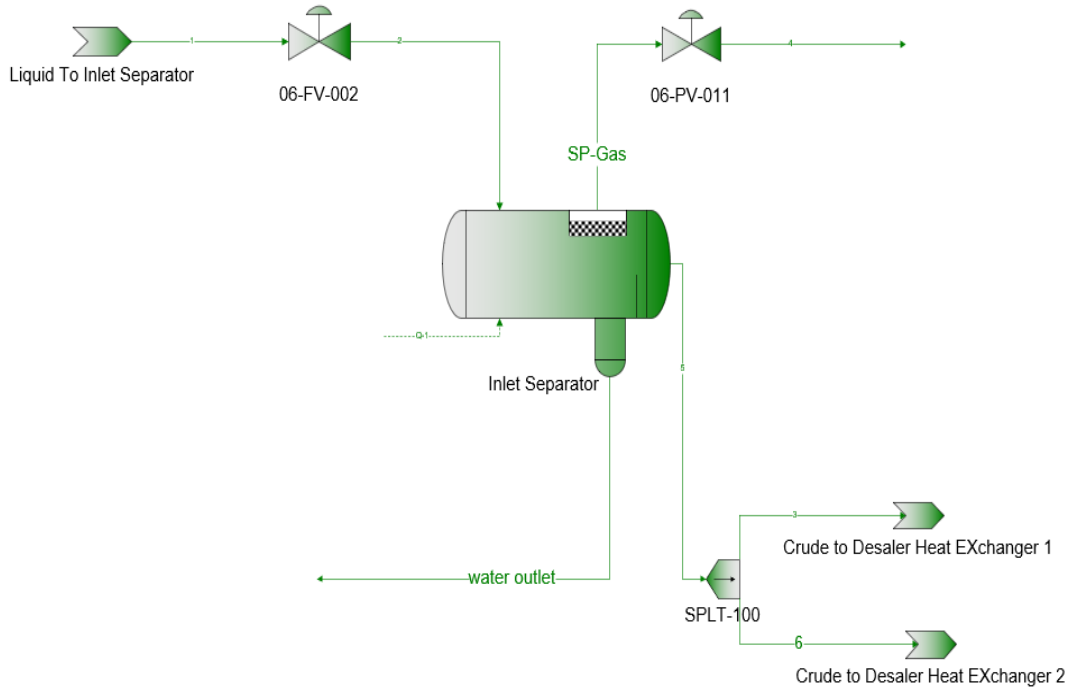


Figure 4.11: Inlet separator.

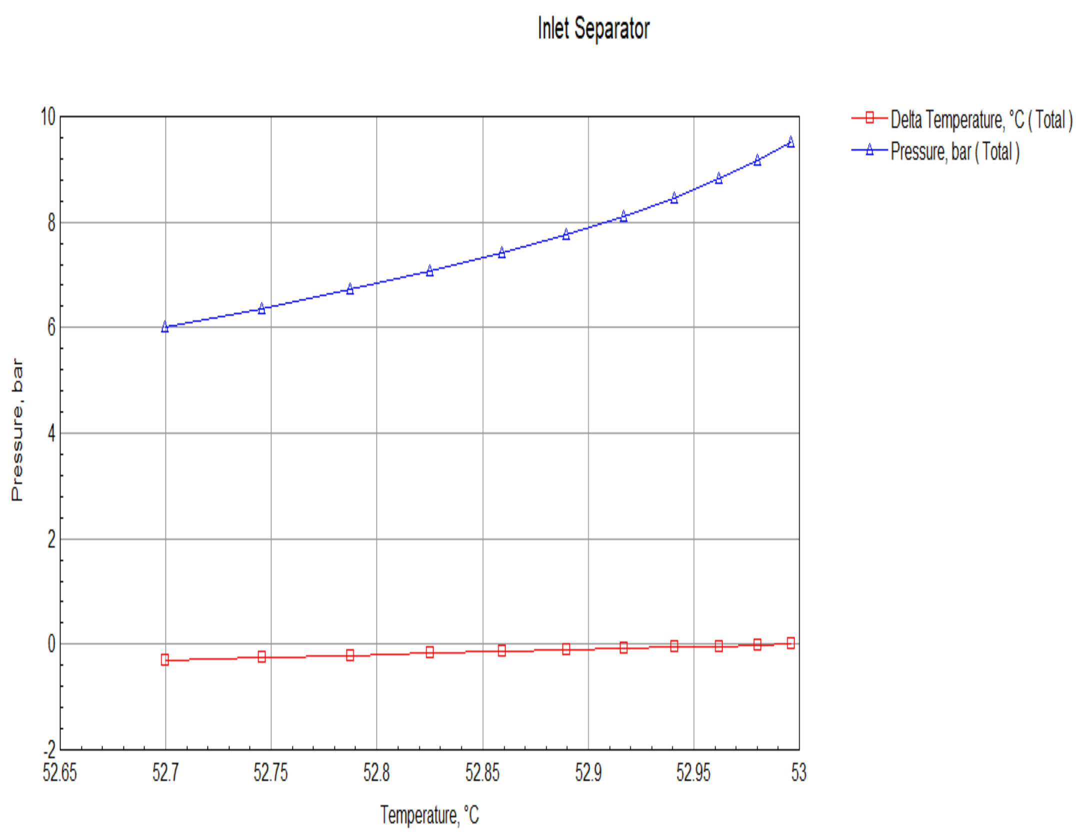


Figure 4.12: Inlet Separator pressure and temperature.

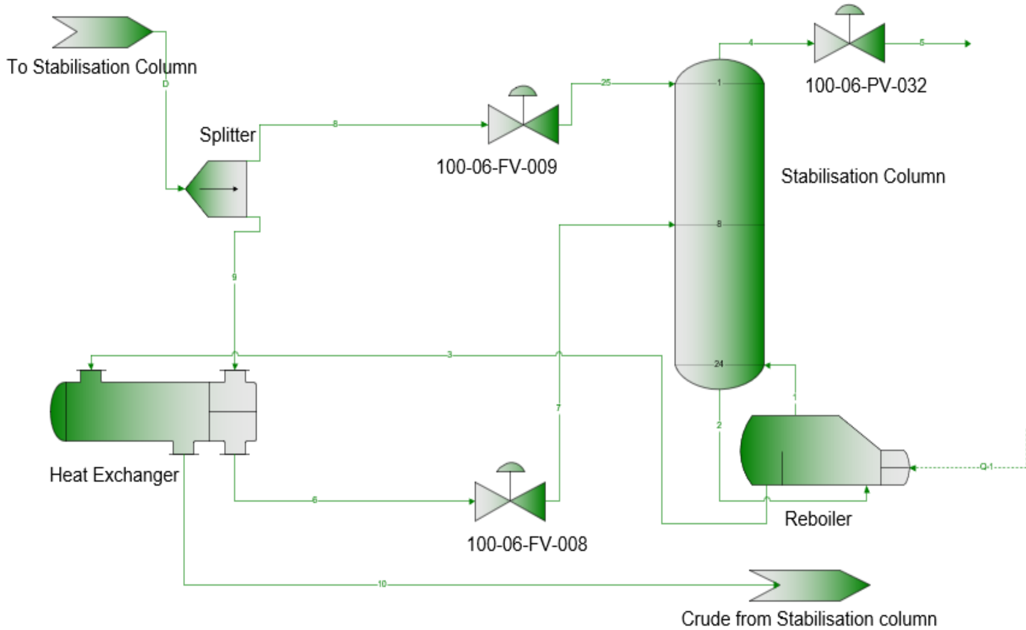


Figure 4.13: Stabilization column.

Pressure Change	0.2	bar
Bottoms Head	0	bar
Pressures from Hardware	☐	

Stage	Show Stage	3 Phases	Pressure	Temperature		Molar Flow		
				Vapor	Liquid	Vapor	Light Liquid	Heavy Liquid
			bar	°C		kmol/h		
1		☐	2.65	46.1432	45.3581	35.3762	102.951	
2	☐	☐	2.6587	47.8409	46.9229	32.377	106.614	
3	☐	☐	2.66739	49.1922	48.396	36.0396	110.12	
4	☐	☐	2.67609	50.3746	49.6967	39.5455	113.24	
5	☐	☐	2.68478	51.4005	50.8012	42.6663	115.879	
6	☐	☐	2.69348	52.338	51.7343	45.3052	118.049	
7	☐	☐	2.70217	53.3327	52.5583	47.4748	119.82	
8	☑	☐	2.71087	54.6917	53.9405	49.2455	155.217	
9	☐	☐	2.71957	55.7993	55.0593	49.3262	158.751	
10	☐	☐	2.72826	56.7776	56.0708	52.8597	161.897	
11	☐	☐	2.73696	57.7372	57.0152	56.0061	164.747	
12	☐	☐	2.74565	58.7437	57.9534	58.856	167.466	
13	☐	☐	2.75435	59.8672	58.9554	61.575	170.251	
14	☐	☐	2.76304	61.1767	60.0933	64.3599	173.306	
15	☐	☐	2.77174	62.7343	61.4361	67.4154	176.827	
16	☐	☐	2.78043	64.5899	63.0418	70.9363	180.975	
17	☐	☐	2.78913	66.7818	64.9454	75.084	185.833	

Add Stage(s) Delete Stage(s)

Figure 4.14: Stabilization column pressure.

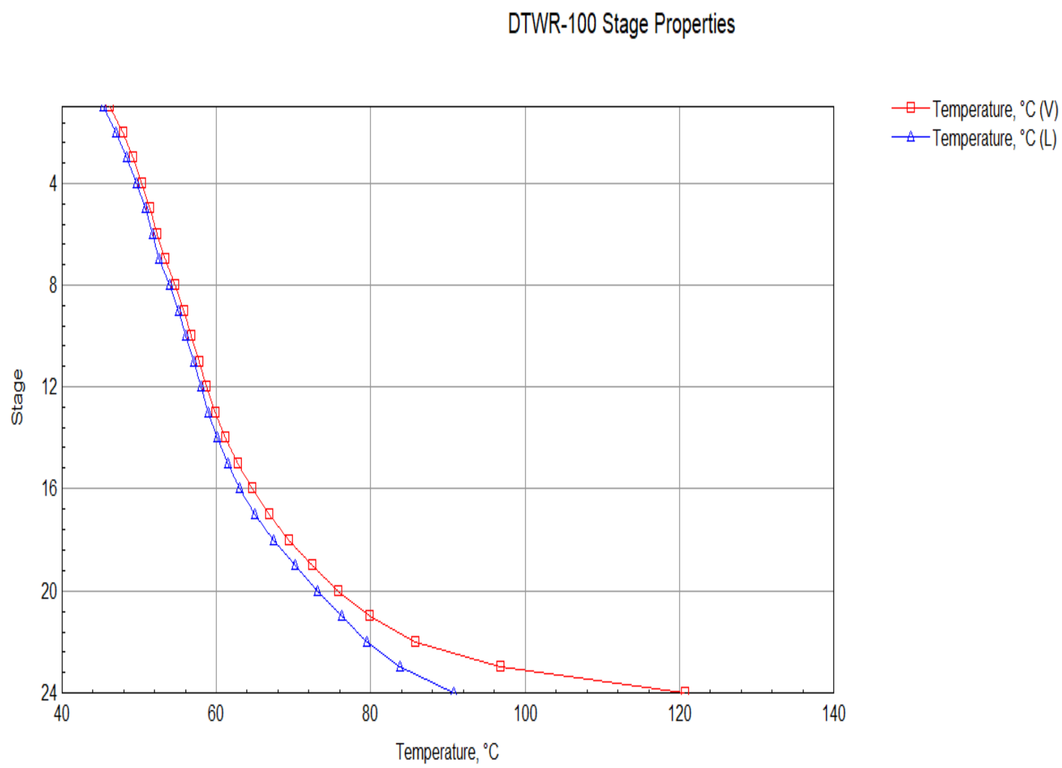


Figure 4.15: Stabilization column temperature.

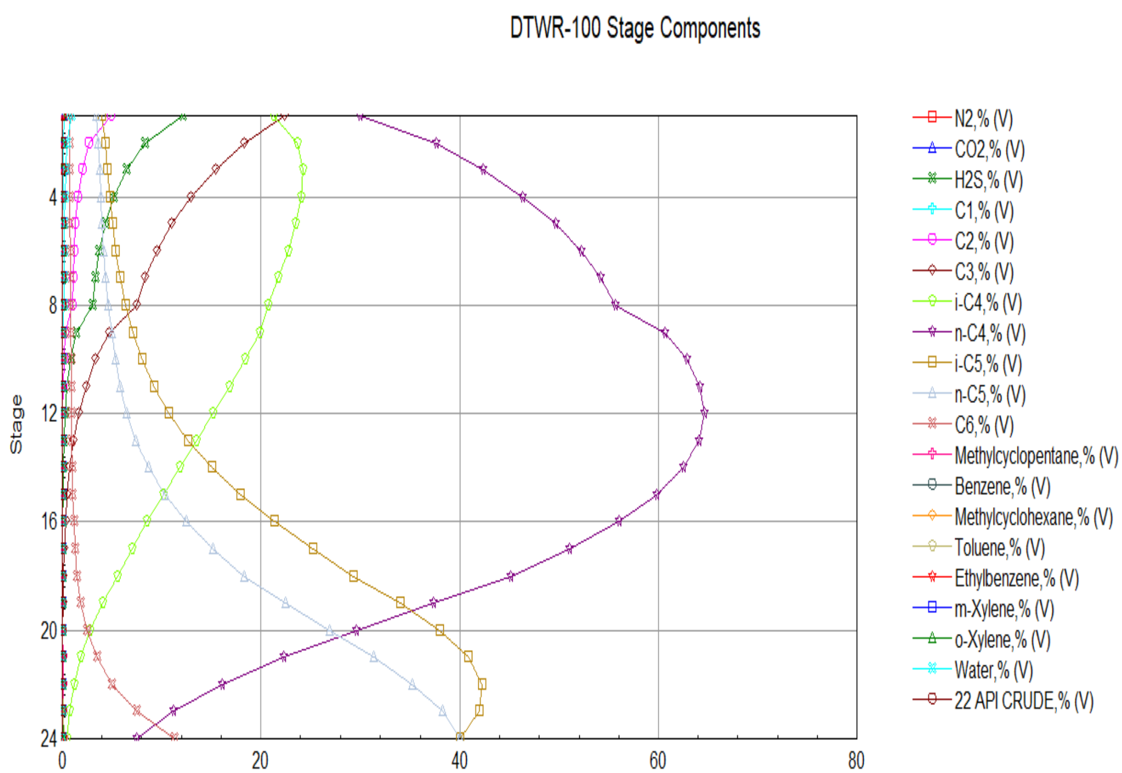


Figure 4.16: Stabilization column components.

Simulation Cases Study Two

Pressure of the following pressure vessel is being adjusted and optimized:

- Slug catcher pressure increased 2 bar.
- Inlet separator pressure increased 1 bar.
- Stabilization column pressure increased 0.1 bar.

Table 4.5: Change in pressure vessels for case study two.

Vessel	Pressure
Slug catcher	10.5 bar
Inlet separator	6.5 bar
Stabilization column	2.7 bar

Simulation results for case study one show that the hydrogen sulfide (H_2S) is 8 ppm as average, while the result of reid vapor pressure (RVP) is 2.55 psi as average.

Table 4.6: simulation results for case two

H_2S	RVP
5.5 ppm	2.55 psi

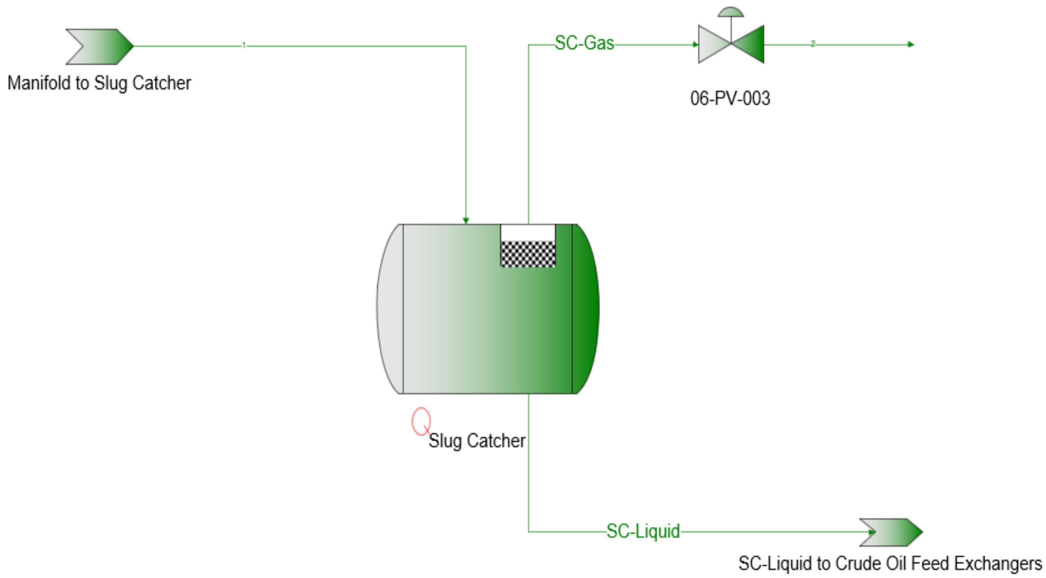


Figure 4.17: Slug catcher.

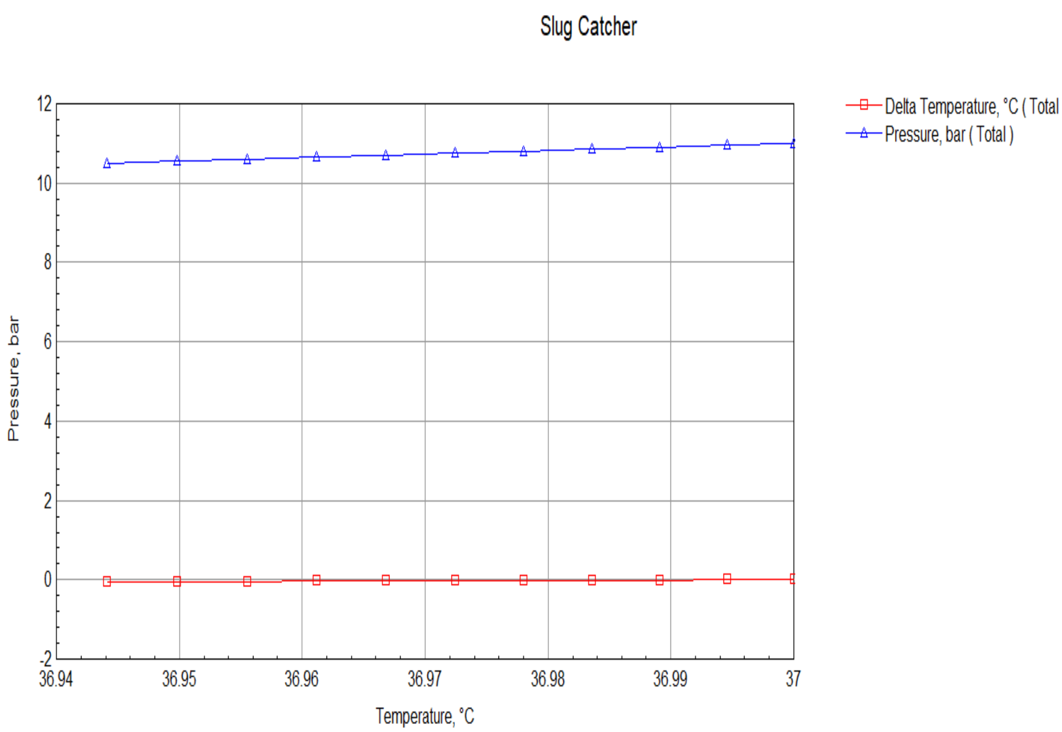


Figure 4.18: Slug catcher pressure and temperature.

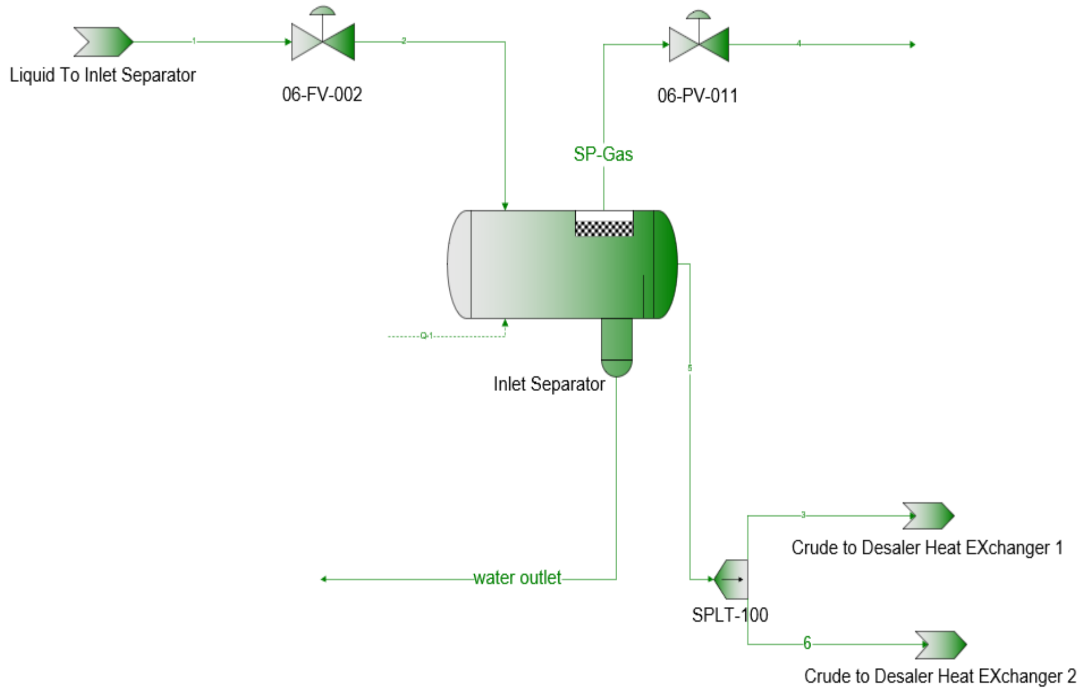


Figure 4.19: Inlet separator.

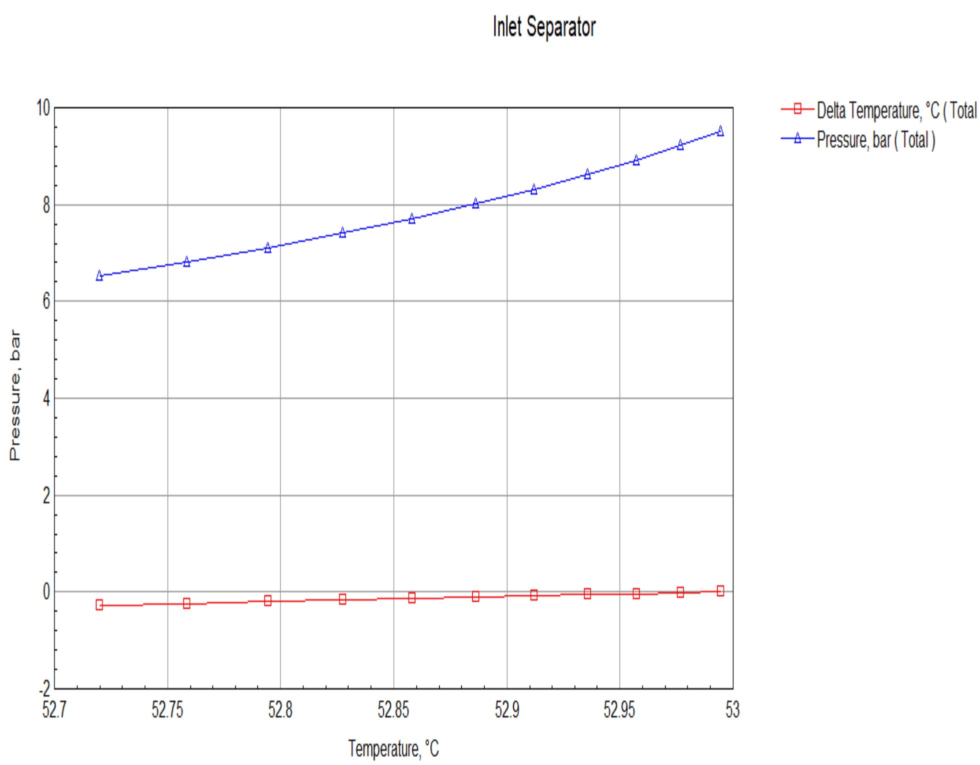


Figure 4.20: Inlet separator pressure and temperature.

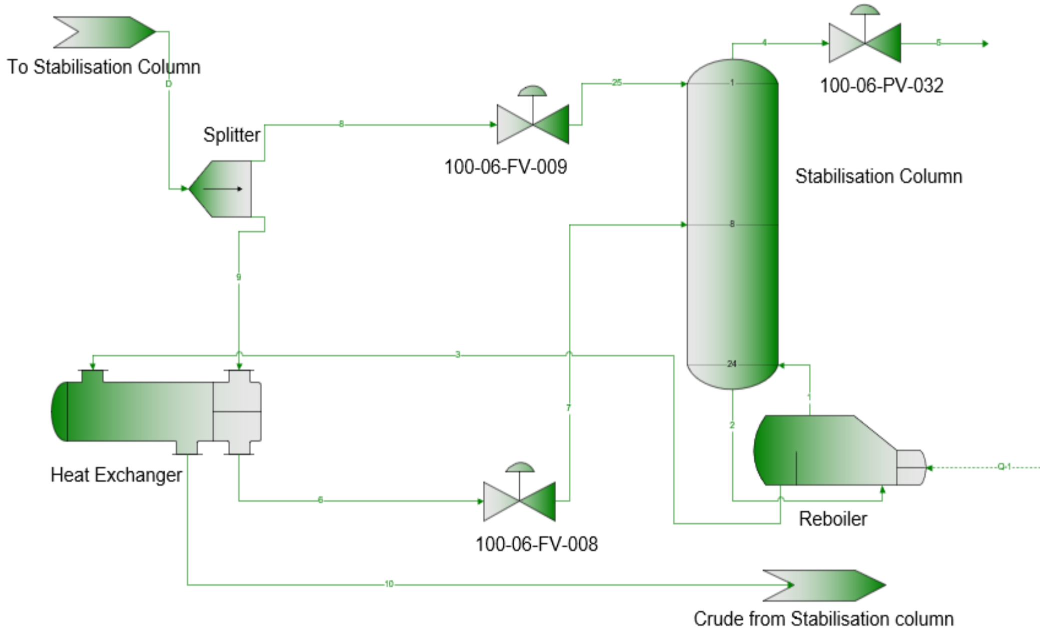


Figure 4.21: Stabilization column.

Pressure Change	0.2	bar
Bottoms Head	0	bar
Pressures from Hardware	☐	

Stage	Show Stage	3 Phases	Pressure	Temperature		Molar Flow		
				Vapor	Liquid	Vapor	Light Liquid	Heavy Liquid
			bar	°C		kmol/h		
1		☐	2.7	47.6682	46.7404	26.9967	100.562	
2	☐	☐	2.7087	49.2591	48.3042	28.1454	104.264	
3	☐	☐	2.71739	50.641	49.8077	31.8472	107.882	
4	☐	☐	2.72609	51.8578	51.1526	35.4653	111.151	
5	☐	☐	2.73478	52.9071	52.2965	38.7341	113.931	
6	☐	☐	2.74348	53.8459	53.2507	41.5136	116.203	
7	☐	☐	2.75217	54.8125	54.0692	43.7858	118.024	
8	☑	☐	2.76087	56.1084	55.4421	45.6069	152.86	
9	☐	☐	2.76957	57.0277	56.4226	47.3048	156.03	
10	☐	☐	2.77826	57.8202	57.2736	50.4752	158.759	
11	☐	☐	2.78696	58.5554	58.028	53.2038	161.123	
12	☐	☐	2.79565	59.2865	58.7345	55.5678	163.258	
13	☐	☐	2.80435	60.0722	59.4488	57.7034	165.325	
14	☐	☐	2.81304	60.9761	60.2301	59.7697	167.488	
15	☐	☐	2.82174	62.0675	61.1412	61.9329	169.917	
16	☐	☐	2.83043	63.4249	62.2485	64.362	172.781	
17	☐	☐	2.83913	65.1423	63.6214	67.2256	176.234	

Figure 4.22: Stabilization column pressure.

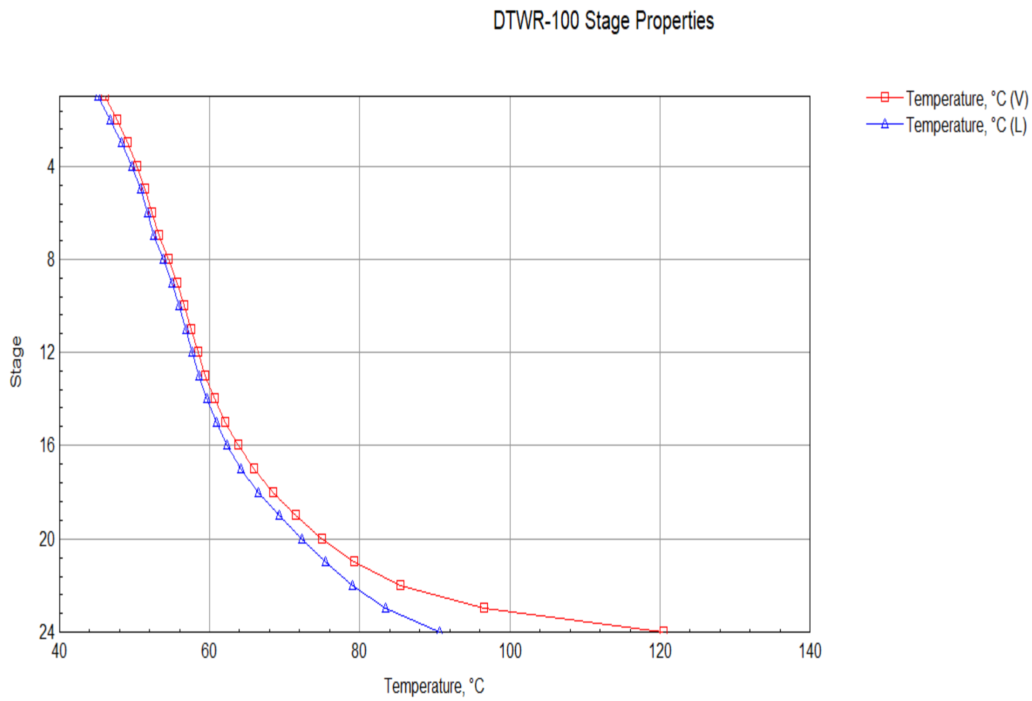


Figure 4.23: Stabilization column temperature.

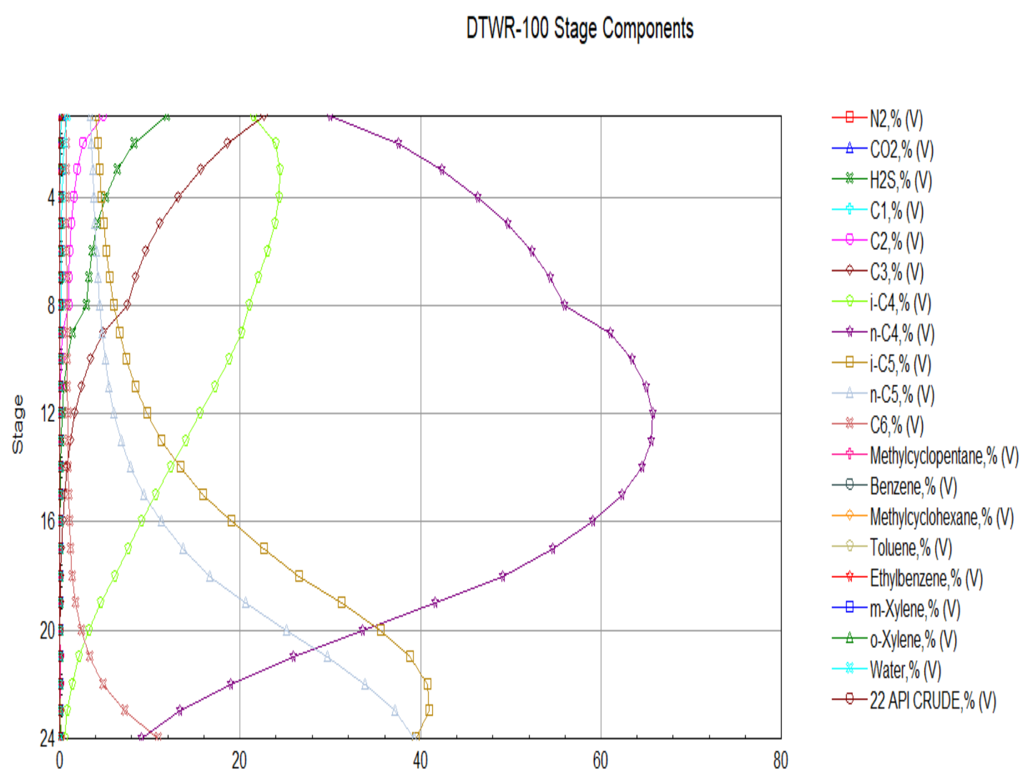


Figure 4.24: Stabilization column components.

Simulation Case Study Three

Pressure of the following pressure vessel is being adjusted and optimized:

- Slug catcher pressure decreased 1 bar.
- Inlet separator pressure decreased 0.5 bar.
- Stabilization column pressure decreased 0.05 bar.

Table 4.7: Change in pressure vessels for case study three.

Vessel	Pressure
Slug catcher	7.5 bar
Inlet separator	5 bar
Stabilization column	2.55 bar

Simulation results for case study one show that the hydrogen sulfide (H_2S) is 5.7 ppm as average, while the result of reid vapor pressure (RVP) is 2.3 psi as average.

Table 4.8: Simulation results for case study three.

H_2S	RVP
5.7 ppm	2.3 psi

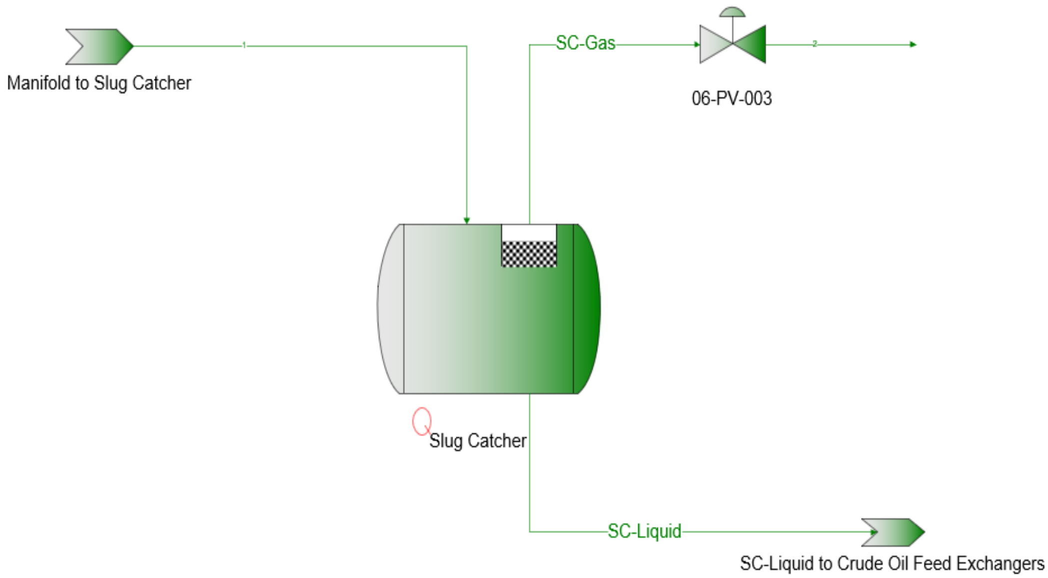


Figure 4.25: Slug catcher.

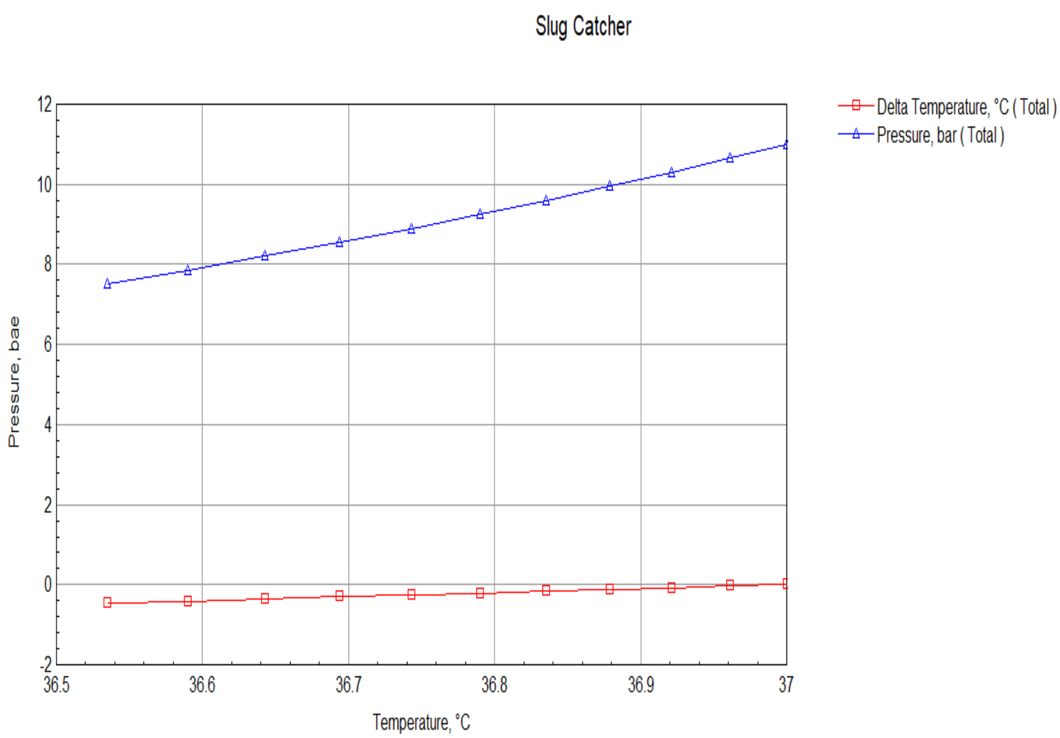


Figure 4.26: Slug catcher pressure and temperature.

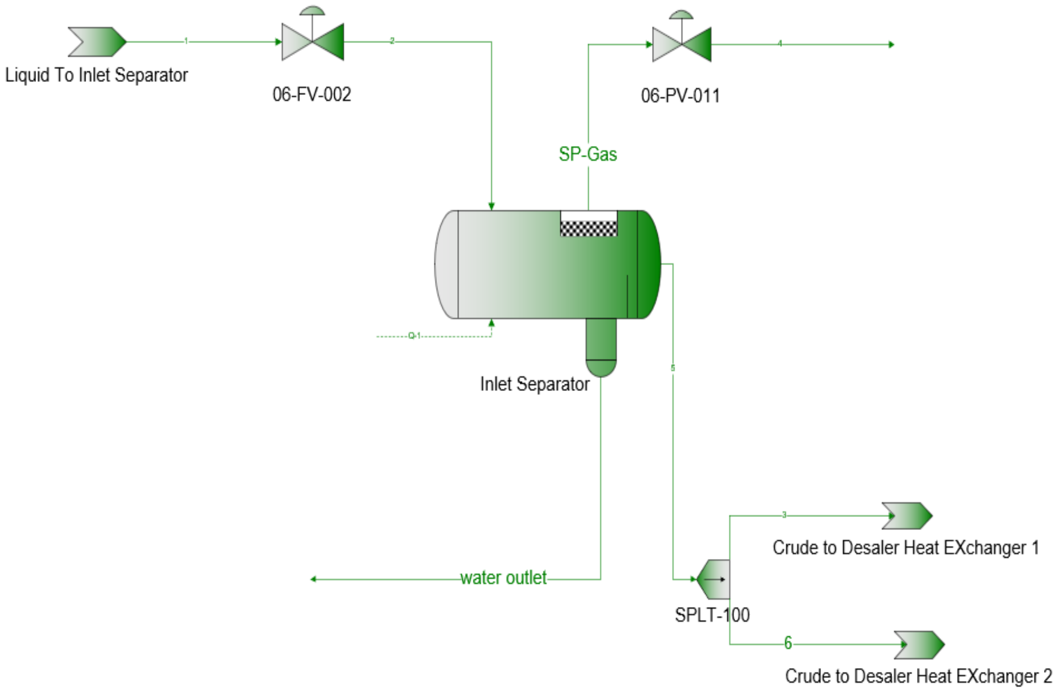


Figure 4.27: Inlet separator.

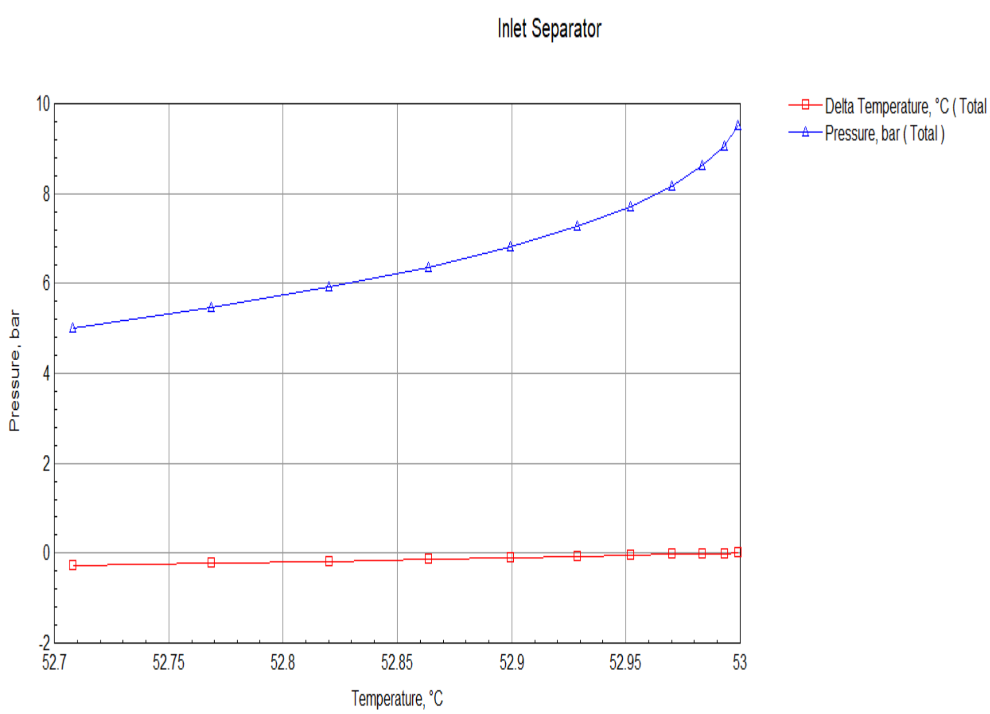


Figure 4.28: Inlet Separator pressure and temperature.

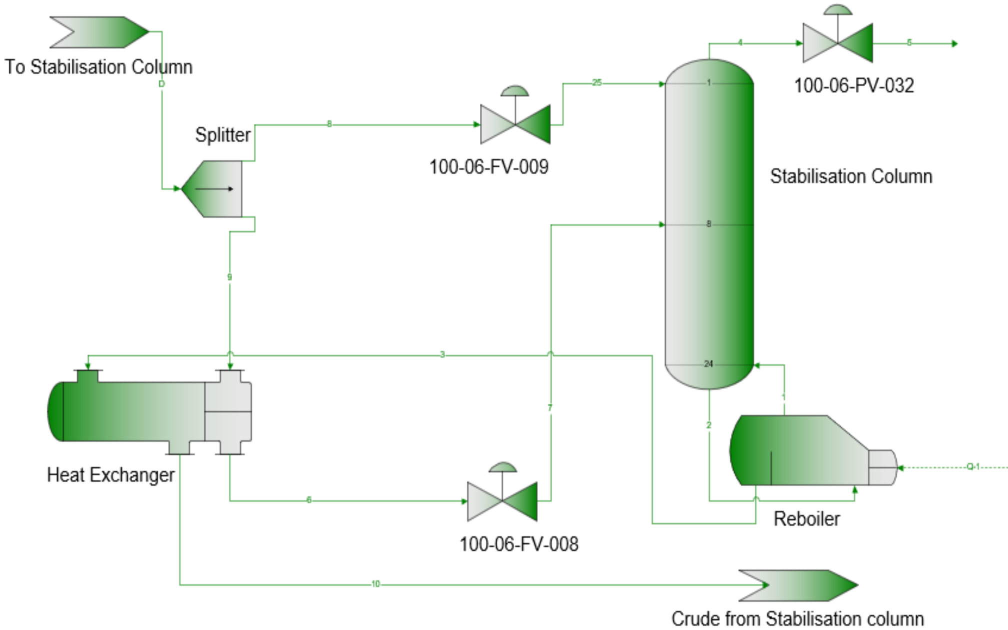


Figure 4.29: Stabilization column.

Pressure Change	0.2	bar
Bottoms Head	0	bar
Pressures from Hardware	☐	

Stage	Show Stage	3 Phases	Pressure	Temperature		Molar Flow		
				Vapor	Liquid	Vapor	Light Liquid	Heavy Liquid
			bar	°C		kmol/h		
1		☐	2.55	46.7786	45.971	30.5609	100.84	
2	☐	☐	2.5587	48.3635	47.4672	29.5031	104.337	
3	☐	☐	2.56739	49.6769	48.8904	32.9997	107.714	
4	☐	☐	2.57609	50.8407	50.1616	36.3771	110.752	
5	☐	☐	2.58478	51.8662	51.2553	39.4153	113.353	
6	☐	☐	2.59348	52.8206	52.1944	42.0161	115.525	
7	☐	☐	2.60217	53.8508	53.0398	44.1879	117.336	
8	☑	☐	2.61087	55.2692	54.4962	45.9986	152.192	
9	☐	☐	2.61957	56.3769	55.6008	46.8886	155.621	
10	☐	☐	2.62826	57.4112	56.6366	50.3184	158.774	
11	☐	☐	2.63696	58.4689	57.6476	53.4706	161.75	
12	☐	☐	2.64565	59.615	58.6961	56.4472	164.721	
13	☐	☐	2.65435	60.9144	59.8516	59.418	167.884	
14	☐	☐	2.66304	62.4235	61.1812	62.5806	171.434	
15	☐	☐	2.67174	64.1803	62.7398	66.1309	175.538	
16	☐	☐	2.68043	66.1984	64.5571	70.2351	180.292	
17	☐	☐	2.68913	68.4729	66.6248	74.9892	185.669	

Add Stage(s) Delete Stage(s)

Figure 4.30: Stabilization column pressure.

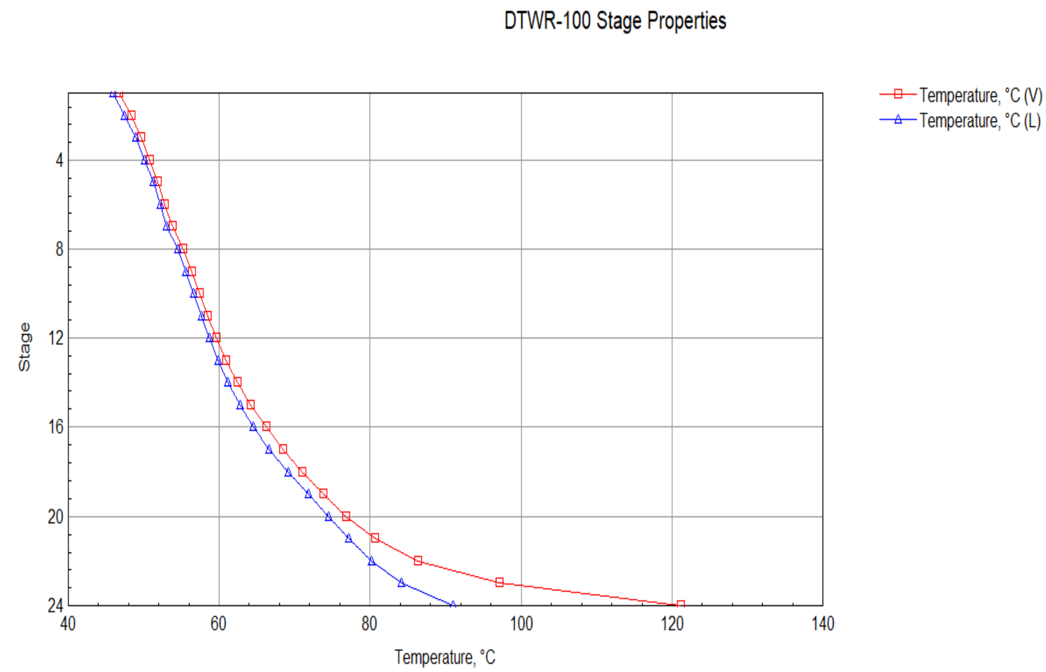


Figure 4.31: Stabilization column temperature.

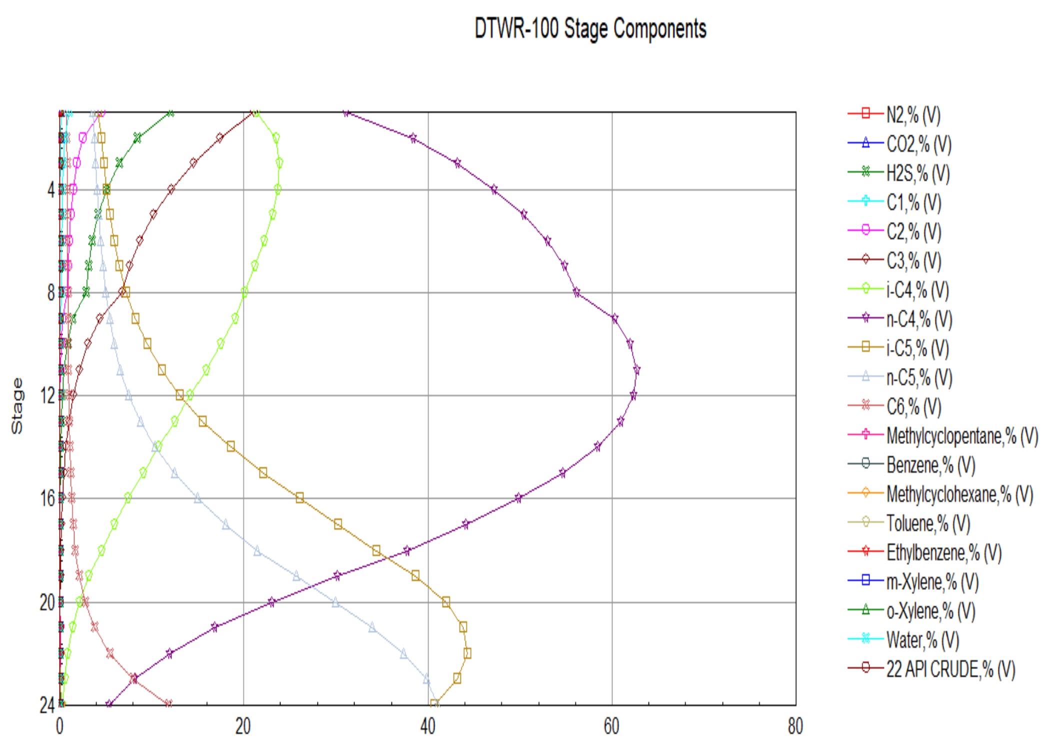


Figure 4.32: Stabilization column components.

Simulation Cases Study Four

Pressure of the following pressure vessel is being adjusted and optimized:

- slug catcher pressure decreased 2 bar.
- Inlet separator pressure decreased 1 bar.
- Stabilization column pressure decreased 0.1 bar.

Table 4.9: Change in Pressure vessels.

Vessels	**Pressure**
Slug catcher	6.5 bar
Inlet separator	4.5 bar
Stabilization column	2.5 bar

Simulation results for case study one show that the hydrogen sulfide (H_2S) is 5.5 ppm as average, while the result of reid vapor pressure (RVP) is 2.25 psi as average.

Table 4.10: simulation results for case four.

H_2S	**RVP**
5.5 ppm	2.25 psi

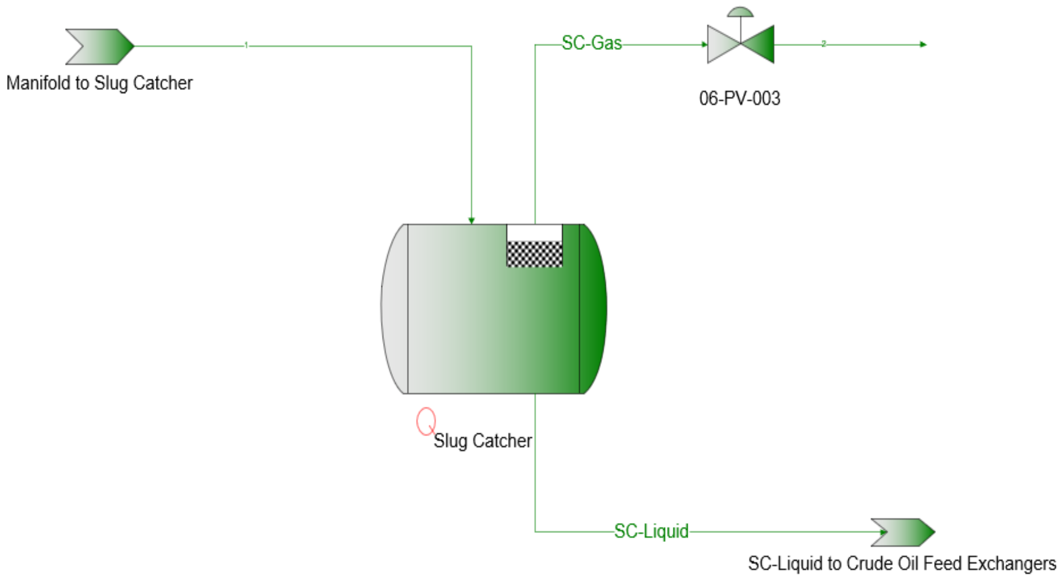


Figure 4.33: Slug catcher.

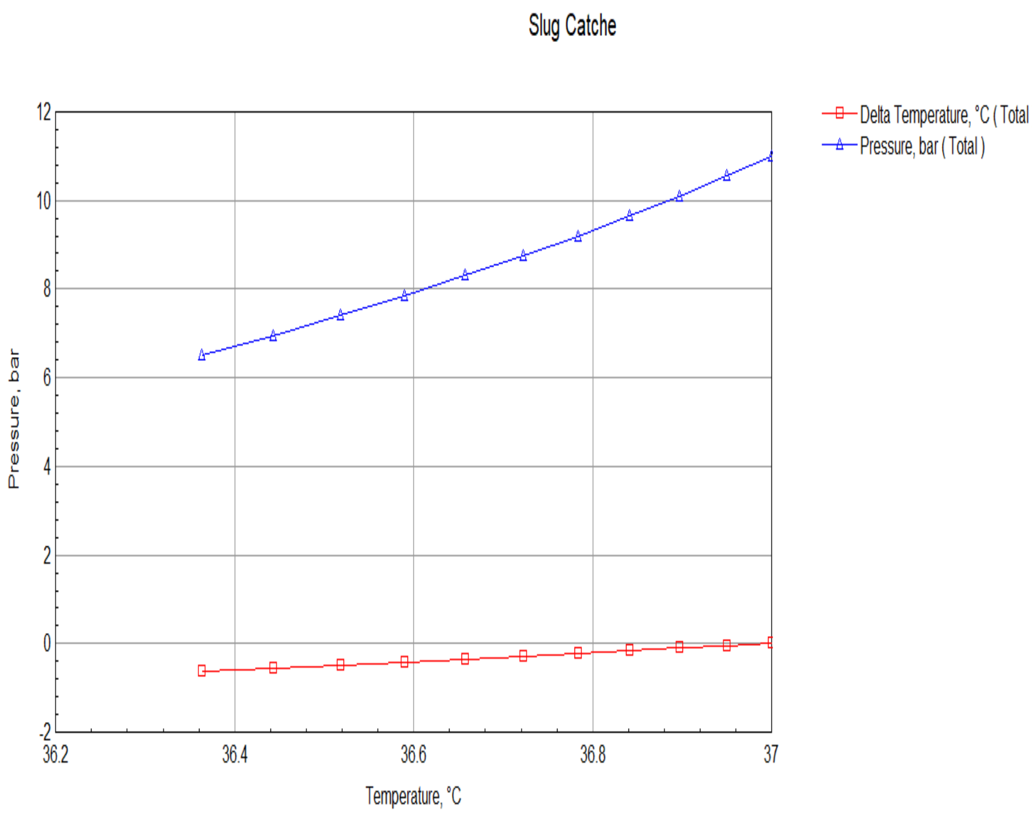


Figure 4.34: Slug catcher pressure and temperature.

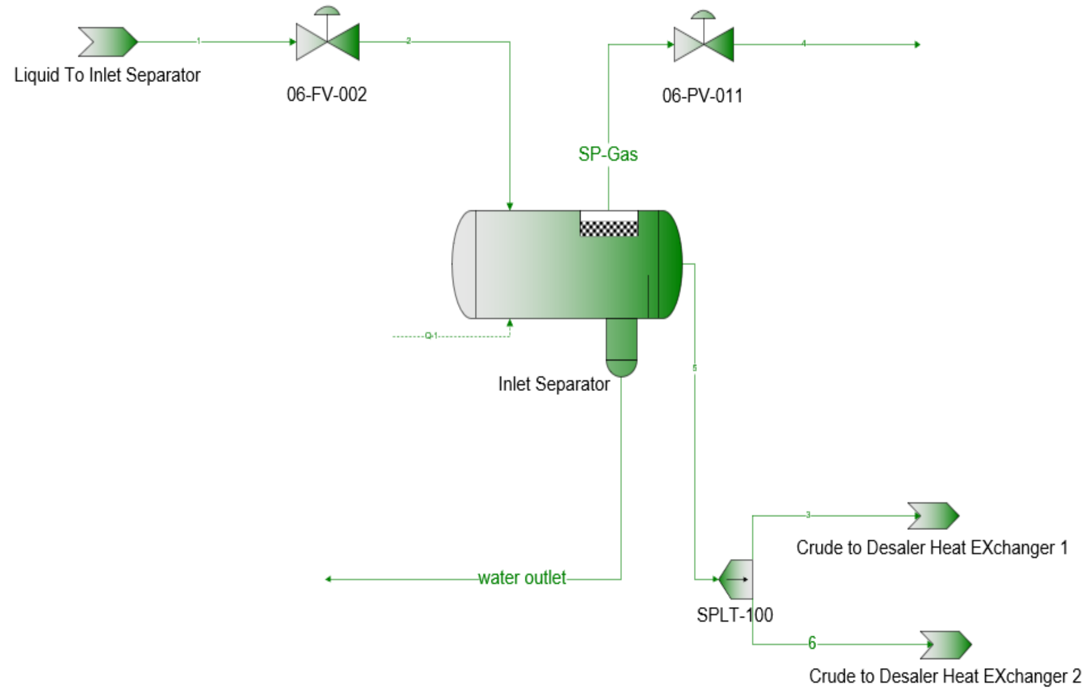


Figure 4.35: Inlet separator.

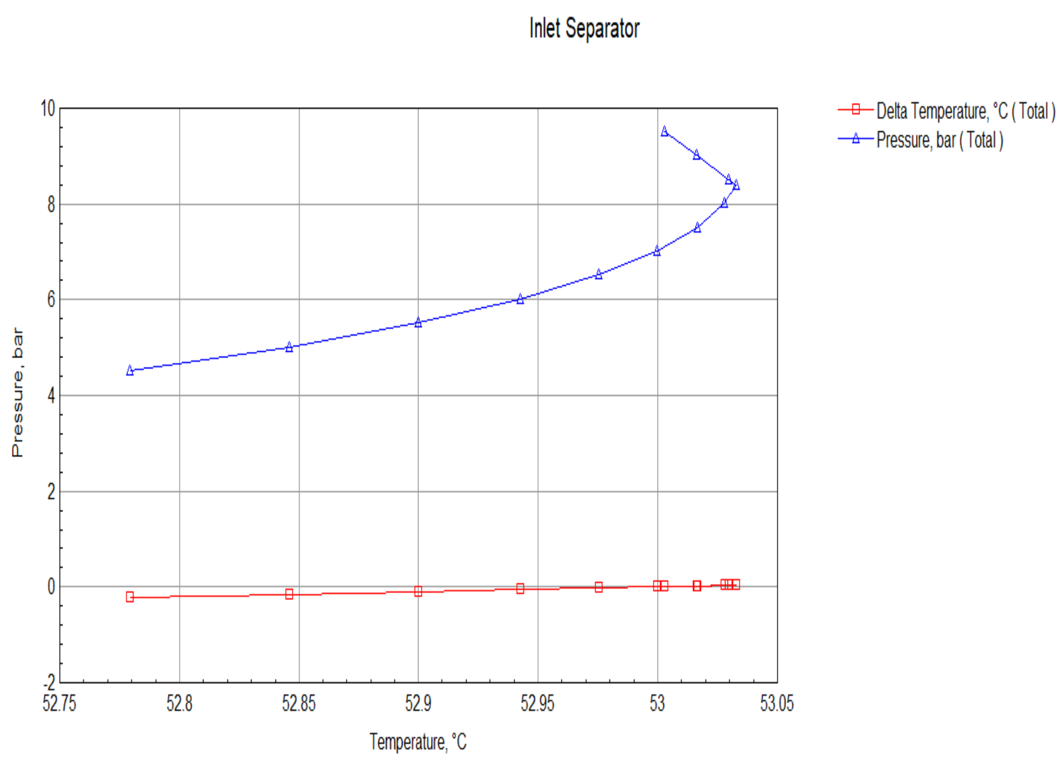


Figure 4.36: Inlet Separator pressure and temperature.

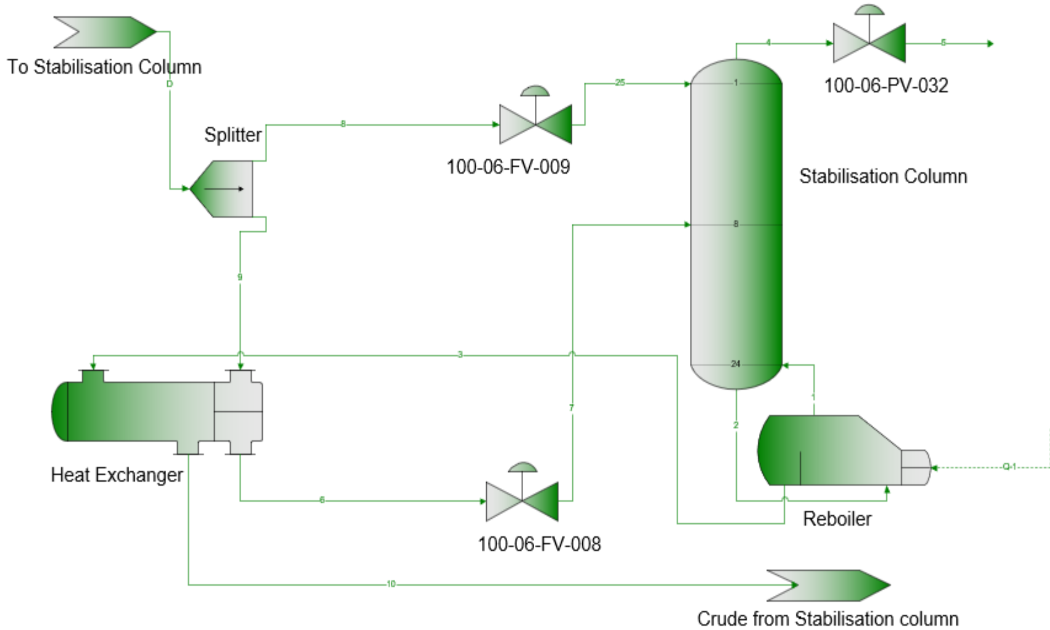


Figure 4.37: Stabilization column.

Pressure Change	0.2	bar
Bottoms Head	0	bar
Pressures from Hardware	☐	

Stage	Show Stage	3 Phases	Pressure	Temperature		Molar Flow		
				Vapor	Liquid	Vapor	Light Liquid	Heavy Liquid
			bar	°C		kmol/h		
1		☐	2.5	47.1746	46.3542	27.6175	99.33	
2	☐	☐	2.5087	48.6946	47.8095	27.5337	102.734	
3	☐	☐	2.51739	49.9857	49.2042	30.938	106.045	
4	☐	☐	2.52609	51.1373	50.4589	34.2491	109.045	
5	☐	☐	2.53478	52.1579	51.545	37.2488	111.629	
6	☐	☐	2.54348	53.1124	52.4816	39.8332	113.799	
7	☐	☐	2.55217	54.1476	53.3271	42.0028	115.617	
8	☑	☐	2.56087	55.5796	54.8202	43.8202	150.048	
9	☐	☐	2.56957	56.648	55.8895	45.1142	153.362	
10	☐	☐	2.57826	57.6592	56.898	48.4278	156.423	
11	☐	☐	2.58696	58.6989	57.8881	51.489	159.332	
12	☐	☐	2.59565	59.8294	58.9203	54.3981	162.253	
13	☐	☐	2.60435	61.1134	60.0613	57.3191	165.376	
14	☐	☐	2.61304	62.6043	61.3756	60.442	168.889	
15	☐	☐	2.62174	64.3377	62.9153	63.9552	172.951	
16	☐	☐	2.63043	66.3254	64.7073	68.0163	177.647	
17	☐	☐	2.63913	68.5622	66.7414	72.7129	182.945	

Add Stage(s) Delete Stage(s)

Figure 4.38: Stabilization column pressure.

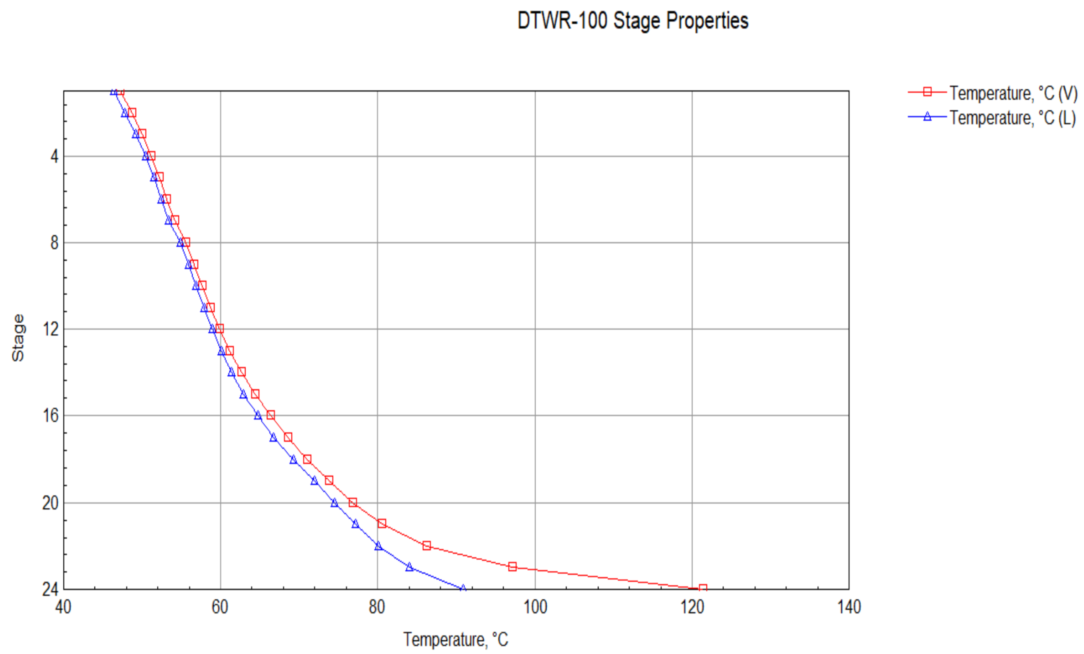


Figure 4.39: Stabilization column temperature.

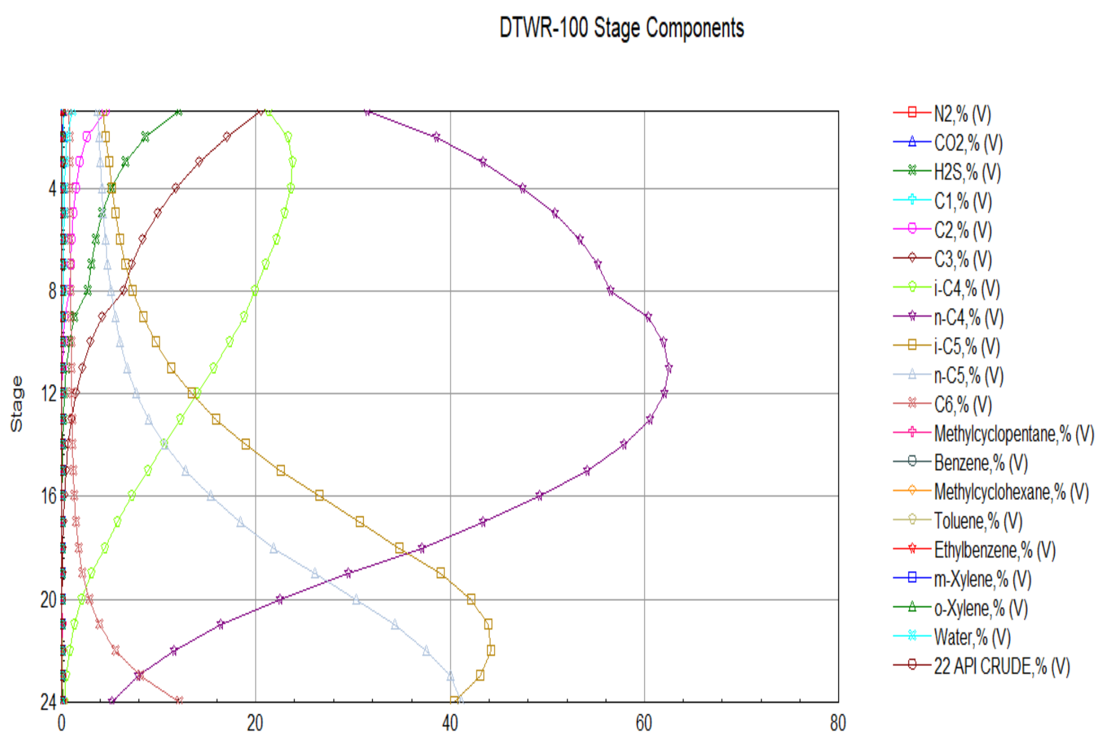


Figure 4.40: Stabilization column components.

CHAPTER V

Result and Discussion

Normal Plant Operating

Simulation results from first case without changing the pressure shows that the H_2S and RVP meet the export specification for constant production rate, but it needs to be optimized in order to get better H_2S and RVP levels for storing and exporting purpose.

Case Study One

In case one operating pressure is increased for each vessel as follow slug catcher one bar, inlet separator 0.5 bar and stabilization column 0.05 bar. Increasing the pressure of the plant show the effect of the pressure on the processing products, here we can observe that with same production rate 33000 bbl/day normal back pressure from the wells on the central processing facility vessels which allow to control the plant and the operations smoothly and safely without facing any safety issue or shutdown as a result of abnormal conditions causing time losing and financial losing.

Obviously, the result of this case showing that H_2S is 8 ppm which is near to our normal case and RVP is 2.55 psi which mean releasing less light components and heavy components with gas which enhance the quality of the crude oil and increase the price of selling.

Based on the earlier statement we can conclude as the best case among all simulation cases that run during this work because it is more reasonable and more practical to be applied in the field from technical and economical sides.

Case Study Two

As the working pressure of the vessels increased more, caused more keeping the light gases and H_2S dissolved in the oil and therefore these gases remained with oil which is economic and safe for storing and exporting purpose.

pressure of vessels are increased as follow slug catcher to 10.5 bar, inlet separator to 6.5 bar and stabilization column to 2.7 bar which result increasing H_2S from 7 ppm to 9.2 ppm and RVP from 2.5 psi to 2.6 psi.

In this case due to high pressure of vessel the back pressure increased from plant on the wells which cause decreasing production rate less than 33000 bbl./day it means losing some of the daily field production rate which mean less revenues than planned by the company, and increasing pressure cause increasing H_2S because less gases has been released from the plant.

Case Study Three

In this case the working pressure of the vessels are decreased to check the pressure decreasing effect.

Slug catcher decreased to 7.5 bar, inlet separator to 5 bar and stabilization to 2.55 bar. simulation results show that the levels of both H_2S and RVP are decreased to 5.7 ppm and RVP 2.3 psi respectively.

Reducing vessels pressure decrease back pressure one the wells which resulted in coming more oil from wells. In this situation the controlling of the plant will be difficult due to higher flow rate than normal.

In this case H_2S is reduced to an acceptable level but the RVP reduced to undesirable level because this RVP value shows that lighter component will release out with gas stream which effect directly on the quality of the crude oil because it reduces its API and its price.

Case Study Four

Pressure is decreased more, slug catcher decreased to 6.5 bar, inlet separator to 4.5 bar and stabilization column to 2.5 bar which give the levels of H_2S and RVP 5.5 ppm and 2.25 psi respectively.

In this case we can observe that less H_2S and less RVP but according to field daily production operations it is difficult to control the levels of the vessel because it will be less back pressure from the wells on the plant vessels which result in more production coming from the wells and cause losing the control on the operations which can cause safety issue and perhaps result in shutdown due to abnormal cases which cause losing time to restart back the plant this leads to economical loses.

RVP in this case is less than all cases which mean releasing all light components and releasing a portion of heavy components as well with gas which effect negatively on the ^{o}API of crude oil which mean crude oil price.

We can conclude this simulation case as the worst case among all cases due to the reasons mentioned earlier this means we cannot apply this case practically in the field and should be ignored because it gives opposite results than planned results with same production rate which is about 33000 bbl./day.

Table 5 showing pressure change for slug catcher and inlet separator and stabilisation column, and results for case studies.

Table 5: Case studies results.

Case studies	Slug catcher	Inlet separator	Stabilisation column	H_2S	RVP
Normal plant	8.5 bar	5.5 bar	2.6 bar	7 ppm	2.5 psi
Case study one	9.5 bar	6 bar	2.65 bar	8 ppm	2.55 psi
Case study two	10.5 bar	6.5 bar	2.7 bar	9.2 ppm	2.6 psi
Case study three	7.5 bar	5 bar	2.55 bar	5.7 ppm	2.3 psi
Case study four	6.5 bar	4.5 bar	2.5 bar	5.5 ppm	2.25 psi

CHAPTER VI

Conclusion

The results of simulation model after running four cases with the case of normal conditions show that case one is the best case and more reasonable case among all cases because in case three H_2S and RVP levels are desirable which allow better crude oil storing and exporting and most important is to meet the customers' requirements and specifications.

Improving pressure profile in case one indicates that we are capable of running and controlling the plant at same production rate and controlling exported crude oil specifications which prove that this case is the best case to be followed for the pressure profile optimization program during planning for next step of the field expanding and developing for future.

Last case is not reasonable and not logic to be followed for the field because it gives negative results which consider as the worst case due to high light and medium component's losing.

Results from case two and case three are between result of best case which is case one and the worst case which is case four and these results are not desirable to be followed because it is not safe and cause safety issue.

References

Arnold, K and Stewart, M. (2008). Surface Production Operations Design of Gas-Handling Systems and Facilities. https://doi.org/10.1016/B978-0-7506-7853-7.X5001-7.

David, J. and Kenneth, GL. (2016). The Safety Critical Systems Handbook: A Straightforward Guide to Functional Safety.

Francis, S and Richard, E. (1991). Oilfield Processing of Petroleum. Published in 1991ISBN:9780878143436.

James, G. (2022). Dewatering, Desalting, and Distillation in Petroleum Refining. CRC Press, 2022 ISBN: 1000802639.

Klein and Nelis, (2011). Thermodynamics book. Cambridge University Press, 2011 ISBN: 1139498185.

Lieberman, N. (2019). Understanding Process Equipment for Operators and Engineers. Elsevier Science Publishing Co Inc, 9780128161616.

Lieberman, N. (2022).Troubleshooting Process Plant Control: A Practical Guide to Avoiding and Correcting Mistakes. John Wiley & Sons, 2017 ISBN:1119267765.

Maria, L. and Lona, F. (2018). A Step by Step Approach to the Modeling of Chemical Engineering Processes. Springer International Publishing AG, 9783319660462.

Maurice Stewart, (2014). Surface Production Operations: Vol 2: Design of Gas-Handling Systems and Facilities. Gulf Professional Publishing eBook ISBN: 9780123822086.

TAQA Global (2020) A. System user manual. AB-PF1A-PF01-B00-MAN-0004-TAQ_U1.

TAQA Global (2020) B. System user manual. AB-PF1A-PF01-B00-MAN-0007-TAQ_U1.

TAQA Global (2020) C. System user manual. AB-PF1A-PF01-B00-MAN-0017-TAQ_U1.

TAQA Global (2021) D. System user manual. AB-PF1A-PF01-B00-MAN-0021-TAQ_U1.

TAQA Global (2021) E. System user manual. AB-PF1A-PF01-B00-MAN-0021-TAQ_U1.

Yasser, k (2018). Fundamentals of Oil and Gas Processing: Design and Operation of Oil Field Treatment Facilities. Independently Published ISBN:1790348560.

Appendices

Appendix A

Central Processing Facility (CPF) Characteristics

- **Volume:** The space the liquid occupies. Volume is measured in gallons, liters, barrels 1 barrel of oil=42 US gallons.

- **Weight:** A measure of how heavy the liquid (Ib).

- **Density:** The ratio of mass to unit volume. Density of liquid is measured in gm/cm^3 or Kg/m^3.

- **Specific Gravity:** The ratio of density of a liquid to the density of water. Specific Gravity of water is 1.0 at 60 °F.

- **Compressibility:** The ability of matter to be reduced in size or volume by squeezing. Liquids cannot be compressed (psia).

- **Viscosity:** A measure of a liquid's resistance to flow ($N.S/m^2$).

Gas phase

Matter that has neither shape nor volume but tends to expand forever.

- **Natural gas:** A mixture of the lightest hydrocarbons Methane is the major component, Propane, Butane Pentane in lesser amounts.

- **Associated gas:** Gas associated with oil.

- **Non-Associated gas:** Gas not associated with oil.

Properties of Gases

- **Density:** A weight measure of a certain volume of gas, expressed in pounds per cubic feet, and measured at standard condition
- **Compressibility:** The ability of matter to be reduced in size or volume by squeezing. All gases can be compressed; Compressing a gas increases the pressure and temperature.

- **Toxicity:** The ability of a material to cause harm is referred to as its toxicity. These impacts can have an impact on a single cell, a group of cells, an organ system, or the entire body.
- **Flammability:** Ability of a gas to burn if ignited in presence of air.
- **Inertness:** A property of a gas to remain without reacting or doing anything, not flammable eg, Nitrogen, CO_2 are inert gases.

Standard Condition

A gas is measured at a standard temperature of 60 °F and pressure of 14.7 psi.

SCF

Standard cubic feet, a gas is measured in cubic feet at the standard condition and is given as standard cubic feet.

Crude Oil Physical Properties

- **Vapor Pressure:** The pressure existing upwards from the surface of a liquid, the measure of liquid tendency to vaporize at any given temperature.
- **RVP:** Reid vapor pressure is the pressure caused by the vaporized part of a liquid and the enclosed air. This is usually expressed in psi at 100 °F (38 °C).
- **API Gravity** A standard measurement to measure density of crude and petroleum products at 60 °F. API Gravity of an oil is inversely proportionate to its specific gravity. API Gravity = (141.5/Specific Gravity)-131.5.
- **B S & W:** Basic sediment and water. It is a measure of the impurities (heavy material composed of water and foreign material) found in crude oil (Maria and Lona, 2018).

Appendix B

Crude Oil Classifications

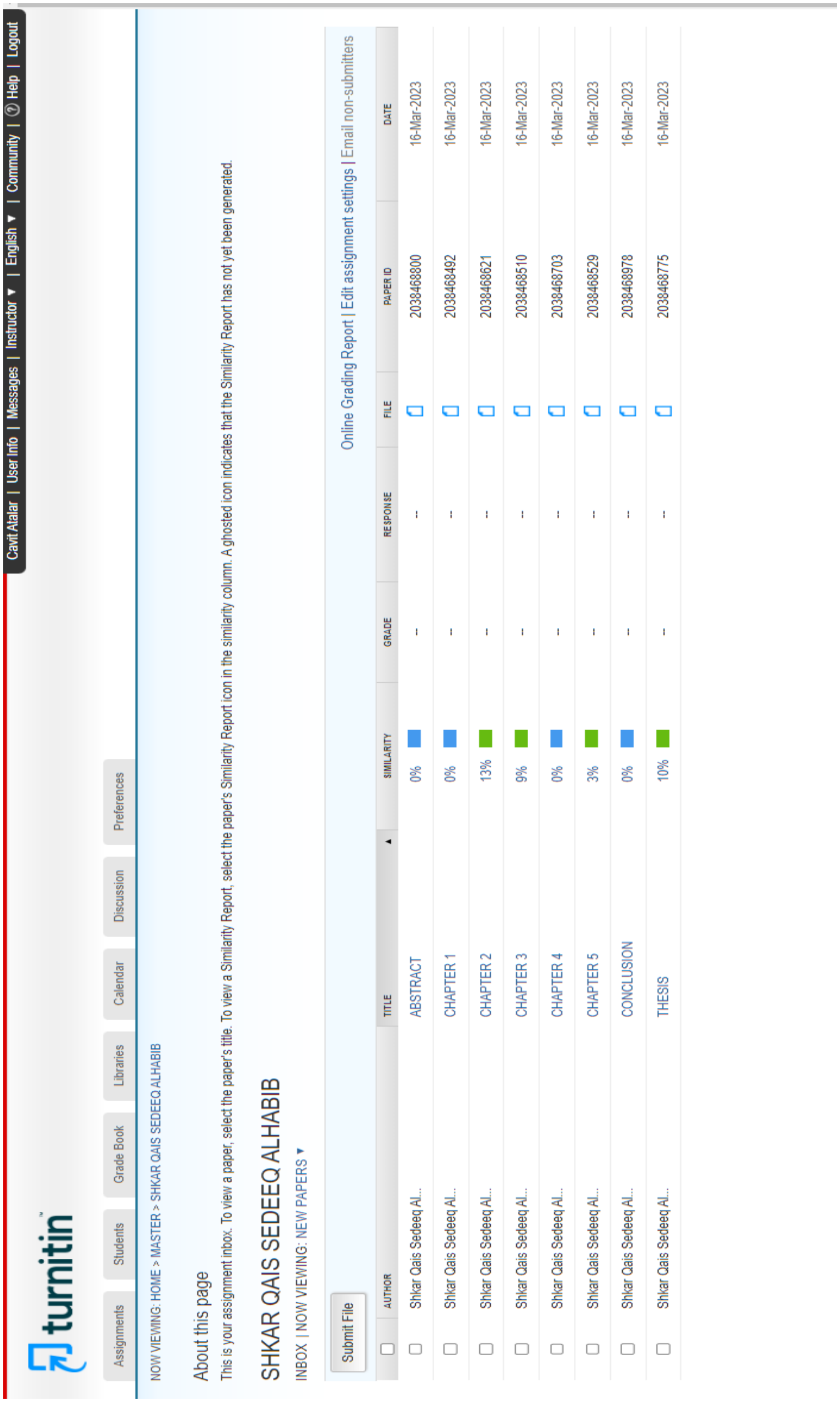
- **Oil classification chemically**
  - **Paraffinic Base Oil**: Where the oil contains paraffin's with small percentages of naphthenic and aromatic materials and is almost free of asphalt materials.
  - **Naphthenic Base Oil**: It contains naphthenic, cyclic paraffin's and larger quantities of asphalt than in paraffin's.
  - **Aromatic Base Oil**: It contains large quantities aromatic and asphalt compound.
- **Classification by sulfur content**
  - **Sweet oil**: Oil containing a very low sulfur content less than 0.5% is considered sweet oil.
  - **Sour oil**: Oil containing a very high sulfur content more than 0.5% is considered sour oil.
- **Classification by density**
  - Light oil API more than 31.1.
  - Medium oil ^{o}API is between 31.1 and 22.3.
  - Heavy oil ^{o}API is between 22.3 and 10.
  - Extra heavy oil ^{o}API less than 10.

Sulfur is undesirable in oil because it causes problems such as difficulty distillation, corrosion of equipment and pipes, and accumulation inside the equipment, which increases the cost of maintenance (Maria and Lona, 2018).

Light oil is more desirable than heavy oil because it is easy to process and contains high levels of light hydrocarbons in addition to its easy flow (Maria and Lona, 2018).

Appendix C

Turnitin Similarity Report



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Appendix D

Ethical Approval Letter

YAKIN DOĞU ÜNİVERSİTESİ

ETHICAL APROVAL DOCUMENT

Date: / /2023

To the **Institute of Graduate Studies**

The research project titled **"OPTIMIZATION OF THE PRESSURE PROFILE FOR CENTRAL PROCESSING FACILITY USING PROMAX SOFTWARE**" has been evaluated. Since the researcher will not collect primary data from humans, animals, plants or earth, this project does not need through the ethics committee.

Title: Prof. Dr.

Name Surname: Salih SANER

Signature:

Role in the Research Project: Supervisor