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Design of Oil and Gas Separation Plant

Bachelor thesis

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Design of Oil and Gas Separation Plant

Anotace:

Téma této bakalářské práce se zaměřuje na praktické modelování a návrh kompletního ropného separačního řetězce,nacházejícím se v hypotetické oblasti Kurdistánu v Iráku. Návrhové parametry jsou založeny na datech, která velmi věrně odrážejí skutečné hodnoty, a efektivně simulují typické výzvy, s nimiž se setkávají tato zařízení na pevnině . Významná část projektu je věnována výpočtům vstřikování vody do ropného podloží, které má za následek udržování tlaku v podloží a tím prodlužuje životnost ropného ložiska, V uvedené práci se odděluje voda, ropa a plyn za použití třífázových separátorů, přičemž produkovaná voda je zpracována samostatně. Práce zahrnuje komplexní návrh a základní výpočty pro každé procesní zařízení v rámci zařízení. Navíc je v základním návrhu zahrnuta přeprava oddělené ropy a plynu prostřednictvím 50 km dlouhého potrubí.

Teoretická část práce popisuje různé vybavení a metody používané při zpracování ropy. Závěrečná část se zabývá bezpečností a dopady těžby ropy na životní prostředí.

Annotation:

This bachelor's thesis focuses on the practical modeling and design of a crude oil separation train for a field located in a hypothetical area of the Kurdistan Region of Iraq. The design parameters are based on data that closely resemble real-world figures, effectively simulating the typical challenges encountered in onshore facilities. A significant portion of the project is dedicated to calculating water injection and predicting water separation using three-phase separators, with the produced water undergoing separate treatment. The thesis provides a comprehensive design and fundamental calculations for each piece of process equipment within the facility. Additionally, the transportation of the separated oil and gas via a 50 km pipeline is included in the basic design.

The theoretical part of the thesis details various equipment and methods used to treat crude oil. The final section addresses the safety and environmental impact of crude oil operations.

Klíčová slova: Separace ropy a plynu, Separátní zařízení, Aspen HYSYS
Keywords: Oil and Gas Separation, Separation plant, Aspen HYSYS.

Number of pages: 49

Number of annexes: 6

I declare that I have prepared the bachelor's thesis myself and that I have stated all the used information resources in the thesis.

In Olomouc, May 27, 2024

Mohammed Ziyad Ahmed

Acknowledgement

I would like to express my deepest gratitude to all those who have supported and guided me throughout my academic journey.

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Contents

List of Figures

List of Tables

1. Introduction

This research is to design a separation plant of oil and gas, it is divided into several parts, such as water injection, simulation of separation and designing a 50 km exporting pipeline, risk and safety and lastly considering environmental aspects.
The first aspect is how much water is needed for it to be injected back into an oil reservoir over a 10-year period, a critical aspect of secondary oil recovery methods. While primary oil recovery is utilized during the initial stages of oil production, secondary recovery, such as water injection, enhances effectiveness and optimizes operating costs. The recovery factor for oil typically ranges between 10-20%; for this study, an 18% recovery factor was assumed, slightly above the midpoint to account for optimistic yet realistic projections.

Understanding and optimizing water injection results is vital for oil companies as it allows for accurate production forecasting and operational optimization. This project employs HYSYS simulation software, utilizing data from an oilfield in the Kurdistan Region of Iraq, including crude oil composition, pressure, and temperature data (Confidential Data).

The HYSYS simulation did not include specific parameters for high- and low-pressure separators; instead, the software calculated the necessary diameters autonomously. This flexibility underscores the importance of accurate simulation tools in designing efficient oil recovery systems.

Additionally, this project addresses the design of a 50 km long onshore pipeline for transportation. For gas transport, three parallel compressors were employed due to the significant energy requirements, despite an initial assumption of needing only one compressor. Each compressor is paired with a separate cooler to ensure optimal operation. In contrast, a single large pump was chosen for oil transport over multiple parallel pumps, resulting in energy savings.

Risk, safety, and environmental considerations are integral to this project. A comprehensive HAZOP (Hazard and Operability Study) analysis and Emergency Shutdown Systems (EDS) were discussed to ensure safety and mitigate risks. Environmental aspects were also considered, with an emphasis on reducing field waste. Although achieving zero waste is not economically feasible, the project proposes drilling a thinner wellbore as a viable solution to minimize environmental impact.

This thesis will delve into the theoretical foundations of secondary oil recovery, the detailed methodologies used in the HYSYS simulation, pipeline design, and the associated risk and environmental assessments. Through this comprehensive approach, the study aims to provide valuable insights and practical guidelines for optimizing oil recovery operations in the field.

2. Aim of Study

The project task for this bachelor thesis is to design a separation plant, which includes onshore pipelining, calculations of water injection, , this study is focuses on the points below:

- Analysis of Oil assay
- New 50km export pipelines of produced oil and gas well be designed.
- Oil separation plant will be designed using hand calculations, Excel and Aspen HYSYS.
- Water injection production to provide necessary amount of water for the next 10 years.
- Steam generator for crude oil heat exchangers.
- Risk and Safety
- Environmental aspects.

The solution strategy is divided into four flows which are described in Fig – . At first the project task was discussed in the first chapter. Now is the process of starting the solution strategy. First solved problem is in chapter 3 which in this chapter is solving the problem of water injection for the next 10 years. Later, the whole process of HYSYS simulation which includes; separation, and oil and gas transport via designing a new 50 k m onshore pipeline, this part also includes the material selectionfor pipelines. In the third step of this project, is heat echangers which I will be designing and aslo sizing it. Lastly, envrionmental aspects, risk and saftey considerations will be discussed at the end of this project.

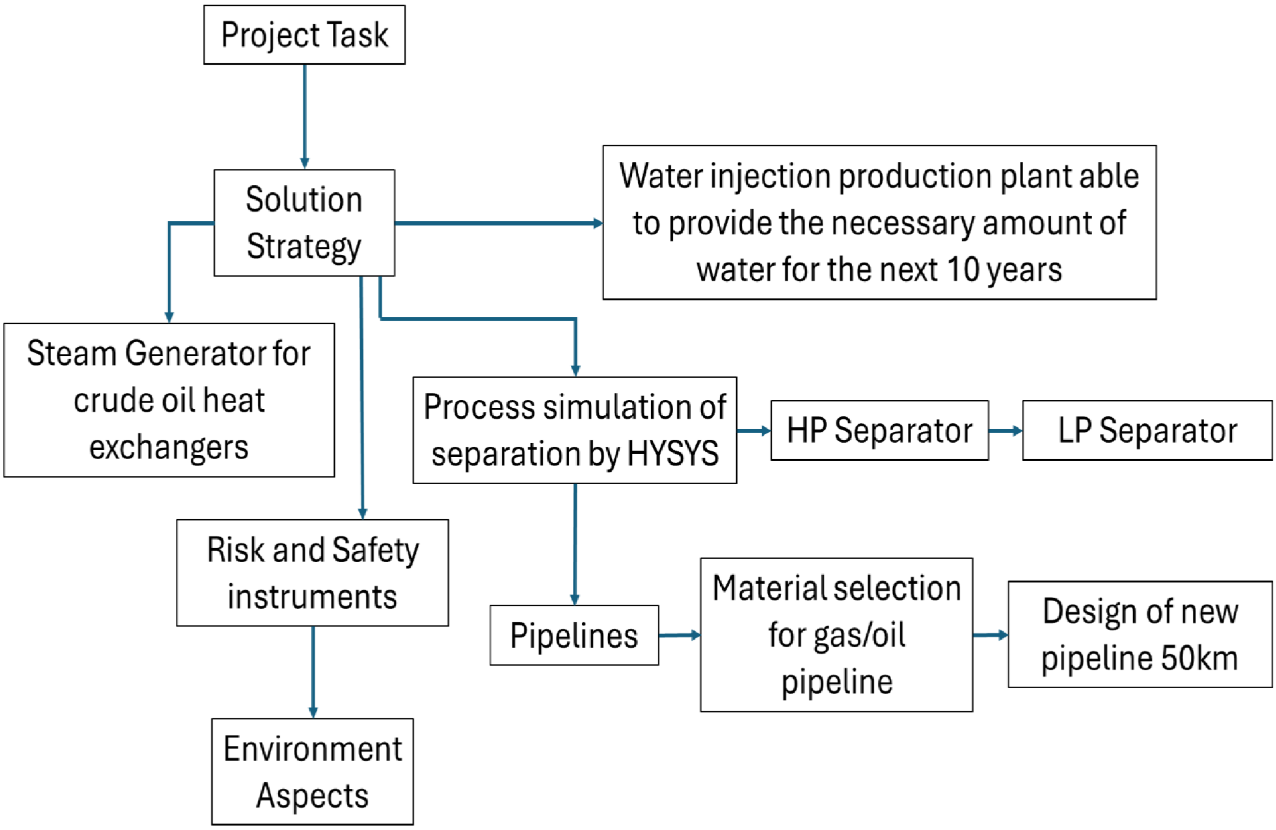

Figure 1Solution Strategy

3. Litreture Review

3.1 Separation:

The separation of oil and gas is a crucial process in the petroleum industry, ensuring the efficient extraction and processing of hydrocarbons. This process involves various techniques and technologies designed to separate the multiphase flow of oil, gas, and water produced from wells. The review covers the fundamental principles, key technologies, and recent advancements in the field.

Inlet stream (feed 1) = this is the primary incoming flow originating from the reservoir. It is necessary to put all the parameters for the simulation, including temperature, pressure, and the mass fraction of various components (as specified in the project requirements). Each simulation must be commenced by establishing the thermodynamic model and units, which will be utilized throughout the simulation process.

Streams = for adding a new stream, typically you only need to input the temperature, pressure, and volume flow rate in some cases. HYSYS automatically computes the remaining parameters.

Energy stream = each device, such as a compressor, heater, heat exchanger, pump, expander, or oil pipeline, requires an inlet stream. The energy stream is computed within HYSYS for these devices.

2 phase-separator = the slug catcher and gas scrubber are crucial components for separating the liquid phase from the gaseous phase in the process.

Figure 2 2-Phase Separator (Mashood, 2020)

3 phase-separator = LP (low Pressure) and HP (High Pressure) separators play critical roles. If the separator pressure is excessively high, it can cause significant amounts of light components to remain within the liquid phase, resulting in their loss along with other valuable components to the gas phase at the stock. Conversely, if the pressure is too low, it can lead to the separation of substantial amounts of light components from the liquid, attracting significant quantities of intermediate and heavier components. Achieving an optimal pressure balance is essential to ensure efficient separation while minimizing losses and maintaining the desired composition of the separated phase.

Figure 3 3-Phase Separator (TechFab, 2022)

Mixer =it is utilized when there’s a necessity to combine two or more streams. It enables the mixing of both liquid and gas streams.

Heat exchangers = the heat exchanger can function both as a cooler and a heater. Its advantages lie in its versatility; the cold stream can cool hotter streams, while hotter streams can heat up colder ones. This flexibility allows for the use of recycled streams, ultimately saving energy required.

Figure 4 Heat Exchanger (TITAN Metal Fabricators, 2024)

Compressor = this device is utilized for compressing gas. The energy required for the gas compressor can be sourced from the energy produced by the gas expander.

Figure 5 Compressor (Pichit Boonhuad , 2023)

Pump = used for oil pumping.

Figure 6 Centrifugal Pump (Lauren Cella, 2020)

3.2 Simulation

This context serves the applied methodology in the simulation process for the design of an oil and gas separation plant. Furthermore, it will describe types of separators, and demonstrate advantages, disadvantages, and uses of each separator type, and additionally it will indicate the sizing of the separators and calculating the capacity of oil and/or gas in each separator.

The methodology deployed in this design, where the characteristics of crude oil properties, such as viscosity, density, and composition, are examined to achieve the expected sales. Furthermore, the design methodology extends into hand calculations, and detailed systematic analysis software ASPEN HYSYS.

For the procedure of designing the separation plant, aspen HYSY is used because, this software enables dynamic modeling of the separation plant and explores various scenarios that provides insights into optimal configurations, operational parameters, and potential bottlenecks with the designed facility. By combining the capabilities of aspen HYSYS, the methodology aims for an in-depth analysis of the separation processes, ensuring that the final design meets the sales expectations.

The use of simulation and modeling techniques has greatly improved the oil and gas separation process. Dynamic simulations using software like Aspen HYSYS allow for detailed analysis of separation units under different operating conditions. Aspen HYSYS is very useful because it has strong thermodynamic models and can simulate complex processes with multiple phases. This software helps assess separator performance, find bottlenecks, and optimize operating conditions. By modeling the behavior of multiphase flow systems over time, Aspen HYSYS captures the complexities of oil and gas separation, such as phase transitions, pressure drops, and flow dynamics.

Aspen HYSYS can simulate various separation equipment, including three-phase separators, scrubbers, and gas processing units. It allows for the detailed design and operational analysis of these systems, making sure they meet the desired specifications and performance criteria. Additionally, Aspen HYSYS integrates with other process simulation tools, offering a complete platform for process design, optimization, and troubleshooting.

Separating vessels are referred to by many names such as:

Separator: it is primarily used to separate a combined liquid-gas stream into phases that are relatively free of each other. A two-phase separator achieves only vapor-liquid separation, while a three-phase separator also removes free water from the crude oil.

Knockout: they are also referred to as separators and fall into two categories, free-water, and total-liquid knockouts. The free water is used to separate the three phases from a combined gas, hydrocarbon liquid, and a water well stream. Free-liquid knockout is often used to remove liquids from a high-pressure gas stream (3,000 psig and above).

Scrubber: this term is applied to a vessel normally more efficient than conventional separator in removing small liquid drops from a gas phase. Scrubbers are often used ahead of compressors, glycol, and amine units, and they are often applied downstream of field separator to remove condensed liquids.

Filter: this separator tool is designed to remove small quantities of mist, oil fog, rust, scales, and dust from gases. Solids are trapped by the filter fibers while liquid droplets are coalesced into large drops that are then separated by gravity. These filter separators are often protected by a scrubber or a separator.

Pipes:

In recent years there has been an increase of transporting oil/gas via pipelines, but these pipelines that are installed for transportation can face some unacceptable results, which could be facing corrosion. So, the pipeline material needs to be considered wisely.

The selected condition for the pipeline:

Thermal Conductivity: the rate at which heat is transferred through a solid material in a steady state, where the temperature distribution remains constant over time, is determined by its thermal conductivity. (Perpar, Matjaz, 2012).

The yield strength: it is the stress level at which a material starts to deform plastically. Before reaching the yield point, the material deforms elastically, meaning it will return to its original shape once the applied stress is removed. Beyond the yield point, a portion of the deformation becomes permanent and irreversible. In the three-dimensional space of principal stresses, these yield points collectively form a yield surface. (Zhu, Xian-Kui, and Brian N. Leis,2006)

Tensile strength: measures the force needed to pull an object, like a rope, wire, or structural beam, to the point of breaking. It represents the maximum tensile stress a material can withstand before failure. The definition of failure varies based on the type of material and the design methodology used. (Sharma, Satish Kumar, and Sachin Maheshwari, 2017).

Flammability: ceramics and glasses are non-combustible. While metals can be potentially combustible in fine powder form, they generally do not pose a flammability issue in bulk, even for magnesium. Conversely, most polymers are inherently flammable, although their flammability varies. We classify flammability on a three-point scale, non-flammable, self-extinguishable, and flammable. (Shin, Seolin, 2018)

Corrosion: the type of corrosion is influenced by various factors, including the environment, materials, system construction, scale and oxide film formation, temperature, microbial presence, and hydraulic conditions.

Be able to form pipes: various materials are utilized in pipeline production, including metallic materials, plastics, ceramics, and glasses.

Insulation and Pipeline protection

Thermal insulation plays a crucial role in both industrial and commercial piping applications by reducing heat transfer between surfaces. It minimizes heat flow in hot or ambient piping systems. In this project, the insulation material is specifically used to protect the pipeline from the cold salt water.

The following specifications were settled.

Temperature ranges from -40 to 80 °C.

Low thermal conductivity

Fresh and saltwater resistant

Corrosion protection:

Pipeline corrosion can occur both externally and internally. Internal corrosion, caused by corrosive components such as H2S, typically reduces pipeline efficiency. It can be managed by cleaning with scraped pigs and injecting a corrosion inhibitor into the transported fluid. The two primary methods for corrosion protection are pipe coating or insulation to enhance the pipe's resistance to soil and cathodic protection to ensure the pipe remains cathodic.

Pipeline pigs:

It is an instrumented device that travels internally along a pipeline, monitoring operating parameters such as flow and temperature, as well as physical parameters like wall thickness and corrosion.

Cathodic protection:

This method, utilizes for over a century, is known as cathodic protection. The technique involves connecting the pipeline to an anode bed, which causes the pipeline to act as a cathode by applying a direct current voltage. This setup ensures that the anode bed corrodes instead of the steel pipe, effectively protecting it from corrosion

3.3 Water Injection

The water injection method is used in oil production, it is when water is injected back into the reservoir to increase pressure and increase production flow.

Water injected is a procedure to improve pressure buildup after primary production. The water injected back to the reservoir is usually transported by centrifugal pumps which are located at production platform and pumped through small-bore piping. The amount of water injected back to the reservoir is limited because of the capacity of water injection pumps. If water is injected back to the reservoir there will be the need of pipes, and then will be collected in a large basin of water pumping station, later the water is pressurized and passed through filters to the de-oxygenation tower. So, it means the water needs to be treated before injected into the reservoir. Here are the types of water treatment: (Zhu, Sipeng, 2019)

- Filtration
- Biocide treatment
- Desulphurizing
- Deoxygenation

Filtration

In this type of treatment, in this process the substances are removed from the solution based on the particle size. These solid particles in water causes abrasion and erosion corrosion, this could be the source of mechanical damage to water injection facility, also in the reservoir it could cause the block of reservoir pores, which affects permeability and the reason to decrease of production flow. (Yang, Y., X. Zhang, and Z. Wang, 2002)

Biocide Treatment

Biocide is used to minimize biological fouling; this prevents the growth and the settlement of marine organisms. The organisms can cause corrosion, scaling, souring oil, and gas.

Desulphurizing

Desulphurizing treatment is the process where compounds that consists of Sulphur are removed from the water.

Deoxygenation

The oxygen that is dissolved in water helps aerobic organisms to respire, this also causes corrosion in the equipment. It can be removed in two ways; by mechanical deareation or chemical methods. (Al Dawery, Salam, 2022)

In figure - 2, demonstrates the cycle of water injection process. The cycle starts from inside the reservoir, when the oil starts producing from producing well, it is still a mixture of some fluids including water. The water is separated from oil, which that produced oil is going through separation and refinery plants, the water travels towards the water storage. Before injecting the water back to the reservoir, it needs to be treated and filtered and goes through the injection well to get back into the reservoir. (Bolland, O., and J. F. Stadaas, 1995)

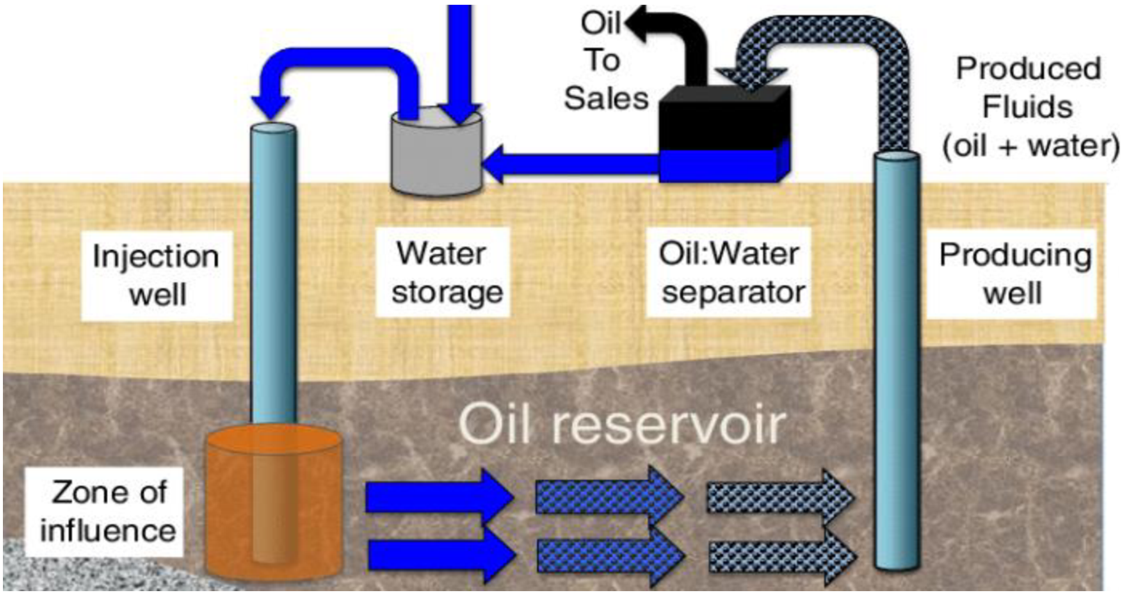

Figure 7 Water Injection Cycle (Lisa M Gieg, 2011)

3.4 General overview of the steam generator

In the oil gas industry to adjust the temperatures for the feeds to the separation of the crude oil, it is needed to use steam.

Advantages:

- Steam is cheap to generate.
- It is colorless, clean, and sterile.
- Has a very high heat content which results in smaller pipe diameter carrying a greater amount of heat relative to water at the same pressure.
- Releases heat at a constant temperature by phase change.
- Readily distributed and easily controlled.

Disadvantages:

- Steam is distributed under pressure which the leaks in the system can be very costly.

Table 1 Features of different heating media.

Feature	**Heating Media**		
	Steam	**Hot Water**	**Hot Oil**
Heat content	high	moderate	Low
Source cost	cheap with some treatment	cheap	Expensive
heat transfer	good	moderate	relatively poor
circulating pump	not required	required	Required
pipe size	small	large	Large
pressure needed for high temperature	high	high	Low
flash loss problems	present	no	No
corrosion problems	possible	less likely	Unlikely

The steam generated is done by usually using monotube or coil steam generator on oil platforms. These two types are preferred because of:

- They do not hold bulk water; they are lighter.
- Occupy limited space.
- Rapid start up
- No risk of steam explosion since no storage of large volumes of heated water

Water is forced into the tube end and travels towards the hot areas of the generator. As the water traves towards the tube, heat is absorbed from the tube wall, and it raises until reaching the saturation temperature. In this stage the water begins to boil, the temperature remains almost constant in this saturation state until the water that has been vaporized turns into steam. The temperature continues to rise until the steam leaves the boiler.

The steam temperature functions its pressure. The steam, which is saturated or of a very high quality, is distributed to the heat exchangers, and provides heat by condensing back to the water. The temperature that is desired at the heat exchangers can be adjusted by a pressure reducing valve. To ensure minimum heat loss from the distribution pipes, suitable materials are used, for example fiber glass materials are used.

3.5 Risk and Saftey

SCADA (Supervisory Control and Data Acquisition)
SCADA is a control system which maintains steady state conditions. Its objective is to gather information such as pressure in the HP separator, then transfers to the information back to the central site, which alerts the home station when the pressure is reaching a high level, that carries out necessary analysis and control, such as determining how much the pressure is high, and displays the information on the information desk. In the Figure – 10, demonstrates how SCADA System looks. (Daneels, Axel, and Wayne Salter, 1999).

Figure 8 SCADA control system (CTI Supply, 2020)

EDS (Emergency Shutdown System)
It depends on SCADA and its purpose is to handle those situations that SCADA can't carry out. It is designed to prevent and minimize dangerous situations in the field.

HAZOP Analysis

Design of the separator

Parts which should be included:

- Make a sketch of the plant and short description.
- Determining whether the plant is operating in batch or continuous process.
- Drawing the overall control strategy.
- Make a detailed PI diagram which includes TAG numbers and a description of the suggested control strategy.
- Do a proper evaluation of the need for a more optional control strategy regarding the more stable operation of the plant.
- Sketch the final plant including the SCADA control program.
- Design of the safety systems (EDS) including various and stand-alone safety components.
- Carry out the HAZOP analysis at significant parts of the plant and with most relevant key parameters.
- The HAZOP analysis should be extended to an operational analysis regarding the start-up and close.
- Critical Safety components should be analyzed further by an FMEA analysis, which means that the wea point in the instrumentation should be identified.
- To be able to state that the plant is safe in critical events regarding staff, plant, or product, you should analyze some typical 'top event' by putting up a fault tree analysis.
- At the end given evaluation of the safety of the total plant and whether a completely different design.
- Make an evaluation of the various standard tools to make sure the plant is operational and safe.

The following table demonstrates all the cases and consequences in an HP Separato, in addition it includes action needed for any unexpected events.

Table 2 HAZOP Analysis for HP Separator

HAZOP ANALYSIS					
HAZOP ANALYSIS for the HP Separator					
Keyword	**Deviaton**	**Cause**	**Consequence**	**Safegaurds**	**Action**
OIL	No	Low oil Level	No production	FAH, FAL	Install PAL, LAL, ESD
		Inlet valve closed	No production		
		Leak in the pipe	Production reduction	Pressure transitetr at the end of the pipe with PAL	
		High gas pressure in HP	No production	Install the PAHH and PSV	
	Low	Leak in the pipe	Production reduction	Pressure transitetr at the end of the pipe with PAL	
		High pressure	no production	Install the PAHH and PSV	Regular inspection of the equipment
	High	inlet valve fully opened	Poor separation, damage of the separator	FAH/ Inlet pipe	Reducing opening of the inlet valve
		Too many open wells	high gas pressure	FAH, PAHH	
		Low gas pressure in the separator	high water level	LAH, LAHH	
Water	No	Water outlet fully opened	oil in water pipe	LSLL and close the valve and inlet valve as well	Reduce the opening of the water valve
	Low	Water valve too much opened	risk of the oil in the water pipe	LAL	

Table 3 HAZOP Analysis for HP Separator continued

Water	No	Water outlet fully opened	oil in water pipe	LSLL and close the valve and inlet valve as well	Reduce the opening of the water valve
	Low	Water valve too much opened	risk of the oil in the water pipe	LAL	
	High	Water Valve Closed	Poor Separation, water in the water pipe	LAHH, instal second valve, VW2, LC, LT	
Temperature	Low	Not enough steam in the heat exchanger	Poor separation	TAL	
	High	External heat source	Explosion of the separator	TAHH, cool down the separator, Fire fighting system	Check the steam supply, cool the separator
Pressure	Low	Leak of the separator	Poor separation	Compare the inlet flow and out flow	Install the reduction for the opening of valves
		Gas valve opened	Poor separation	PAHH	
		No/lo inlet steam	No production	PALL	
		To high inlet flow	No production	PSV	Add one more PSV

3.6 Environmental Aspects

This section addresses critical concerns related to water, gas, and waste disposal, highlighting its significance, particularly in today's context where the environment is controlled more by various institutions and international law. Public opinion plays a pivotal role in shaping these discussions. It raises significant questions, such as whether companies should invest in more environmentally friendly technologies to reduce costs associated with CO2 emissions, or to pay taxes for waste release instead. These decisions have found implications not only for companies but also for the environment and society, underscoring the importance of informed and responsible decision-making in addressing environmental challenges.

Produced Water Treatment

The volume of produced water encompasses various processes, including de-oiling, de-sanding, chemical treatment, pH balancing, and the removal of naturally occurring radioactive scale material (NORM). Additionally, the treatment may involve softening, upon the ultimate disposal method of the produced water. (Fakhru'l-Razi, Ahmadun, 2009)

The produced water is separated by using hydro cyclones, which is a mechanism that leads to air-core development. The top of the cylindrical section is closed with a plate and axially mounted overflow pipe, it is efficient for promoting solid-liquid and liquid-liquid separation. The device's procedure is converting pressure that is generated by pumps into centrifugal force, which causes solids in the liquid to be separated from the fluid. In the figure 15 – 16, demonstrates how hydro cyclone looks inside and outside. (. Cullivan, J. C., Richard A. Williams, and R. Cross, 2003).

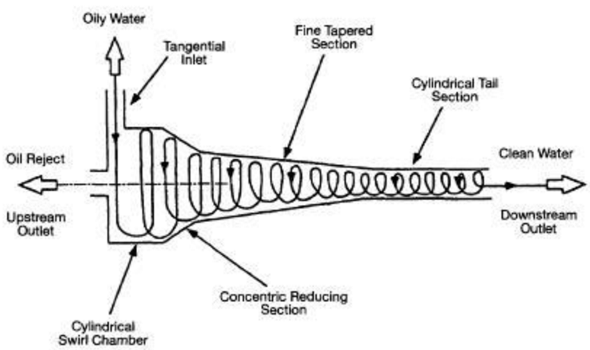

Figure 9 Hydro-Cyclone Scheme

Figure 10 Hydro-Cyclone

The de-oiling process is the most common because it is typically necessary regardless of whether the water is being discharged into the environment or re-injected back to the reservoir.

De-sanding can be achieved through a variety of methods, including industrial filters or de-sanding hydro cyclones. (Knauder, Christoph, 2020).

Oil in water emissions

When water is co-produced with oil, the separation process may result in residual water remaining in the oil. The current maximum oil-in-water emission limit typically stands at around 25 pp. Disposal of oily water takes place at processing platforms, certain drilling platforms, and oil terminals. However, if methods to decrease produced water at the source can be reduced, such as water shut-off or re-injection into the reservoir, it significantly mitigates surface handling challenges.

Gas venting and flaring

The release of methane into the atmosphere contributes to global warming. Greenhouse gases, including methane, function similarly to glass in the greenhouse; they permit ultraviolet radiation from the sun to penetrate the Earth's surface while trapping some of the infrared energy that is reflected.

Flaring gas emits carbon dioxide and water vapor into the air. While carbon dioxide is also a greenhouse gas, it is generally considered less harmful than methane.

Petroleum and surface engineers, particularly during the feasibility study stage of a field, emphasize the importance of dedicating significant efforts to capturing excess gas and exploring opportunities for commercial utilization. Additionally, re-injecting gas into reservoirs is a key consideration, reflecting a proactive approach to resource management and environmental responsibility.

Implementing methods to reduce water at its source, such as water shut-off or re-injection into reservoirs, represents a proactive approach to mitigating surface handling challenges. By addressing the issue directly at its origin, the overall burden and complexities associated with surface handling can be significantly alleviated.

Waste Disposal

The oil and gas industry generates a significant amount of waste material, including scrap metal, human waste, unspent chemicals, oily sludge, and radiation. All incoming streams to a facility, like a production platform, ultimately find their way somewhere, with only a few outgoing streams being useful products. It is our responsibility to minimize the influx of materials that will eventually become waste. The entails implementing practices and technologies aimed at reducing waste generation and promoting efficient resource utilization throughout the industry. (Knauder, Christoph, 2020).

Reducing waste in slim drilling holes involves drilling a smaller hole than conventional methods. This approach decreases the amount of waste generated as drill cutting, making it a more cost-effective option compared to conventional drilling.

4. Methodology

4.1 Crude Oil Assay

The table below shows crude oil assay used for the task of this project, which is from an oil company in Kurdistan Region pf Iraq (Confidential Data). This crude oil is used for all the methods of this research.

Table 4 Oil Assay

Stream State			
Vapor Fraction			0.51
Tempwrature		ºC	40.00
pressure		kpaa	900
LIQUID PROPERTIES			
Liquid Mass Flow		kg/h	61.8
Liquid Volume Flow Std C		m3/day	1610.0
Actual Volume		m3/day	1639.0
Liquid Density		kg/m3	905.0
Liquid Viscosity		cP	90.5
VAPOR PROPERTIES			
Volume Std Conditions		m3/day	115.60
Mass Flow		kg/h	5028.00
Density		kg/m3	8.80
Molecular Weight		kg/kgmole	166.18
Compressibilty			0.97
Gas Viscosity		cP	0.01

This oil assay indicates that the gas part is composed of mainly methane gas, the task is to find chemical composition of PF groups which most of oil phase is composed in the PF groups. Incoming crude oil from the nearby field, 50% of it is steady flow, while the other remaining flow, 50% of it is a sluggish flow. Due to the increase of water injection to the reservoir, the water inlet in the crude oil will be 50-70% of the crude oil, these number might be doubled in over a decade as mentioned because of water injection.

This is a part of the crude oil assay; the continuation of crude oil will be found in the Appendix.

4.2 Simulation of the separation process

The simulation methodology used for this research was Aspen HYSYS simulatio, which is a software many companies worldwide use it considering any related subjects related to this field. The data for the oil and gas composition was used from an Oilfield in Kurdistan Region of Iraq. These data also include pressure, temperature, and molar flow of the inlet which has been used for this project. The data that had been given to me includes components and fluid properties.

Table 5 Data of the inlet

Pressure	9 Bar
Temperature	40 °C
Vapor Fraction	0.507

4.2.1 Units of Operation

While using HYSYS it was needed for me to learn units of each operation and its usage, after studying it, these are the units of operation I used in separation of crude oil.

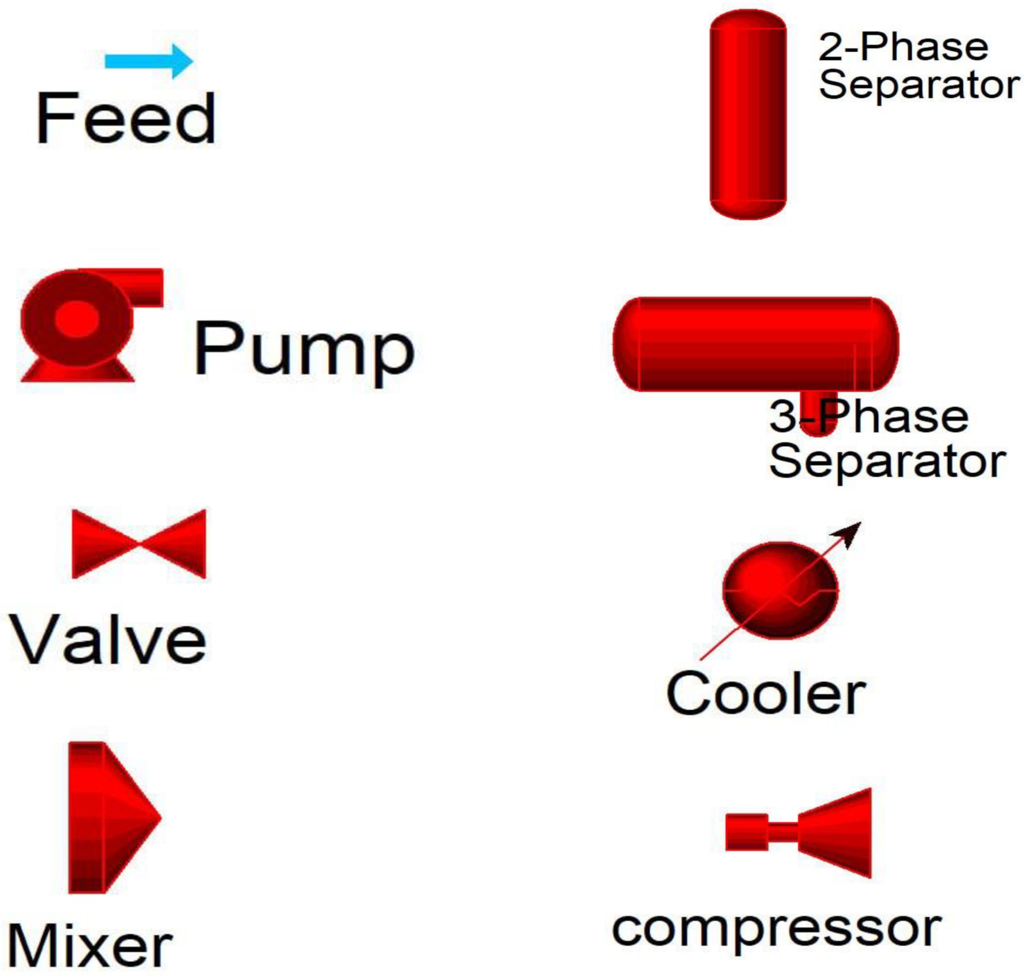

Figure 11 Operation Units for Separation

4.2.2 Thermodynamics:

To separate the crude oil into gas and water phases, it undergoes a series of separators. When crude oil, with specific temperature and pressure, enters a separator with different pressure, the oil-gas-water equilibrium adjusts, leading to changes in the compositions of the three phases. These new compositions require calculation. Due to crude oil's mixture of components and potentially high separator pressures, effective calculation using equations based on pure substances and ideal conditions is impractical. Instead, the Peng-Robinson Equation of state is employed. The Peng-Robinson EOS accounts for non-ideal conditions, describing the relationship between various properties like temperature, pressure, and volume. It predicts PVT (Pressure-Volume-Temperature) behavior based on critical pressure, temperature, and acentric factor.

For applications in oil, gas and petrochemical industries, the Peng-Robinson EOS is commonly recommended as the property package. HYSYS currently provides both Enhanced Peng-Robinson and Soave-Redlich-Kwog equation of state options.

The Peng-Robinson and Soave-Redlich-Kwog equation of state (EOS) can accommodate the widest range of operating conditions and a diverse array of systems. These EOS methods directly generate all necessary equilibrium and thermodynamic properties. Furthermore, their formats are widely shared among other commercial simulators, ensuring compatibility, and they adhere to API standards, making them suitable for industry-standard-applications.

4.3 Pipeline

The task is to make a 50 km oil pipeline for transportation, same as separation methodology, I used Aspen HYSYS simulation to design the exortation line.

4.3.1 Units of operation:

Feed/stream – this uses the same properties and compositions as the separation plant.
Cooler – it is necessary to use coolers for the protection of the compressor. When the gas is compressed, the temperature increases, and it is necessary to cool the compressor gas down.
Energy streams – energy streams are used to know how much energy is needed for the required device.
Compressor – to compress the gas 3 parallel compressors are installed.
Pump – to pump the oil.
Oil pipeline – is to design an onshore 50 km long pipeline.
Gas pipeline – gas pipeline is also to design a 50 km long onshore pipeline.
For both pipelines it is necessary to define: inlet flow, pressure, temperature.
Inside of each pipeline is necessary to define: ambient temperature, amount of segments, diameters, buried depth, type of material, type of surrounding ground.

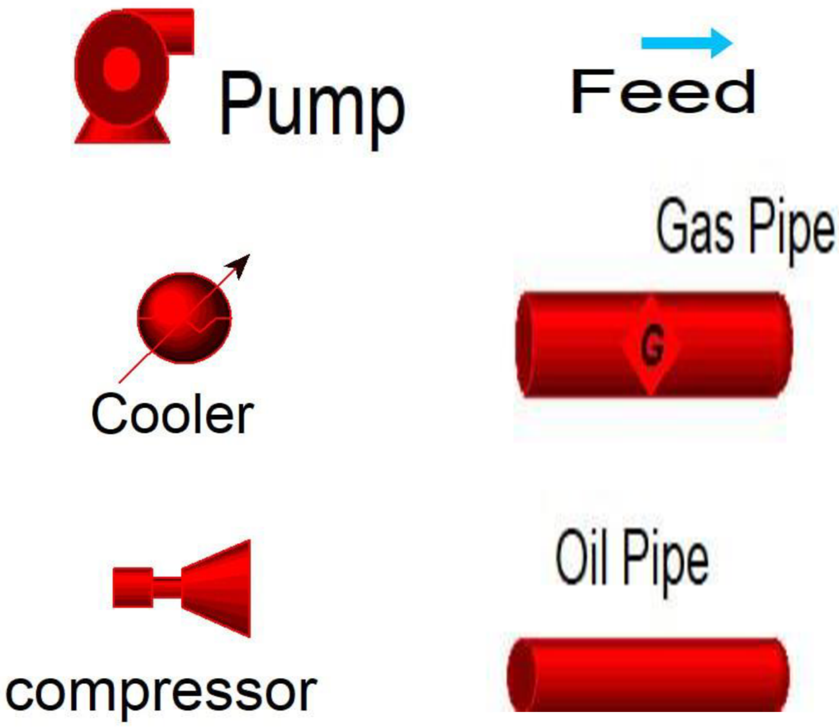

Figure 12 Operation Unit for Pipeline

4.4 Water Injection

These are the equations necessary for the water injection.

Initial oil and water saturation:	$So + Sw = 1$	**Equation 1**
	$So = 1 - Sw$	**Equation 2**
Archie formula:	$Sw = \sqrt{\frac{F \cdot Rw}{Rt}}$	**Equation 3**
Formation factor:	$F = \frac{1}{\emptyset^2}$	**Equation 4**
Stock tank oil initially in place:	$STOIIP = GRV \cdot \frac{N}{G} \cdot \emptyset \cdot So \cdot \frac{1}{Bo}$	**Equation 5**
Gas initially in place:	$GIIP = GRV \cdot \frac{N}{G} \cdot \emptyset \cdot Sg \cdot \frac{1}{Bg}$	**Equation 6**
Oil reserves:	$Oil\,reserves = STOIIP * RFo$	**Equation 7**
Gas reserves:	$Gas\,reserves = GIIP * RFg$	**Equation 8**

Where:

So	=initial oil saturation
Sw	=Initial water saturation
F	=Formation factor
Rw	=Resistivity of water in reservoir conditions
Rt	=Resistivity of formation
Ø	=Porosity
STOIIP	=Stock Tank Oil Initially in place
GRV	=Gross reservoir volume
N/G	=Net gross ratio

GIIP =Gas initially in place

Sg =Gas saturation

Bg =Formation volume factor for the gas

Bo =Formation volume factor for the oil

RFo =Oil recovery factor

RFg =Gas recovery factor

The volume of water to be injected into the reservoir is made by material balance for the reservoir.

$$N \cdot\ Boi = (N - Np).\ Bo + We - Wp$$

$$We = N\ \cdot\ Boi - (N - Np) \cdot Bo$$

$$We = N\ \cdot\ Bo + N \cdot (Boi - Bo) = Np \cdot B0 - N \cdot (Bo - Boi)$$ **Equation 9**

We =Water influx into the reservoir

Wp =Produced water

Boi = Initial compressibility factor

Bo =Compressibility factor

N =Total oil reserves

Np =Oil production per year

5. Results and Discussion

5.1 Simulation of the separation process by using HYSYS

The data for the oil and gas composition was used from an Oilfield in Kurdistan Region of Iraq (Confidential Data).

These data also include pressure, temperature, and molar flow of the inlet which has been used for this project. The data that had been given to me includes components and fluid properties.

Table 6 Data Inlet

Pressure	9 Bar
Temperature	40 °C
Vapor Fraction	0.507

The incoming flow (feed/inlet) from the wells was settled for:

Table 7 Stream Data

Stream Name	Inlet
Vapour / Phase Fraction	0.505595285
Temperature [C]	40
Pressure [kPa]	900
Molar Flow [kgmole/h]	402.05
Mass Flow [kg/h]	144246.0224
Std Ideal Liq Vol Flow [m3/h]	161.7729155
Molar Enthalpy [kJ/kgmole]	-751676.5139
Molar Entropy [kJ/kgmole-C]	1404.575399
Heat Flow [kJ/h]	-302211542.4
Liq Vol Flow @Std Cond [m3/h]	144.8673753

It is necessary at the beginning to settle all the essential conditions for any inlet flow. These conditions include chemical compositions, temperature, and ideal volume flow. When all those mentioned conditions are settled, then the simulation can start.

In the figure below indicates the conditions of the inlet/feed:

2. the flow continuous through throttling valve -100, which reduces the pressure.

3. Then the stream no.2 goes in the two-stage separator (V-100), and the outlet streams which are gas and liquid from the two-phase separator. The energy of gas stream is used in turbo expander. Turbo-expander, known as a turbo-expander or expansion turbine, this device is a centrifugal or axial flow turbine used to expand high-pressure gas. This expansion generates work, which is frequently employed to power a compressor.

Since work is extracted from the expanding high-pressure gas, the expansion process is isentropic, meaning it occurs at constant entropy. As a result, the low-pressure exhaust gas from the turbine is at a very low temperature, sometimes reaching as low as -90 °C or even lower.

4. later, the streams 3 and 5 are mixed in a static mixer (MIX-101).

5. mixed stream is cooled down by the cooler before the HP separator. The temperature is settled at 30 °C and pressure at 70 bar.

6. HP Separation

The chosen pressure for HP separator was 70 bar and 40 °C. The pressure is very high because this oilfield contains many heavy components, so I increased the pressure to produce more gas. When I tried to decrease the pressure to 25 bars, the amount of gas production decreased a lot.

The diameter for the HP separator was calculated automatically by ASPEN HSYS.

The rest of the results are found in the Appendix.

Table 8 Results of the HP Separator

3 Phase Separator: HP Separator				
CONDITIONS				
Name	7	9	8	Water
Vapour	0.511644265	0	1	0
Temperature [C]	30	30	30	30
Pressure [kPa]	700	700	700	700
Molar Flow [kgmole/h]	402.05	141.258864	205.7065766	55.08455943

Mass Flow [kg/h]	144246.0224	42291.13249	5110.432475	96844.45741
Std Ideal Liq Vol Flow [m3/h]	161.7729155	48.14086459	11.75148709	101.8805638
Molar Enthalpy [kJ/kgmole]	-759124.7891	-630499.8348	-105959.3184	-3528137.547
Molar Entropy [kJ/kgmole-C]	1381.895927	794.0018242	177.3347592	7387.778712
Heat Flow [kJ/h]	-305206121.5	-89063690.41	-21796528.65	-194345902.4
SIZING				
Volume [m3]	602			
Diameter [m]	6.5			
Length [m]	17.5			
Head height [m]	0			
NOZZLES				
	7	8	9	Water
Diameter [m]	6.10E-02	6.10E-02	6.10E-02	6.10E-02
Elevation (Base) [m]	1.2192	1.2192	0.6096	0
Elevation (Ground) [m]	1.2192	1.2192	0.6096	0
Elevation (% of Height) [%]	100	100	50	0
OPTIONS				
PV Work Term Contribution	100			
LEVEL TRAPS				
Level tap	PV High	PV Low	OP High	OP Low

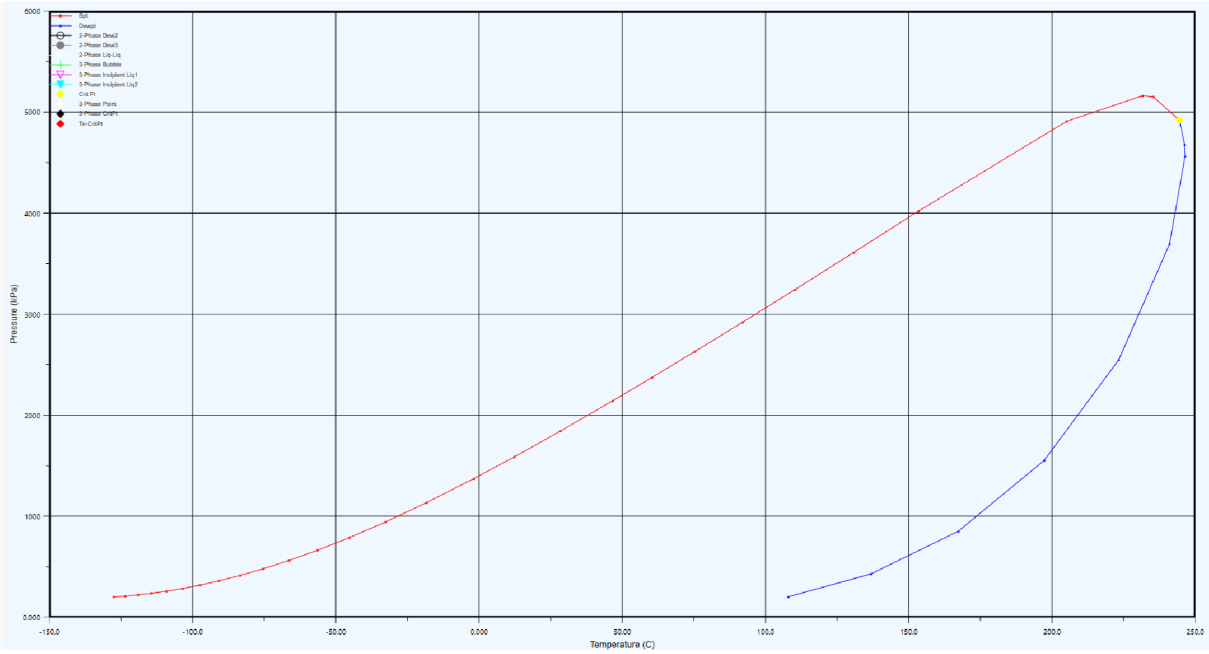

Figure 13 Quality of HP Separator

Where: cricodentherm =200 °C
Cricodenbar = 50 bar

Cricodenthrem, is defined as maximum temperature above which liquid cannot be formed regardless of pressure.

Cricodenbar, is the maximum pressure above which no gas can be formed regardless of temperature.

Critical point, is referred to as state of pressure and temperature at which all intensive properties of the gas and liquid phases are equal.

Phase envelope, the region enclosed by the bubble point and dew point curve, where gas and liquid coexist in equilibrium.

The bubble point curve, is defined as the line separating the liquid-phase region from the two-phase region.

Dew-point curve, is defined as the line separating the vapor phase region from the two-phase region.

7. Stream no. 8 is the mixture of HP oil's outlet and gas scrubber outlet, then transferred to a valve (VLV-101) to reduce pressure.

8. LP Separator

The pressure was chosen 35 bars and temperature at 35 C. The number of the pressure couldn't be decreased more because it gave negative pump ahead, which is not possible.

The diameter and size of LP separator same as the HP separator has been calculated automatically by HYSYS.
Then I added another 2phase separator to remove all the fluids so there is only gas to go through the gas pipeline.
The rest of the results are found in the Appendix.

Table 9 Result of the LP Separator

3 Phase Separator: LP Separator				
CONDITIONS				
Name	16	18	17	Water 2
Vapour	3.34E-02	0	1	0
Temperature [C]	34.99366	34.99366	34.99366	34.99366466
Pressure [kPa]	350	350	350	350
Molar Flow [kgmole/h]	141.4042	136.6453	4.721717	3.72E-02
Mass Flow [kg/h]	42293.81	42151.67	141.4674	0.670267056
Std Ideal Liq Vol Flow [m3/h]	48.14357	47.85904	0.283857	6.72E-04
Molar Enthalpy [kJ/kgmole]	-627005	-644772	-115521	-285238.3776
Molar Entropy [kJ/kgmole-C]	804.0944	825.6232	186.9421	56.39925436
Heat Flow [kJ/h]	-8.9E+07	-8.8E+07	-545457	-10601.82739
SIZING				
Volume [m3]	602			
Diameter [m]	6.5			
Length [m]	17.5			
Head height [m]	0			
NOZZLES				
	16	17	18	Water 2
Diameter [m]	5.00E-02	5.00E-02	5.00E-02	5.00E-02
Elevation (Base) [m]	0.6096	0.6096	0.3048	0
Elevation (Ground) [m]	0.6096	0.6096	0.3048	0
Elevation (% of Height) [%]	100	100	50	0
OPTIONS				
PV Work Term Contribution	100			
LEVEL TRAPS				
Level tap	PV High	PV Low	OP High	OP Low

9. 2 phase separator (V-104), gets the vapour from the mixer (MIX-104) that mixes vapor of HP separator (V103) and also from 2 phase separator (V-103)
9. water, water 2, are water disposal which can be further treated in hydro cyclones, further discussed in Environmental Aspects chapter.

10. the gas outlet from the LP separator is then mixed with the mixer and then can be further treated in the Glycol plant (related to gas cleaning).
11. Oil outlet is pumped and send into pipelines.

HP Separator:

Diameter: 6.5

Length: 17.5 m

Volume: 602 m^3

LP Separator:

Diameter: 6.5

Length: 17.5 m

Volume: 602 m^3

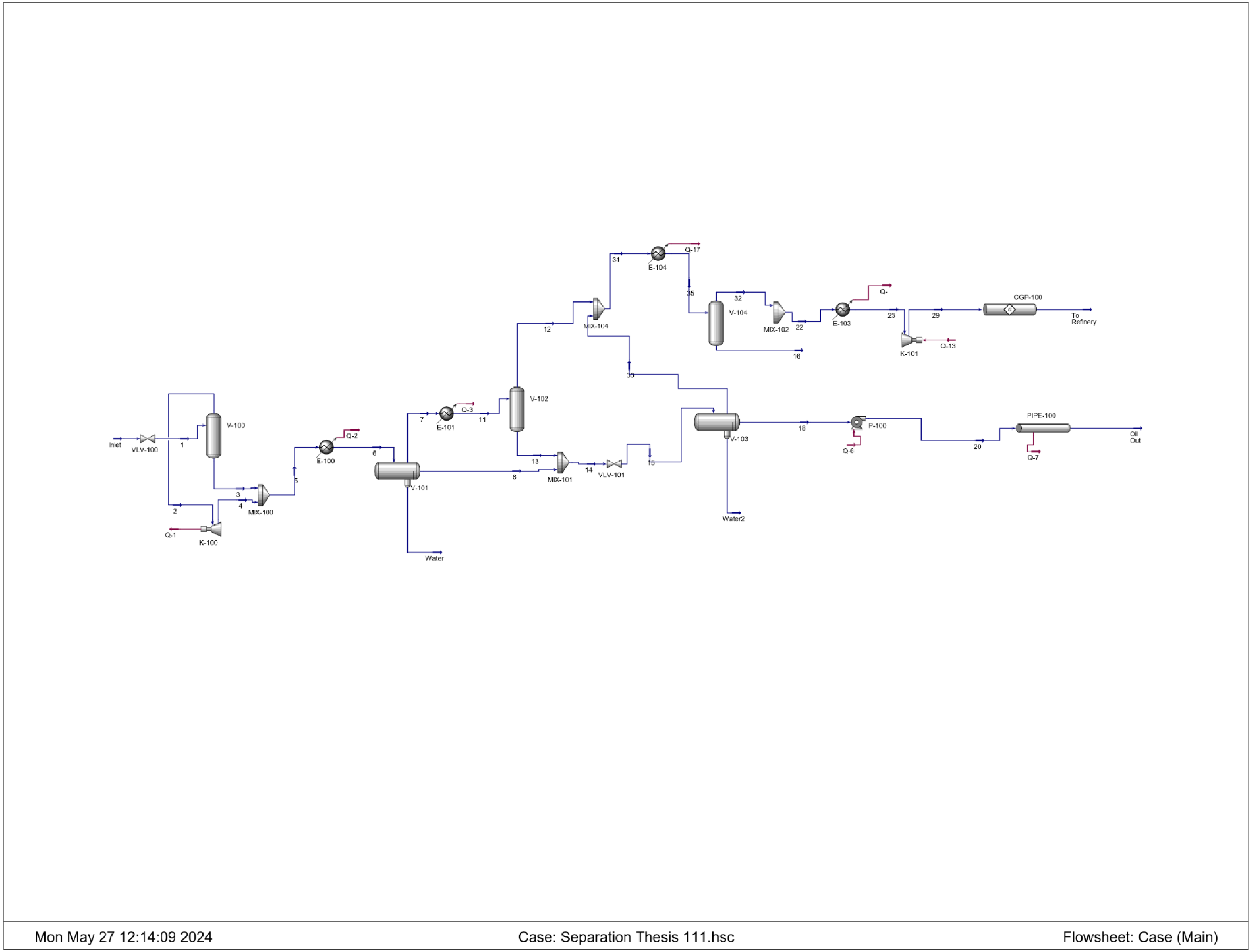

Figure 14 HYSYS Simulation for Separation

5.2 Pipeline

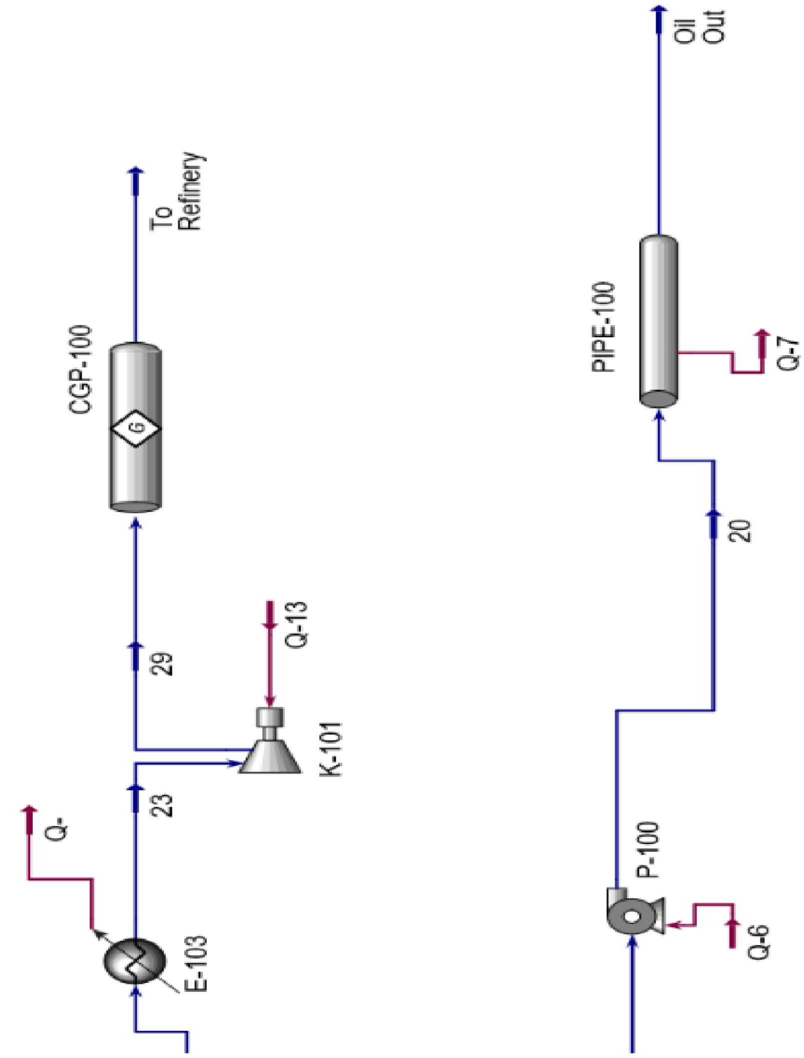

Figure 15 Oil Pipeline and Transport by HYSYS

Oil Pipeline:

In the following table indicates results of the oil pipeline, the rest of the results is found in the apendix.

Table 10 Oil Pipeline Results

Oil Pipeline (Pipe-100)		
Conditions		
Name	20	Oil Out
Vapour	0	0
Temperature [C]	33.2846478	33.28581182
Pressure [kPa]	5000	4997.337377
Molar Flow [kgmole/h]	194.729888	194.729888
Mass Flow [kg/h]	16673.97111	16673.97111
LiqVol Flow [m3/h]	24.11097657	24.11097657
Molar Enthalpy [kJ/kgmole]	-188604.1444	-188604.1444
Molar Entropy [kJ/kgmole-C]	186.9001536	186.9012361
Heat Flow [kJ/h]	-36726863.93	-36726863.93
Profiles		
Axial Length (m)	Elevation	Cells
0	0	
25000	0	25
25000	0	25
Sizing		
Segment	1	2
Fitting/Pipe	Pipe	Pipe
Length/Equivalent Length	25000	25000
Elevation Change	0	0
Outer Diameter	500.1	500.1
Inner Diameter	400	400
Material	Mild Steel	Mild Steel
Roughness	4.57E-05	4.57E-05
Pipe Wall Conductivity	45	45
Increments	25	25
FittingNo	<empty>	<empty>

I used one centrifugal pump, becuase it was more effecient than having 3 small pumps and also to save energy. This centrifugal pump that I installed has 40.5 kW of energy

Gas Pipeline:

Gas conditions before the pipeline in the following figure, indicates the gas quality before going to pipeline.

Where: cricodentherm = -5 °C

Cricodenbar = 90 bar

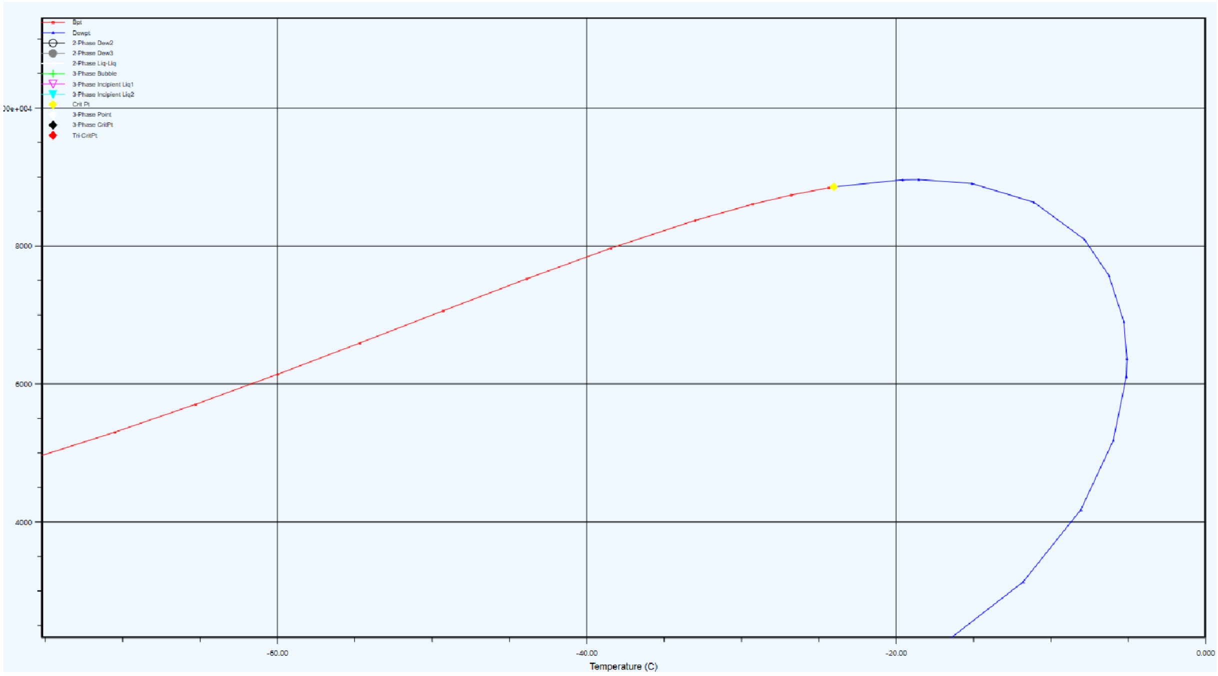

Figure 16 Gas Quality before gas pipeline

Here are the results of the gas pipeline from Aspen HYSYS. The rest of the results is found in appendix.

Table 11 Gas Pipeline Results

Gas Pipeline (GCP-100)		
Conditions		
Name	29	To Refinery
Vapour	1	1
Temperature [C]	106.2709942	106.2709846
Pressure [kPa]	1126.448255	1114.502329
Molar Flow [kgmole/h]	198.2388034	198.2388034
Mass Flow [kg/h]	4698.883501	4698.883501
LiqVol Flow [m3/h]	11.09466706	11.09466706
Molar Enthalpy [kJ/kgmole]	-102844.0352	-102841.8434
Molar Entropy [kJ/kgmole-C]	181.7728946	181.8657399

Heat Flow [kJ/h]	-20387678.47	-20387243.98
Profiles		
Axial Length (m)	Elevation	Cells
0	0	
50000	0	10
Sizing		
Section	1	
Length	50000	
Elevation Change	0	
Cells	10	
Overall Dimensions		
Pipe Schedule	Pipe Schedule	
Material	Plastic Tubing	
Roughness	1.40E-02	
Nominal Diameter	<empty>	
External Diameter	500	
Internal Diameter	400	

In the beginning, I chose the material of my pipeline, which was Plastic-Tubing, and determined the insulation material such as, Polyethylene or polypropylene foams. Then the HYSYS work was done for 50 k m long onshore pipeline. Then I added only one compressor which was also enough and tosave more energy the compressor I added to transport gas was 200kW.

5.3 Water Injection

The results for the calculation of the data table ((())), was calculted from equations in chapter 4.1, the following table indicates my results, these results of the data are used later to calculate water injection.

First resistivity of water reservoir conditions and the resistivity of formation are determined.

R_w = 0.005 Ω.m ………. At reservoir temperature (140 °C/65 °C)

This data is from the Oilfield in Kurdistan Region of Iraq(Confedential Data).

Rt =10 Ω.m ………. Water resistivity, from the data that has been gotten from Oilfield in Kurdistan Region of Iraq.

Then the calculation for the initial water saturations is made.

$Sw = \sqrt{\frac{F \cdot Rw}{Rt}} \quad = \sqrt{\frac{5.9\ X\ 0.05}{10}} = 0.28$

From the result of initial water saturation is possible to calculate the initial oil saturation.

So = 1-0.28 = 0.72

Table 12 Data table

Data Table	Units	Results
Sg	Gas saturation	70%
So	Initial oil saturation	0.725
Sw	Initial water saturation	0.28
Ø	Porosity	41%
F	Formation factor	5.9
Rw	Resistivity of water at reservoir condition	0.05
Rt	Resistivity of formation	10
N/G	Net to gross ratio	75%
Bo	Formation volume factor	1.35
Bg	Formation volume factor for gas	1/200
Rfo	Oil recovery factor	18%
RFg	Gas recovery factor	52%

The volume of water to be injected into the reservoir is made by material balance for the reservoir.

$$N \cdot\ Boi = (N - Np).\ Bo + We - Wp$$

$$We = N\ \cdot\ Boi - (N - Np) \cdot Bo$$

$$We = N\ \cdot\ Bo + N \cdot (Boi - Bo) = Np \cdot B0 - N \cdot (Bo - Boi)$$

We =Water influx into the reservoir

Wp =Produced water

Boi = Initial compressibility factor

Bo =Compressibility factor

N =Total oil reserves

Np =Oil production per year

Calculations for the water injection are made from the equation.

Table 13 Calculations for water injection

N	Total oil reserves	165.4 X 10^6
Np	Cumulative production	15,000 X 365
Boi	Initial compressibility factor	1.33
Bo	Compressibility factor	1.35

$We = Np \cdot Bo + N \cdot (Boi - Bo) = Np \cdot B0 - N \cdot (Bo - Boi)$

W1 = 5,475,000 X 1.35 + 165,400,000 X (1.33-1.35)

= 7,391,250 – 3,308,000

= 4,083,250

W2 = 5,475,000 X 1.35 + (165,400,000 – 5,475,000) X (1.3-1.35)

= 7,391,250 – 3,198,500

= 4,192,750

W3 = 5,475,000 X 1.35 + (165,400,000 – 2(5,475,000) X (1.3-1.35)

= 7,321,250 – 3,089,000

= 4,302,250

W4 = 5,475,000 X 1.35 (165,400,000 – 3(5,475,000)) X (1.3-.1.35)

= 4,341,750

W5 =

Table 14 Results of Water Injection

Year	Volume of Produced Oil	Water Injection per year	Injected Water
1	5475000	4091250	4091250
2	10950000	4083250	8174500
3	16425000	4302250	12476750
4	21900000	441750	12918500
5	27375000	4521250	17439750
6	32850000	4630750	22070500
7	38325000	4740250	26810750
8	43800000	4849750	31660500
9	49275000	4959250	36619750
10	**54750000**	**5068750**	**41688500**
11	60225000	5178250	46866750
12	65700000	5287750	52154500
13	71175000	5397250	57551750
14	76650000	5506750	63058500
15	**82125000**	**5616250**	**68674750**

The water injected is estimated from the year of production to 10 years of production according to the project task. The calculations for 15 years were calculated additionally.

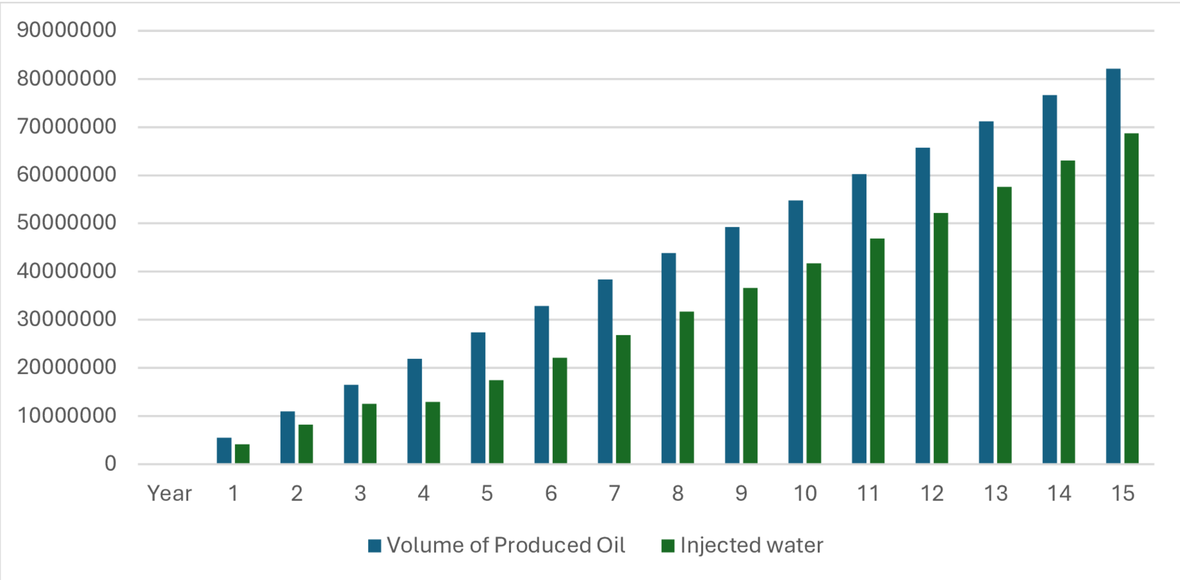

Figure 17 Water Injection, Volume of Produced Oil

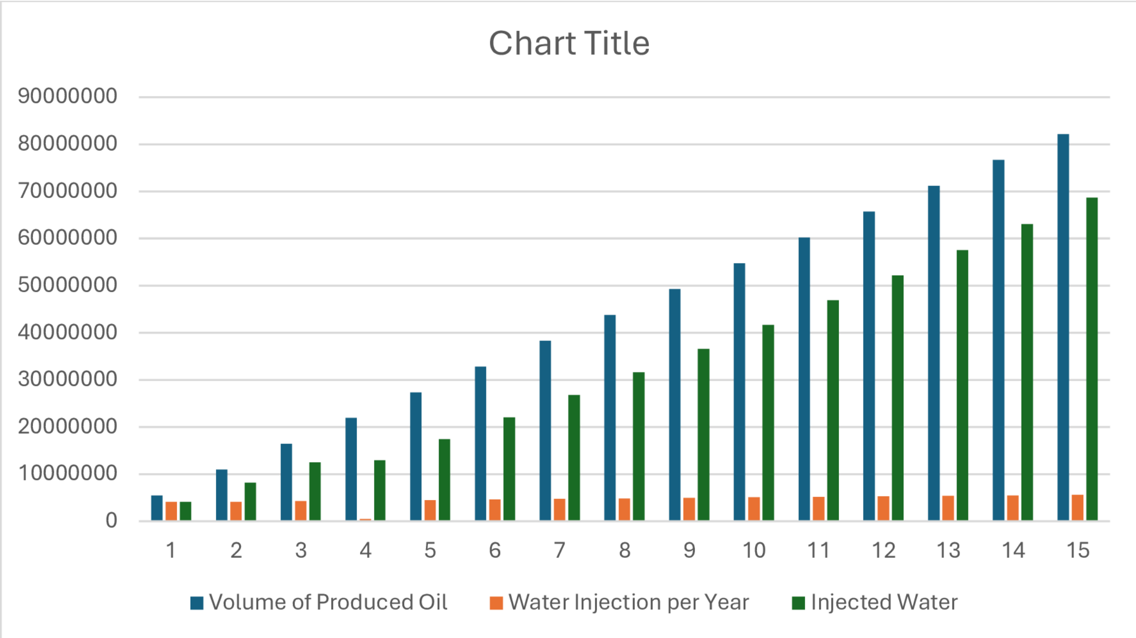

Figure 18 Water Injection, Volume of Produced Oil and Total Injected

Figure - 17, describes water injection according to extracted oil from the reservoir.
Figure – 18, describes the volume of injected water per year, and the volume of the produced oil per year and total injection water into the reservoir. Normally the difference between the total injected water and total produced water must be minimal, but because of the oil recovery factor of 18%.

5.4 HAZOP Analysis

The HAZOP analysis identifies any possible deviations from SCADA by using systematic technique, it oversees operations and ensures that appropriate safeguards are in place to help prevent accidents. The HAZOP technique uses adjectives such as (high, low, no, etc.) with process conditions such as (flow, pressure, etc.) to systematically consider all credible deviations from normal conditions.
The strength of the HAZOP is the most possible hazard that can be taken to safeguards which prevention can be made. The process plant is divided into small parts.
The sketch of the designed system must be made before HAZOP analysis.

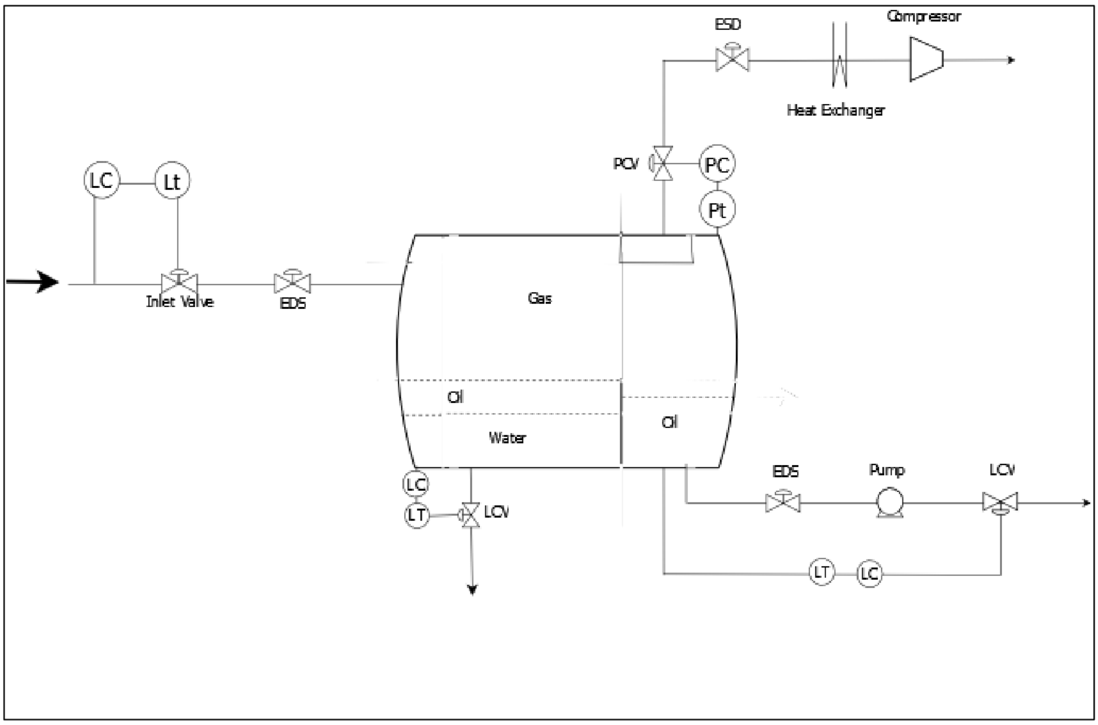

Figure 19 HAZOP Analysis

Fault tree analysis

Fault Tree Analysis is a systematic method for dissecting accidents or system failures. It begins by pinpointing the main event and then traces back through logical gates such as AND and OR to uncover the contributing factors. Each cause is scrutinized in turn, delving deeper into the root of the issue. This process results in a structured tree diagram that elucidates the sequence of events leading to the initial incident. By visually representing casual relationships, Fault Tree Analysis aids in understanding the complex interactions within a system and identifying potential points of failure. Ultimately, it provides valuable insights for mitigating risks and enhancing the safety and reliability of systems. (Ericson, Clifton A., and Clifton Ll, 1999).

On a Fault Tree, qualitive analysis can be conducted, such as identifying individual points of failure or degerming the minimal combinations of events that can lead to the main event.

Qualitive analysis involves combining the probabilities or frequencies of events based on the gates in the tree, ultimately deriving a probability or frequency for the main event.

There are some symbols used in Fault Tree analysis.

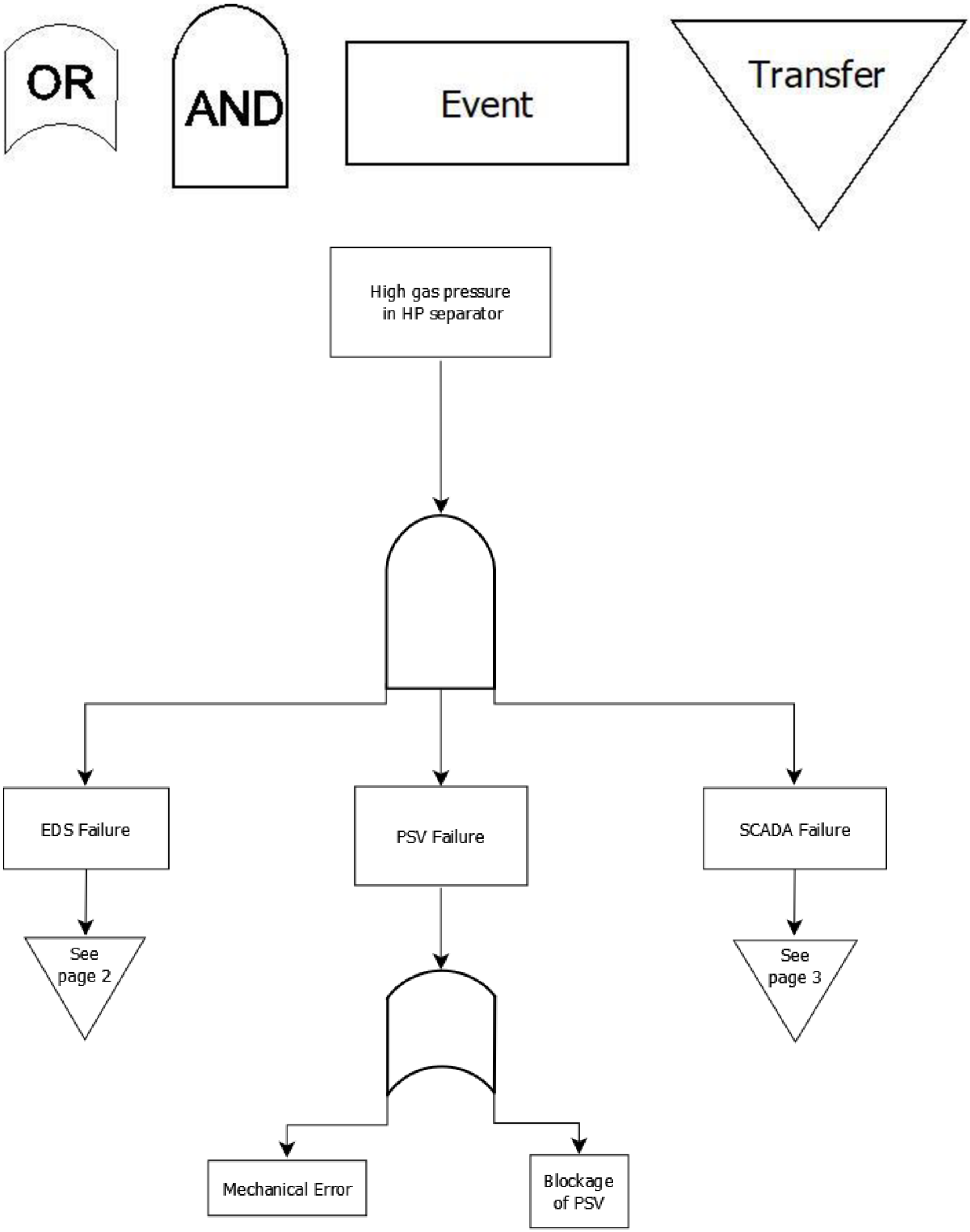

Figure 20 Fault Tree analysis 1st. Page.

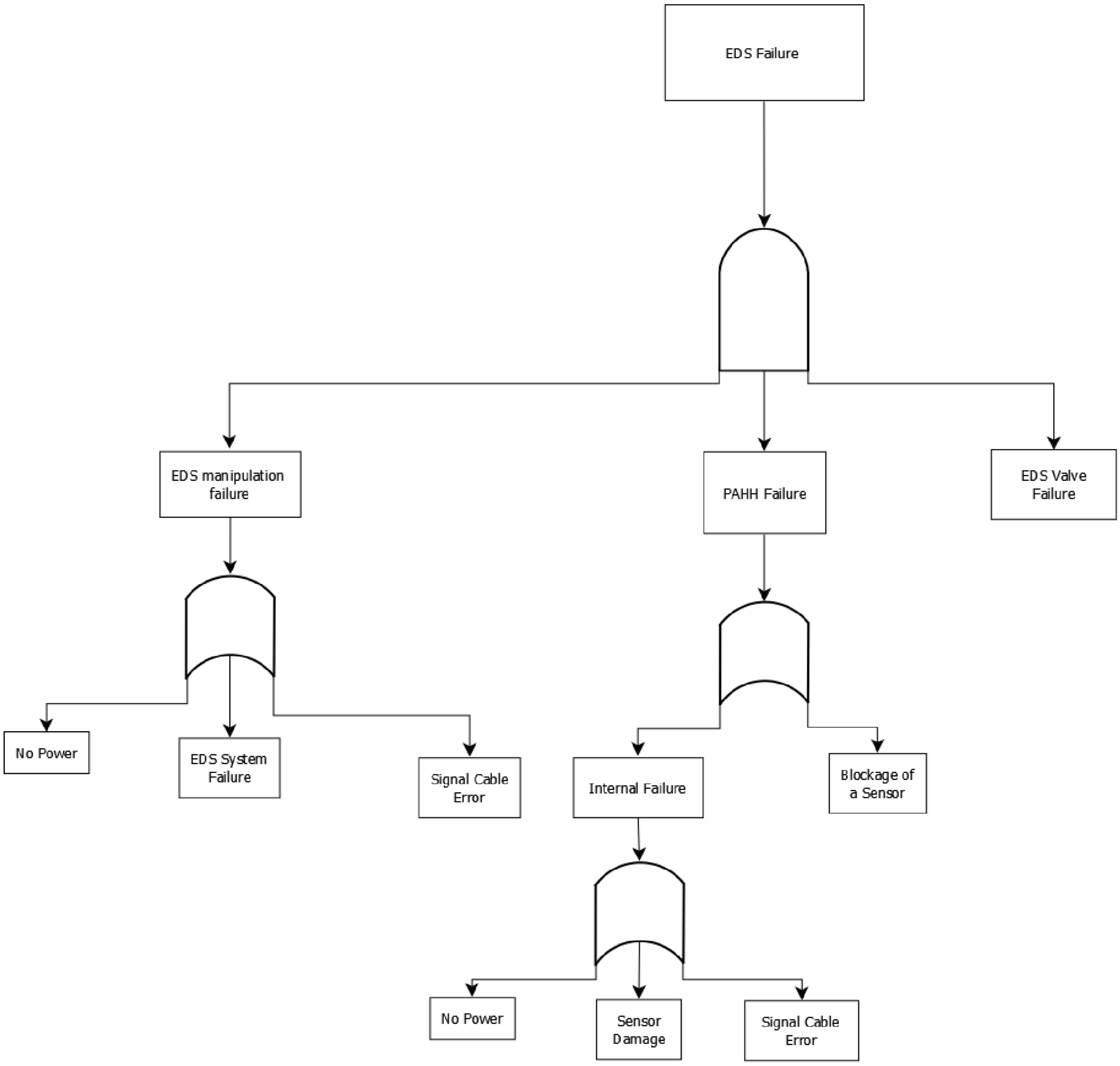

Figure 21 Fault Tree analysis 2nd. Page.

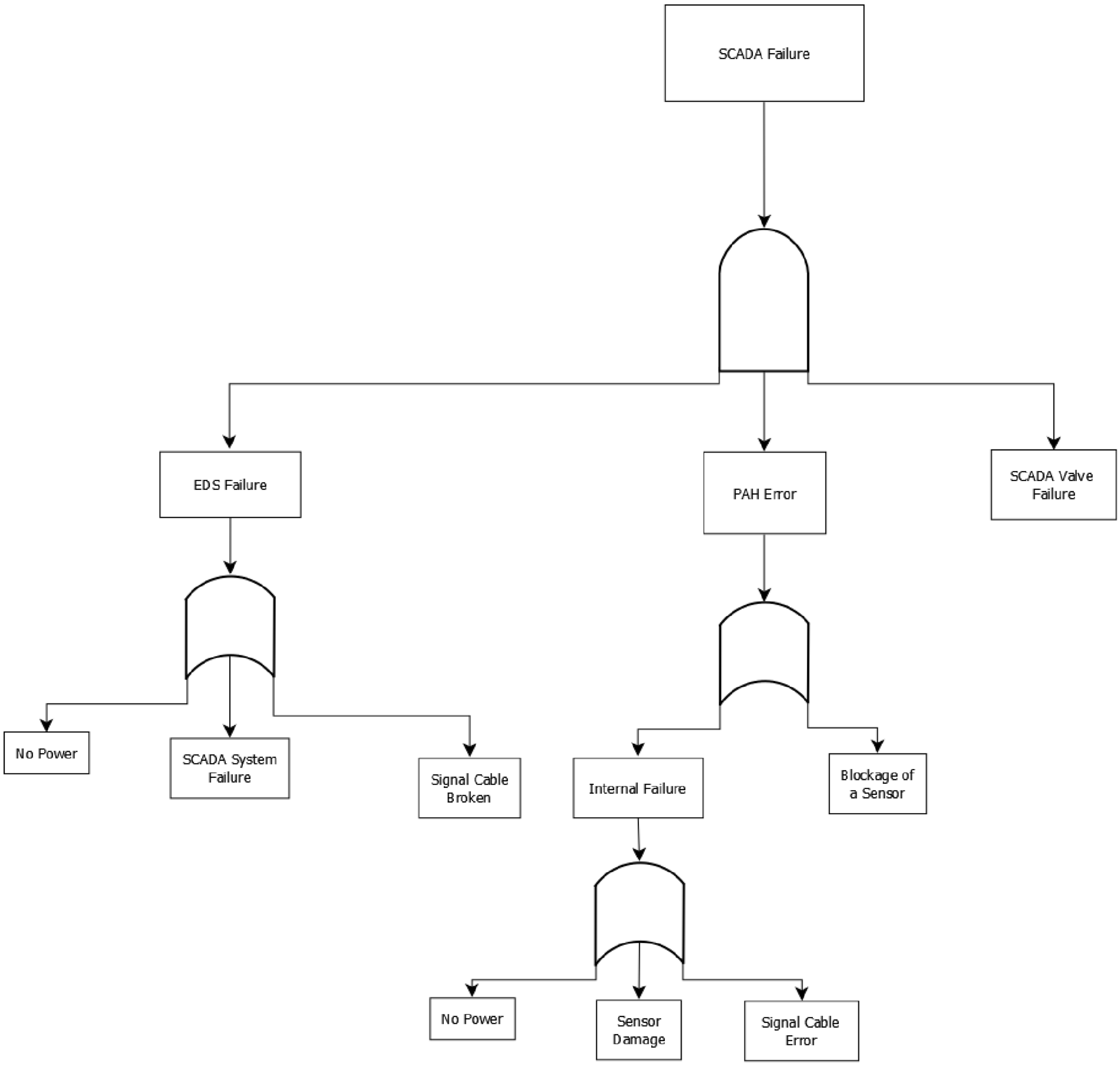

Figure 22 Fault Tree analysis 3rd. Page

6. Conclusions

The aim of this project was to calculate water injection into the reservoir for 10 years which is considered is one of the secondary oil recovery methods. Furthermore, the primary oil recovery method is used in the early stage of oil production and is well-completed by the secondary method which brings effectiveness and optimizes the operating cost. The recovery factor for the oil is usually between 10-20%, I assumed it for 18% made it a bit higher than the middle value. The results of water injection are important for companies because it can predict production and can be optimized.

In the HYSYS simulation, the data that were inserted and used for this project was from an oilfield in Kurdistan's Region of Iraq (Confidential Data), this data included the crude oil composition plus pressure and the temperature. There were no parameters for high- and low-pressure separators. HYSYS was able to calculate diameters by itself.

In addition, the given task for the pipelines was to design a 50 km long onshore pipeline for transportation. For the transport of gas 3 parallel compressors were used. It was only guessed to use one compressor, but because of needed a high energy it was needed to install 3 compressors, and each compressor was cooled by separate coolers. For the oil transport I used only one huge pump rather than 3 parallel pumps to save energy.

Finally, I considered all the aspects according to risk and safety and environmental aspects. Which for risk and safety I discussed about HAZOP analysis and EDS, these factors mentioned always need to be considered in an oilfield facility. Environmental aspects needed to be discussed, in my opinion that making the waste of the field zero is not economically friendly, but it should be reduced, which I assumed that drilling a thin wellbore would be a good solution.

Conclusion is divided into 4 steps:

Step 1: Separation

The crude oil properties were from an oilfield in Kurdistan's region of Iraq. The diameter and size of HP and LP were assumed by the HYSYS simulation. The inlet pressure was 40 °C, and the pressure was 9 bar.

Step 2: Pipeline

The pipeline protection, I considered as external protection and the insulation material. As external protection is used cathodic protection and for increasing the pipeline weight are used concrete blocks. For the transportation of gas compressors were used, and for oil one huge was needed.

Step 3: Water Injection

The STOIIP was calculated for 635.9 $. 10^6\ m^3$. Based on the recovery factor for the oil which was 18% then the initial reserves were established for 663.8 $.10^6$barrels. The porosity of rock is 41%, the water saturation is 27.5% and the initial oil saturation is 72.5%.

In the 10^{th} year of oil production, the total produced oil from the reservoir is 4091250 barrels, to get 4091250 barrels/year, The total water needed to be injected back to the reservoir is 502257000.

Step 4: Risk and Safety

This chapter was focused on HAZARD analysis for the high-pressure separators with the help of FMEA and HAZOP analysis. The PI diagram and tables were used to explain all those analysis in this chapter.

The fault tree analysis includes some devices which can be the cause of dangerous failures and to prevent those dangerous failures several devices were added.

Generally, this project covers: Water Injection, Separation, Pipeline, Risk and Safety

7. References

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Appendix:

a. Crude Oil Assay

STREAM NUMBER		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
STREAM DESCRIPTION		Inlet	Heated Inlet	Separator Gas	Separator Liquids	Feed to E-220	Inlet Water	Inlet	Heated Inlet	Separator Gas	Separator Liquids	Feed to E-221	Inlet Water	Furnace Feed	Furnace Out	Furnace Feed	Furnace Out	Tower Feed	Tower Overhead
Stream State																			
Vapor Fraction		0.507	0.523	1.000	0.000	0.014	0.000	0.507	0.523	1.000	0.000	0.014	0.000	0.086	0.167	0.086	0.167	0.200	1.000
Temperature	°C	40	55	55	55	55	55	40	55	55	55	55	55	174	200	174	200	199	128
Pressure	kpaa	900	800	800	800	580	800	900	800	800	800	580	800	480	300	480	300	230	221
LIQUID PROPERTIES																			
Liquid Mass Flow	kg/h	61,790	61,488		61,488	61,420	0	61,790	61,484		61,484	61,410	0	121,180	118,000	0	0	116,600	
Liquid Volume Flow Std Cond	m3/day	1610.0	1597.7		1597.7	1594.0	0.0	1610.0	1597.6		1597.6	1594.0	0.0	3126.0	3020.0	0.0	0.0	2973.0	
Actual Volume	m3/day	1639.0	1650.6		1650.6	1648.8	0.0	1639.0	1650.5		1650.5	1648.8	0.0	3594.2	3552.5	0.0	0.0	3489.6	
Liquid Density	kg/m3	905.0	894.0		894.0	894.0	833.2	905.0	894.0		894.0	894.0	833.2	809.0	797.0	809.0	797.0	802.0	
Liquid Viscosity	cP	90.50	59.70		59.70	62.10		90.50	59.70		59.70	62.10		6.87	5.89			6.36	
VAPOR PROPERTIES																			
Volume Std Conditions	m3/d	115,600	119,428	119,428		1,481		115,600	119,423	119,423		1,481		18,638	36,390	0	0	43,560	62,164
Mass Flow	kg/h	5028	5331	5331		72		5028	5330	5,330		72		1791	4976	0	0	6420	8,170
Density	kg/m3	8.8	7.6	7.6		5.9		8.8	7.6	7.6		5.9		7.3	6.1	7.3	6.5	5.1	5
Molecular Weight	kg/kgmole	166.18	166.18	25.33	320.85	320.85	18.09	320.85	166.18	25.3	69.00	273.46	18.09	320.85	320.85	320.90	320.90	320.90	75
Compressibility		0.969	0.975	0.975		0.979		0.969	0.975	0.975		0.979		0.970	0.966	0.958	0.958	0.969	0.970
Gas Viscosity	cP	0.0123	0.0127	0.0127		0.0127		0.0123	0.0127	0.0127		0.0127		0.0144	0.0124			0.0117	0.0103
COMPONENT, kgmol/hr	MW																		
Hydrogen	2.02	1.39	1.39	1.38	0.01	0.01	0.00	1.39	1.39	1.38	0.01	0.01	0.00	0.02	0.02	0.00	0.00	0.02	0.13
Hydrogen Sulfide	34.08	29.55	29.55	25.00	4.55	4.55	0.00	29.55	29.55	25.00	4.55	4.55	0.00	9.10	9.10	0.00	0.00	9.10	9.48
Carbon Dioxide	44.01	24.49	24.49	22.74	1.76	1.76	0.00	24.49	24.49	22.73	1.76	1.76	0.00	3.51	3.51	0.00	0.00	3.51	3.57
Nitrogen	28.01	2.66	2.66	2.62	0.04	0.04	0.00	2.66	2.66	2.62	0.04	0.04	0.00	0.07	0.07	0.00	0.00	0.07	0.27
Methane	16.04	127.21	127.21	123.64	3.57	3.57	0.00	127.21	127.21	123.63	3.57	3.57	0.00	7.14	7.14	0.00	0.00	7.14	16.34
Ethane	30.07	19.73	19.73	17.81	1.92	1.92	0.00	19.73	19.73	17.81	1.92	1.92	0.00	3.85	3.85	0.00	0.00	3.85	5.21
Propane	44.10	14.31	14.31	10.99	3.32	3.32	0.00	14.31	14.31	10.99	3.32	3.32	0.00	6.64	6.64	0.00	0.00	6.64	7.95
Isobutane	58.12	1.84	1.84	1.10	0.74	0.74	0.00	1.84	1.84	1.10	0.74	0.74	0.00	1.48	1.48	0.00	0.00	1.47	1.84
Normal butane	58.12	3.80	3.80	2.05	1.76	1.76	0.00	3.80	3.80	2.04	1.76	1.76	0.00	3.52	3.52	0.00	0.00	3.51	4.57
Isopentane	72.15	0.95	0.95	0.33	0.62	0.62	0.00	0.95	0.95	0.33	0.62	0.62	0.00	1.24	1.24	0.00	0.00	1.24	1.90
Normal pentane	72.15	0.89	0.89	0.26	0.63	0.63	0.00	0.89	0.89	0.26	0.63	0.63	0.00	1.25	1.25	0.00	0.00	1.25	2.05
Benzene	78.11	0.11	0.11	0.02	0.10	0.10	0.00	0.11	0.11	0.02	0.10	0.10	0.00	0.19	0.19	0.00	0.00	0.19	0.39
Toluene	92.14	1.87	1.87	0.11	1.76	1.76	0.00	1.87	1.87	0.11	1.76	1.76	0.00	3.53	3.53	0.00	0.00	3.53	4.79
E-Benzene	106.17	1.28	1.28	0.03	1.26	1.26	0.00	1.28	1.28	0.03	1.25	1.25	0.00	2.51	2.51	0.00	0.00	2.51	1.21
PF61	86.00	2.41	2.41	0.40	2.01	2.01	0.00	2.41	2.41	0.40	2.01	2.01	0.00	4.02	4.02	0.00	0.00	4.02	7.69
PF130	119.00	45.82	45.82	0.86	44.99	44.99	0.00	45.82	45.82	0.86	44.96	44.96	0.00	89.97	89.97	0.00	0.00	89.95	41.72
PF225	193.00	16.40	16.40	0.01	16.40	16.40	0.00	16.40	16.40	0.01	16.40	16.40	0.00	32.80	32.80	0.00	0.00	32.80	0.10
PF275	227.00	15.91	15.91	0.00	15.91	15.91	0.00	15.91	15.91	0.00	15.91	15.91	0.00	31.82	31.82	0.00	0.00	31.81	0.01
PF325	275.00	13.37	13.37	0.00	13.37	13.37	0.00	13.37	13.37	0.00	13.37	13.37	0.00	26.73	26.73	0.00	0.00	26.73	0.00
PF360	308.00	4.90	4.90	0.00	4.90	4.90	0.00	4.90	4.90	0.00	4.90	4.90	0.00	9.79	9.79	0.00	0.00	9.79	0.00
PF423	393.00	19.33	19.33	0.00	19.33	19.33	0.00	19.33	19.33	0.00	19.33	19.33	0.00	38.65	38.65	0.00	0.00	38.65	0.00
PF500	517.00	7.83	7.83	0.00	7.83	7.83	0.00	7.83	7.83	0.00	7.83	7.83	0.00	15.67	15.67	0.00	0.00	15.67	0.00
PF528	537.00	1.17	1.17	0.00	1.17	1.17	0.00	1.17	1.17	0.00	1.17	1.17	0.00	2.34	2.34	0.00	0.00	2.34	0.00
PF665	704.00	43.62	43.62	0.00	43.62	43.62	0.00	43.62	43.62	0.00	43.62	43.62	0.00	87.25	87.25	0.00	0.00	87.25	0.00
H2O	18.01	1.21	1.21	1.12	0.09	0.09	0.00	1.21	1.21	1.12	0.09	0.09	0.00	0.18	0.18	0.00	0.00	0.18	0.33
TOTAL	kgmol/hr	402.05	402.05	210.46	191.64	191.64	0.00	402.05	402.05	210.45	191.60	191.60	0.00	383.28	383.28	0.00	0.00	383.24	109.55

STREAM NUMBER		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
STREAM DESCRIPTION		Condenser Outlet	Reflux Drum Gas	Reflux Drum Liquids	Reflux Drum Water	Reflux to Tower	Tower Bottoms	Bottoms To E-220	Bottoms bypassed	Combined Bottoms Out	Bottoms To E-221	Bottoms bypassed	Combined Bottoms Out	Bottoms to E-200	Bottoms Bypassed E-200	Oil Out of E-200	Bottoms to E-201	Bottoms Bypassed E-201	Oil Out of E-201
Stream State																			
Vapor Fraction		0.506	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Temperature	°C	60	60	60	60	60	194	194	194	76	194	194	77	77	77	60	77	77	60
Pressure	kpaa	171	171	171	171	380	238	540	540	440	540	540	440	440	440	340	440	440	340
LIQUID PROPERTIES																			
Liquid Mass Flow	kg/h	5,889		5,889	0	5,889	120,972	60,486	0	60,486	60,486	0	60,486	42,340	18,146	60,486	42,340	18,146	60,486
Liquid Volume Flow Std Cond	m3/day	194.0		194.0	0.0	194.0	3114.6	1557.3	0.0	1557.3	1557.3	0.0	1557.3	1090.1	467.2	1557.3	1090.1	467.2	1557.3
Actual Volume	m3/day	203.9		203.9	0.0	203.9	3653.0	1826.5	0.0	1648.6	1826.5	0.0	1627.6	1154.1	494.6	1627.5	1154.1	494.6	1627.6
Liquid Density	kg/m3	693.3		693.3	830.1	693.2	794.8	795.1	795.1	880.5	795.1	795.1	880.5	880.5	880.5	892.0	880.5	880.5	891.9
Liquid Viscosity	cP	0.35		0.35		0.35	5.62	5.62	5.62	43.40	5.62	5.62	43.40	43.40	43.40	73.00	43.40	43.40	73.00
VAPOR PROPERTIES																			
Volume Std Conditions	m3/d	31,439	31,439																
Mass Flow	kg/h	2,281	2281																
Density	kg/m3	2.6	2.6																
Molecular Weight	kg/kgmole	74.58	41.16	108.77	18.11	108.77	354.93	354.93	354.93	354.93	354.93	354.93	354.93	354.93	354.93	354.93	354.93	354.93	354.93
Compressibility		0.985	0.985																
Gas Viscosity	cP	0.0113	0.0113																
COMPONENT, kgmol/hr	MW																		
Hydrogen	2.02	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrogen Sulfide	34.08	9.48	9.10	0.38	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon Dioxide	44.01	3.57	3.51	0.06	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitrogen	28.01	0.27	0.27	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Methane	16.04	16.34	16.23	0.12	0.00	0.12	0.69	0.35	0.00	0.35	0.35	0.00	0.35	0.24	0.10	0.35	0.24	0.10	0.35
Ethane	30.07	5.21	5.05	0.16	0.00	0.16	0.21	0.10	0.00	0.10	0.10	0.00	0.10	0.07	0.03	0.10	0.07	0.03	0.10
Propane	44.10	7.95	7.28	0.67	0.00	0.67	0.23	0.11	0.00	0.11	0.11	0.00	0.11	0.08	0.03	0.11	0.08	0.03	0.11
Isobutane	58.12	1.84	1.52	0.32	0.00	0.32	0.04	0.02	0.00	0.02	0.02	0.00	0.02	0.01	0.01	0.02	0.01	0.01	0.02
Normal butane	58.12	4.57	3.58	0.99	0.00	0.99	0.10	0.05	0.00	0.05	0.05	0.00	0.05	0.04	0.02	0.05	0.04	0.02	0.05
Isopentane	72.15	1.90	1.18	0.73	0.00	0.73	0.10	0.05	0.00	0.05	0.05	0.00	0.05	0.03	0.01	0.05	0.03	0.01	0.05
Normal pentane	72.15	2.05	1.15	0.90	0.00	0.90	0.12	0.06	0.00	0.06	0.06	0.00	0.06	0.04	0.02	0.06	0.04	0.02	0.06
Benzene	78.11	0.39	0.12	0.27	0.00	0.27	0.07	0.04	0.00	0.04	0.04	0.00	0.04	0.03	0.01	0.04	0.03	0.01	0.04
Toluene	92.14	4.79	0.63	4.15	0.00	4.15	2.91	1.45	0.00	1.45	1.45	0.00	1.45	1.02	0.44	1.45	1.02	0.44	1.45
E-Benzene	106.17	1.21	0.07	1.14	0.00	1.14	2.44	1.22	0.00	1.22	1.22	0.00	1.22	0.86	0.37	1.22	0.86	0.37	1.22
PF61	86.00	7.69	2.89	4.79	0.00	4.79	1.17	0.58	0.00	0.58	0.58	0.00	0.58	0.41	0.18	0.58	0.41	0.18	0.58
PF130	119.00	41.72	2.36	39.36	0.00	39.36	87.67	43.84	0.00	43.84	43.84	0.00	43.84	30.69	13.15	43.84	30.69	13.15	43.84
PF225	193.00	0.10	0.00	0.10	0.00	0.10	32.80	16.40	0.00	16.40	16.40	0.00	16.40	11.48	4.92	16.40	11.48	4.92	16.40
PF275	227.00	0.01	0.00	0.01	0.00	0.01	31.81	15.91	0.00	15.91	15.91	0.00	15.91	11.14	4.77	15.91	11.14	4.77	15.91
PF325	275.00	0.00	0.00	0.00	0.00	0.00	26.73	13.37	0.00	13.37	13.37	0.00	13.37	9.36	4.01	13.37	9.36	4.01	13.37
PF360	308.00	0.00	0.00	0.00	0.00	0.00	9.79	4.90	0.00	4.90	4.90	0.00	4.90	3.43	1.47	4.90	3.43	1.47	4.90
PF423	393.00	0.00	0.00	0.00	0.00	0.00	38.65	19.33	0.00	19.33	19.33	0.00	19.33	13.53	5.80	19.33	13.53	5.80	19.33
PF500	517.00	0.00	0.00	0.00	0.00	0.00	15.67	7.83	0.00	7.83	7.83	0.00	7.83	5.48	2.35	7.83	5.48	2.35	7.83
PF528	537.00	0.00	0.00	0.00	0.00	0.00	2.34	1.17	0.00	1.17	1.17	0.00	1.17	0.82	0.35	1.17	0.82	0.35	1.17
PF665	704.00	0.00	0.00	0.00	0.00	0.00	87.25	43.62	0.00	43.62	43.62	0.00	43.62	30.54	13.09	43.62	30.54	13.09	43.62
H2O	18.01	0.33	0.32	0.01	0.00	0.01	0.02	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.01
TOTAL	kgmol/hr	109.55	55.40	54.14	0.00	54.14	340.83	170.42	0.00	170.42	170.42	0.00	170.42	119.29	51.12	170.42	119.29	51.12	170.42

STREAM NUMBER		37	38	40	41	42	43	44	45	46	47	48	50	51	52	53	54	55	
STREAM DESCRIPTION		Combined Oil to Tank	Oil Entering Tank	Total Inlet Gas	Gas to Flare	Gas To Compressor	Gas To Amine	Liquids From After Separator	Sweet Fuel Gas	Fuel Gas	Fuel Gas to Tower	Tower Fuel Gas Feed	HP Flare Gas	Acid Gas	Stab Ovhd Flare Gas	Total LP Flare Gas	Extra FG Flare	Total Flare Gas	
Stream State																			
Vapor Fraction		0.000	0.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Temperature	°C	60	60	55	55	55	55	55	65	58	58	55	51	55	59	58	58	54	
Pressure	kpaa	340	190	800	128	800	2169	2204	2140	800	800	240	135	135	135	135	135	130	
LIQUID PROPERTIES																			
Liquid Mass Flow	kg/h	120,972	120,972					5											
Liquid Volume Flow Std C	m3/day	3114.6	3114.6					0.2											
Actual Volume	m3/day	3255.0	3255.5					0.2											
Liquid Density	kg/m3	891.9	891.8					700.9											
Liquid Viscosity	cP	73.00	73.10					0.37											
VAPOR PROPERTIES																			
Volume Std Conditions	m3/d			238,851	111,664	127,187	127,160		98,645	91,296	7,349	7,349	111,664	32,065	31,439	63,504	65,000	240,168	
Mass Flow	kg/h			10661	4984	5677	5672		3710	3434	276	276	4984	2074	2281	4355	2445	11784	
Density	kg/m3			7.6	7.6	7.6	21.6		17.2	6.3	6.3	1.9	1.3	2.3	1.7	1.6	1.1	1.4	
Molecular Weight	kg/kgmole	354.93	354.93	25.33	25.33	25.33	25.31	101.10	21.34	21.34	21.34	21.34	25.33	36.71	41.16	38.92	21.34	27.84	
Compressibility				0.975	0.975	0.975	0.933		0.983	0.983	0.983	0.983	0.996	0.979	0.990	0.993	0.996	0.993	
Gas Viscosity	cP			0.0128	0.0128	0.0128	0.0132		0.0129	0.0123	0.0123	0.0121	0.0125	0.0136	0.0125	0.0125	0.0125	0.0126	
COMPONENT, kgmol/hr	MW																		
Hydrogen	2.02	0.00	0.00	2.77	1.29	1.47	1.47	0.00	1.47	1.36	0.11	0.11	1.29	0.00	0.13	0.13	0.97	2.39	
Hydrogen Sulfide	34.08	0.00	0.00	50.00	23.38	26.63	26.62	0.00	0.00	0.00	0.00	0.00	23.38	26.62	9.10	35.73	0.00	59.10	
Carbon Dioxide	44.01	0.00	0.00	45.47	21.26	24.21	24.21	0.00	0.00	0.00	0.00	0.00	21.26	24.21	3.51	27.72	0.00	48.98	
Nitrogen	28.01	0.01	0.01	5.25	2.45	2.79	2.79	0.00	2.79	2.59	0.21	0.21	2.45	0.00	0.27	0.27	1.84	4.56	
Methane	16.04	0.69	0.69	247.27	115.60	131.67	131.67	0.00	131.30	121.52	9.78	9.78	115.60	0.37	16.23	16.60	86.52	218.71	
Ethane	30.07	0.21	0.21	35.62	16.65	18.97	18.96	0.00	18.94	17.53	1.41	1.41	16.65	0.02	5.05	5.07	12.48	34.20	
Propane	44.10	0.23	0.23	21.98	10.28	11.70	11.70	0.00	11.70	10.83	0.87	0.87	10.28	0.00	7.28	7.28	7.71	25.27	
Isobutane	58.12	0.04	0.04	2.21	1.03	1.17	1.17	0.00	1.17	1.09	0.09	0.09	1.03	0.00	1.52	1.52	0.77	3.33	
Normal butane	58.12	0.10	0.10	4.09	1.91	2.18	2.18	0.00	2.18	2.01	0.16	0.16	1.91	0.00	3.58	3.58	1.43	6.92	
Isopentane	72.15	0.10	0.10	0.65	0.30	0.35	0.35	0.00	0.35	0.32	0.03	0.03	0.30	0.00	1.18	1.18	0.23	1.71	
Normal pentane	72.15	0.12	0.12	0.53	0.25	0.28	0.28	0.00	0.28	0.26	0.02	0.02	0.25	0.00	1.15	1.15	0.19	1.58	
Benzene	78.11	0.07	0.07	0.03	0.02	0.02	0.02	0.00	0.02	0.02	0.00	0.00	0.02	0.00	0.12	0.12	0.01	0.15	
Toluene	92.14	2.91	2.91	0.22	0.10	0.12	0.11	0.00	0.11	0.11	0.01	0.01	0.10	0.00	0.63	0.63	0.08	0.81	
E-Benzene	106.17	2.44	2.44	0.06	0.03	0.03	0.03	0.00	0.03	0.03	0.00	0.00	0.03	0.00	0.07	0.07	0.02	0.12	
PF61	86.00	1.17	1.17	0.81	0.38	0.43	0.43	0.00	0.43	0.40	0.03	0.03	0.38	0.00	2.89	2.89	0.28	3.55	
PF130	119.00	87.67	87.67	1.71	0.80	0.91	0.88	0.03	0.88	0.82	0.07	0.07	0.80	0.00	2.36	2.36	0.58	3.74	
PF225	193.00	32.80	32.80	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	
PF275	227.00	31.81	31.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
PF325	275.00	26.73	26.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
PF360	308.00	9.79	9.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
PF423	393.00	38.65	38.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
PF500	517.00	15.67	15.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
PF528	537.00	2.34	2.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
PF665	704.00	87.25	87.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
H2O	18.01	0.02	0.02	2.24	1.05	1.19	1.19	0.00	2.16	2.00	0.16	0.16	1.05	5.29	0.32	5.61	1.42	8.08	
TOTAL	kgmol/hr	340.83	340.83	420.91	196.78	224.13	224.08	0.05	173.83	160.88	12.95	12.95	196.78	56.51	55.40	111.91	114.54	423.23	0.00

b. HP – Separator

3 Phase Separator: HP Separator				
CONDITIONS				
Name	7	9	8	Water
Vapour	0.511644265	0	1	0
Temperature [C]	30	30	30	30
Pressure [kPa]	700	700	700	700
Molar Flow [kgmole/h]	402.05	141.258864	205.7065766	55.08455943
Mass Flow [kg/h]	144246.0224	42291.13249	5110.432475	96844.45741
Std Ideal Liq Vol Flow [m3/h]	161.7729155	48.14086459	11.75148709	101.8805638
Molar Enthalpy [kJ/kgmole]	-759124.7891	-630499.8348	-105959.3184	-3528137.547
Molar Entropy [kJ/kgmole-C]	1381.895927	794.0018242	177.3347592	7387.778712
Heat Flow [kJ/h]	-305206121.5	-89063690.41	-21796528.65	-194345902.4
Name	7	9	8	Water
Molecular Weight	358.7763273	299.38746	24.84331109	1758.105328
Molar Density [kgmole/m3]	0.462169687	2.914836526	0.285372851	0.547439785
Mass Density [kg/m3]	165.815543	872.665504	7.089606515	962.456803
Act. Volume Flow [m3/h]	869.9185838	48.4620193	720.8344305	100.622134
Mass Enthalpy [kJ/kg]	-2115.872011	-2105.966077	-4265.104521	-2006.783946
Mass Entropy [kJ/kg-C]	3.851692048	2.65208778	7.138128994	4.202125205
Heat Capacity [kJ/kgmole-C]	727.9388144	588.9186976	42.09646016	3645.636772
	7.26E-02	<empty>	1	<empty>
Phase Fraction [Mass Basis]	3.54E-02	0	1	0
Phase Fraction [Act. Vol. Basis]	0.828622866	0	1	0
Mass Exergy [kJ/kg]	8.422604102	1.543157946	190.5186315	1.605060315
Partial Pressure of CO2 [kPa]	75.79339339	0	75.79339339	0
Cost Based on Flow [Cost/s]	0	0	0	0
Act. Gas Flow [ACT_m3/h]	720.8344305	<empty>	720.8344305	<empty>
Avg. Liq. Density [kgmole/m3]	2.485273872	2.934281824	17.50472727	0.540677803
Specific Heat [kJ/kgmole-C]	727.9388144	588.9186976	42.09646016	3645.636772
Std. Gas Flow [STD_m3/h]	9506.245668	3339.98623	4863.816074	1302.443364
Std. Ideal Liq. Mass Density [kg/m3]	891.6574321	878.4871824	434.8753851	950.5685267
Act. Liq. Flow [m3/s]	4.14E-02	1.35E-02	0	2.80E-02

Z Factor	<empty>	<empty>	<empty>	<empty>
Watson K	11.79948226	11.80389253	14.78211176	13.11069212
User Property	<empty>	<empty>	<empty>	<empty>
Partial Pressure of H2S [kPa]	81.83861232	0	81.83861232	0
Cp/(Cp - R)	1.011553692	1.014320112	1.246115846	1.002285835
Cp/Cv	1.007078098	1.117660136	1.282793047	1.002285835
Ideal Gas Cp/Cv	1.013046879	1.017148834	1.25432529	1.002530327
Ideal Gas Cp [kJ/kgmole-C]	645.5793801	493.1472821	41.00599608	3294.181958
Mass Ideal Gas Cp [kJ/kg-C]	1.799392354	1.647187501	1.650584978	1.873711379
Heat of Vap. [kJ/kgmole]	759280.5183	589919.8065	24695.03639	4581668.562
Kinematic Viscosity [cSt]	<empty>	17.14286495	1.670522065	13175.95913
Liq. Mass Density (Std. Cond) [kg/m3]	995.7108842	883.6329582	1.055466914	970.6406037
Liq. Vol. Flow (Std. Cond) [m3/h]	144.8673753	47.86051958	4841.868947	99.77375461
Liquid Fraction	0.488355735	1	0	1
Molar Volume [m3/kgmole]	2.163707459	0.343072413	3.504187579	1.82668492
Mass Heat of Vap. [kJ/kg]	2116.306067	1970.422564	994.0316047	2606.026209
Phase Fraction [Molar Basis]	0.511644265	0	1	0
Surface Tension [dyne/cm]	<empty>	24.04846757	<empty>	16.83557884
Thermal Conductivity [W/m-K]	<empty>	0.118691813	2.79E-02	0.139698859
Bubble Point Pressure [kPa]	8860.015148	699.9839726	18481.03365	699.9890541
Viscosity [cP]	<empty>	14.95998688	1.18E-02	12681.2915
Cv (Semi-Ideal) [kJ/kgmole-C]	719.6244944	580.6043776	33.78214016	3637.322452
Mass Cv (Semi-Ideal) [kJ/kg-C]	2.00577474	1.939307603	1.359808282	2.06888768
Cv [kJ/kgmole-C]	722.822605	526.9210904	32.8162522	3637.322452
Mass Cv [kJ/kg-C]	2.014688679	1.759997197	1.320929086	2.06888768
Cv (Ent. Method) [kJ/kgmole-C]	<empty>	<empty>	<empty>	<empty>
Mass Cv (Ent. Method) [kJ/kg-C]	<empty>	<empty>	<empty>	<empty>
Cp/Cv (Ent. Method)	<empty>	<empty>	<empty>	<empty>
Reid VP at 37.8 C [kPa]	<empty>	135.7578538	<empty>	<empty>
True VP at 37.8 C [kPa]	9241.999577	750.9883475	<empty>	734.6423167
Liq. Vol. Flow - Sum(Std. Cond) [m3/h]	4941.642701	0	4841.868947	99.77375461
Viscosity Index	28.01201842	26.38556763	-21.0920426	43.6757048
SIZING				
Volume [m3]	602			
Diameter [m]	6.5			
Length [m]	17.5			
Head height [m]	0			
NOZZLES				

	7	8	9	Water
Diameter [m]	6.10E-02	6.10E-02	6.10E-02	6.10E-02
Elevation (Base) [m]	1.2192	1.2192	0.6096	0
Elevation (Ground) [m]	1.2192	1.2192	0.6096	0
Elevation (% of Height) [%]	100	100	50	0
OPTIONS				
PV Work Term Contribution	100			
LEVEL TRAPS				
Level tap	PV High	PV Low	OP High	OP Low

c. LP – Separator

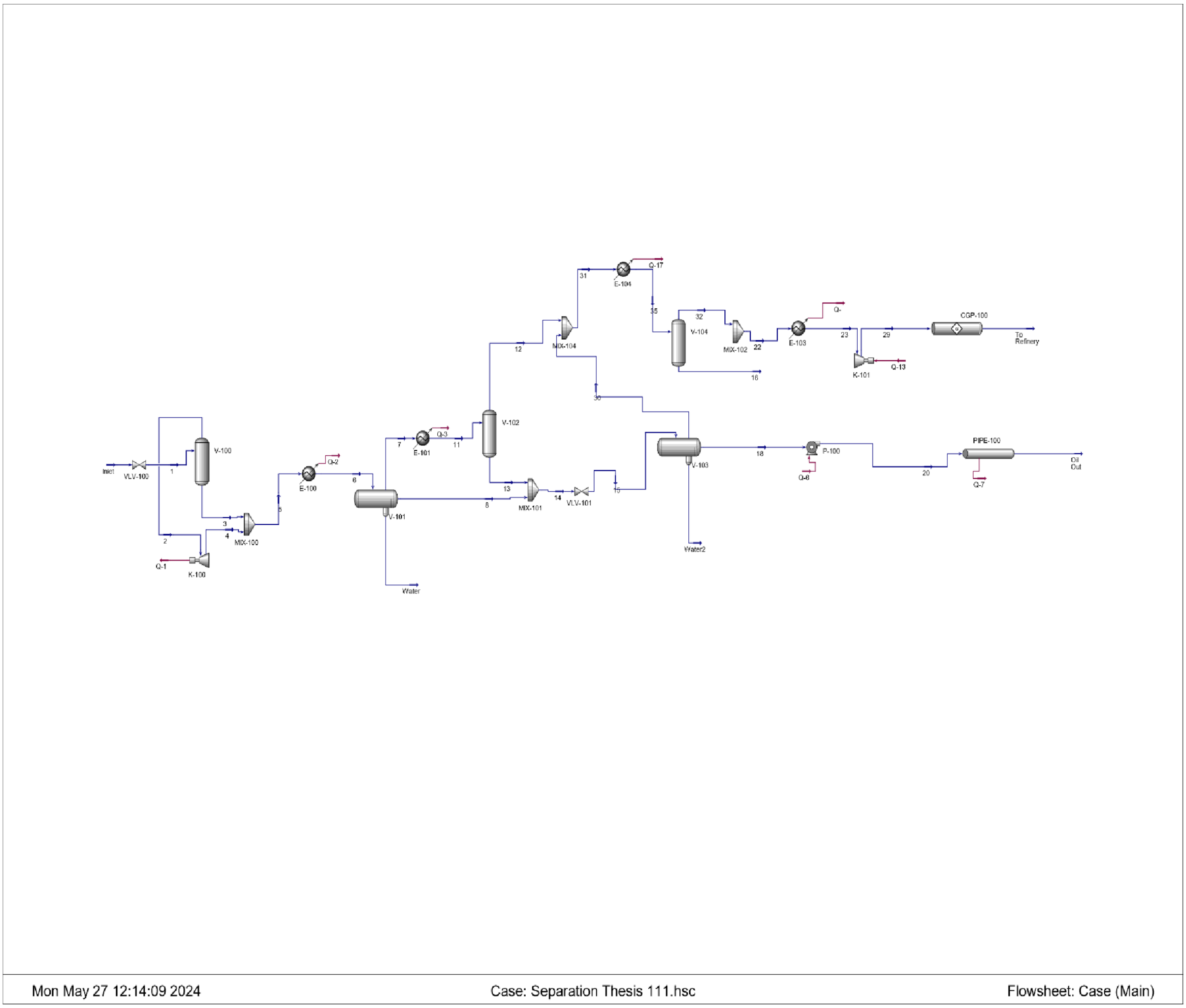
3 Phase Separator: LP Separator				
CONDITIONS				
Name	16	18	17	Water 2
Vapour	3.34E-02	0	1	0
Temperature [C]	34.99366	34.99366	34.99366	34.99366466
Pressure [kPa]	350	350	350	350
Molar Flow [kgmole/h]	141.4042	136.6453	4.721717	3.72E-02
Mass Flow [kg/h]	42293.81	42151.67	141.4674	0.670267056
Std Ideal Liq Vol Flow [m3/h]	48.14357	47.85904	0.283857	6.72E-04
Molar Enthalpy [kJ/kgmole]	-627005	-644772	-115521	-285238.3776
Molar Entropy [kJ/kgmole-C]	804.0944	825.6232	186.9421	56.39925436

Heat Flow [kJ/h]	-8.9E+07	-8.8E+07	-545457	-10601.82739
PROPERTIES				
Name	16	18	17	Water 2
Molecular Weight	299.0987	308.4751	29.96101	18.03329564
Molar Density [kgmole/m3]	1.714938	2.815635	0.13919	55.43719904
Mass Density [kg/m3]	512.9358	868.5532	4.170272	999.7153998
Act. Volume Flow [m3/h]	82.4544	48.53091	33.92282	6.70E-04
Mass Enthalpy [kJ/kg]	-2096.32	-2090.19	-3855.71	-15817.31833
Mass Entropy [kJ/kg-C]	2.688391	2.676466	6.239513	3.127506779
Heat Capacity [kJ/kgmole-C]	593.8206	612.8829	46.22511	77.69518449
Mass Heat Capacity [kJ/kg-C]	1.985367	1.986815	1.542842	4.308429587
LHV Molar Basis (Std) [kJ/kgmole]	<empty>	<empty>	<empty>	435.8095981
HHV Molar Basis (Std) [kJ/kgmole]	<empty>	<empty>	<empty>	41438.42421
HHV Mass Basis (Std) [kJ/kg]	<empty>	<empty>	<empty>	2297.884149
CO2 Loading	<empty>	<empty>	<empty>	<empty>
CO2 Apparent Mole Conc. [kgmole/m3]	<empty>	1.78E-02	<empty>	9.98E-03
CO2 Apparent Wt. Conc. [kgmol/kg]	<empty>	2.05E-05	<empty>	9.98E-06
LHV Mass Basis (Std) [kJ/kg]	<empty>	<empty>	<empty>	24.16694135
Phase Fraction [Vol. Basis]	5.90E-03	<empty>	1	<empty>
Phase Fraction [Mass Basis]	3.34E-03	0	1	0
Phase Fraction [Act. Vol. Basis]	0.411413	0	1	0
Mass Exergy [kJ/kg]	1.233104	0.859614	101.6169	1.020414472
Partial Pressure of CO2 [kPa]	47.02518	0	47.02518	0
Cost Based on Flow [Cost/s]	0	0	0	0
Act. Gas Flow [ACT_m3/h]	33.92282	<empty>	33.92282	<empty>
Avg. Liq. Density [kgmole/m3]	2.937136	2.855162	16.63413	55.31283522
Specific Heat [kJ/kgmole-C]	593.8206	612.8829	46.22511	77.69518449
Std. Gas Flow [STD_m3/h]	3343.423	3230.902	111.6423	0.878823656
Std. Ideal Liq. Mass Density [kg/m3]	878.4934	880.7463	498.3752	997.4727102
Act. Liq. Flow [m3/s]	1.35E-02	1.35E-02	0	1.86E-07
Z Factor	<empty>	<empty>	<empty>	<empty>
Watson K	11.80389	11.82817	13.61614	9.060887901
User Property	<empty>	<empty>	<empty>	<empty>
Partial Pressure of H2S [kPa]	68.79616	0	68.79616	0
Cp/(Cp - R)	1.0142	1.013752	1.219313	1.119835924
Cp/Cv	1.000917	1.117693	1.239544	1.153247459
Ideal Gas Cp/Cv	1.016935	1.016407	1.22342	1.328363946
Ideal Gas Cp [kJ/kgmole-C]	499.2705	515.076	45.52822	33.63476127

Mass Ideal Gas Cp [kJ/kg-C]	1.66925	1.669749	1.519582	1.865147777
Heat of Vap. [kJ/kgmole]	593665.6	576543.5	30610.91	42219.5829
Kinematic Viscosity [cSt]	<empty>	16.34663	2.790309	0.754012488
Liq. Mass Density (Std. Cond) [kg/m3]	883.6169	882.9833	1.275422	1014.687611
Liq. Vol. Flow (Std. Cond) [m3/h]	47.86442	47.73779	110.9181	6.61E-04
Liquid Fraction	0.966608	1	0	1
Molar Volume [m3/kgmole]	0.583111	0.35516	7.184425	1.80E-02
Mass Heat of Vap. [kJ/kg]	1984.849	1869.012	1021.692	2341.201727
Phase Fraction [Molar Basis]	3.34E-02	0	1	0
Surface Tension [dyne/cm]	<empty>	24.3539	<empty>	70.3035958
Thermal Conductivity [W/m-K]	<empty>	0.119466	2.42E-02	0.624230508
Bubble Point Pressure [kPa]	734.2948	349.9875	12591.7	122.8773995
Viscosity [cP]	<empty>	14.19792	1.16E-02	0.753797895
Cv (Semi-Ideal) [kJ/kgmole-C]	585.5063	604.5686	37.91079	69.38086449
Mass Cv (Semi-Ideal) [kJ/kg-C]	1.957569	1.959862	1.265338	3.847375758
Cv [kJ/kgmole-C]	593.2764	548.3463	37.29203	67.37078318
Mass Cv [kJ/kg-C]	1.983547	1.777603	1.244686	3.735910758
Cv (Ent. Method) [kJ/kgmole-C]	<empty>	<empty>	<empty>	66.65747215
Mass Cv (Ent. Method) [kJ/kg-C]	0.222861	0.216087	2.224807	3.696355535
Cp/Cv (Ent. Method)	8.908538	9.194512	0.693472	1.165588523
Reid VP at 37.8 C [kPa]	135.7601	89.51935	<empty>	3971.247704
True VP at 37.8 C [kPa]	753.5031	361.1851	13102.01	129.8627557
Liq. Vol. Flow - Sum(Std. Cond) [m3/h]	158.6565	47.73779	110.9181	6.61E-04
Viscosity Index	25.8898	26.15524	-7.86187	-0.930828886
SIZING				
Volume [m3]	602			
Diameter [m]	6.5			
Length [m]	17.5			
Head height [m]	0			
NOZZLES				
	16	17	18	Water 2
Diameter [m]	5.00E-02	5.00E-02	5.00E-02	5.00E-02
Elevation (Base) [m]	0.6096	0.6096	0.3048	0
Elevation (Ground) [m]	0.6096	0.6096	0.3048	0
Elevation (% of Height) [%]	100	100	50	0
OPTIONS				
PV Work Term Contribution	100			
LEVEL TRAPS				

Level tap	PV High	PV Low	OP High	OP Low

d. Simulation by HYSYS



e. Oil Pipeline

Oil Pipeline (Pipe-100)		
Conditions		
Name	20	Oil Out
Vapour	0	0
Temperature [C]	33.2846478	33.28581182
Pressure [kPa]	5000	4997.337377
Molar Flow [kgmole/h]	194.729888	194.729888
Mass Flow [kg/h]	16673.97111	16673.97111
LiqVol Flow [m3/h]	24.11097657	24.11097657
Molar Enthalpy [kJ/kgmole]	-188604.1444	-188604.1444
Molar Entropy [kJ/kgmole-C]	186.9001536	186.9012361
Heat Flow [kJ/h]	-36726863.93	-36726863.93
Properties		
Name	20	Oil Out
Molecular Weight	85.62615259	85.62615259
Molar Density [kgmole/m3]	8.044366957	8.044317973
Mass Density [kg/m3]	688.8081926	688.8039982
Act. Volume Flow [m3/h]	24.20698721	24.20713461
Mass Enthalpy [kJ/kg]	-2202.64649	-2202.64649
Mass Entropy [kJ/kg-C]	2.182746134	2.182758777
Heat Capacity [kJ/kgmole-C]	182.5866775	182.5879521
Mass Heat Capacity [kJ/kg-C]	2.13237045	2.132385335
LHV Molar Basis (Std) [kJ/kgmole]	<empty>	<empty>
HHV Molar Basis (Std) [kJ/kgmole]	<empty>	<empty>
HHV Mass Basis (Std) [kJ/kg]	<empty>	<empty>
CO2 Loading	<empty>	<empty>
CO2 Apparent Mole Conc. [kgmole/m3]	6.93E-02	6.93E-02
CO2 Apparent Wt. Conc. [kgmol/kg]	1.01E-04	1.01E-04
LHV Mass Basis (Std) [kJ/kg]	<empty>	<empty>
Phase Fraction [Vol. Basis]	0	0
Phase Fraction [Mass Basis]	0	0
Phase Fraction [Act. Vol. Basis]	0	0
Mass Exergy [kJ/kg]	9.277375764	9.273606436
Partial Pressure of CO2 [kPa]	0	0
Cost Based on Flow [Cost/s]	0	0
Act. Gas Flow [ACT_m3/h]	<empty>	<empty>
Avg. Liq. Density [kgmole/m3]	8.076399871	8.076399871
Specific Heat [kJ/kgmole-C]	182.5866775	182.5879521
Std. Gas Flow [STD_m3/h]	4604.278459	4604.278459

Std. Ideal Liq. Mass Density [kg/m3]	691.5510477	691.5510477
Act. Liq. Flow [m3/s]	6.72E-03	6.72E-03
Z Factor	0.243957136	0.243827782
Watson K	12.26785196	12.26785196
User Property	<empty>	<empty>
Partial Pressure of H2S [kPa]	0	0
Cp/(Cp - R)	1.047708771	1.047708422
Cp/Cv	1.292608219	1.292615689
Ideal Gas Cp/Cv	1.062295784	1.062295582
Ideal Gas Cp [kJ/kgmole-C]	141.7795313	141.7799634
Mass Ideal Gas Cp [kJ/kg-C]	1.655797055	1.655802102
Heat of Vap. [kJ/kgmole]	<empty>	<empty>
Kinematic Viscosity [cSt]	0.464205176	0.464197769
Liq. Mass Density (Std. Cond) [kg/m3]	700.8543199	700.8543199
Liq. Vol. Flow (Std. Cond) [m3/h]	23.79092292	23.79092292
Liquid Fraction	1	1
Molar Volume [m3/kgmole]	0.12431059	0.124311347
Mass Heat of Vap. [kJ/kg]	<empty>	<empty>
Phase Fraction [Molar Basis]	0	0
Surface Tension [dyne/cm]	16.88749039	16.88737312
Thermal Conductivity [W/m-K]	1.06E-01	1.06E-01
Bubble Point Pressure [kPa]	514.3692695	514.3770582
Viscosity [cP]	3.20E-01	3.20E-01
Cv (Semi-Ideal) [kJ/kgmole-C]	174.2723575	174.2736321
Mass Cv (Semi-Ideal) [kJ/kg-C]	2.03527021	2.035285095
Cv [kJ/kgmole-C]	141.2544613	141.254631
Mass Cv [kJ/kg-C]	1.649664933	1.649666915
Cv (Ent. Method) [kJ/kgmole-C]	145.7492496	145.7487466
Mass Cv (Ent. Method) [kJ/kg-C]	1.70215223	1.70215223
Cp/Cv (Ent. Method)	1.252749556	1.252758301
Reid VP at 37.8 C [kPa]	255.5522556	255.5522556
True VP at 37.8 C [kPa]	545.0358679	545.0358679
Liq. Vol. Flow - Sum(Std. Cond) [m3/h]	23.79092292	23.79092292
Viscosity Index	-10.10918727	-10.10955051
Profiles		
Axial Length (m)	Elevation	Cells
0	0	
25000	0	25
25000	0	25
Sizing		
Segment	1	2

Fitting/Pipe	Pipe	Pipe
Length/Equivalent Length	25000	25000
Elevation Change	0	0
Outer Diameter	500.1	500.1
Inner Diameter	400	400
Material	Mild Steel	Mild Steel
Roughness	4.57E-05	4.57E-05
Pipe Wall Conductivity	45	45
Increments	25	25
FittingNo	<empty>	<empty>

f. Gas Pipeline results

Gas Pipeline (GCP-100)		
Conditions		
Name	29	To Refinery
Vapour	1	1
Temperature [C]	106.2709942	106.2709846
Pressure [kPa]	1126.448255	1114.502329
Molar Flow [kgmole/h]	198.2388034	198.2388034
Mass Flow [kg/h]	4698.883501	4698.883501
LiqVol Flow [m3/h]	11.09466706	11.09466706
Molar Enthalpy [kJ/kgmole]	-102844.0352	-102841.8434
Molar Entropy [kJ/kgmole-C]	181.7728946	181.8657399
Heat Flow [kJ/h]	-20387678.47	-20387243.98
Properties		
Name	29	To Refinery
Molecular Weight	23.70314702	23.70314702
Molar Density [kgmole/m3]	0.363558893	0.359635682
Mass Density [kg/m3]	8.617489894	8.524497434
Act. Volume Flow [m3/h]	545.2728763	551.2211761
Mass Enthalpy [kJ/kg]	-4338.834633	-4338.742167
Mass Entropy [kJ/kg-C]	7.668724091	7.672641097
Heat Capacity [kJ/kgmole-C]	44.12249236	44.11215303
Mass Heat Capacity [kJ/kg-C]	1.861461363	1.861025163
LHV Molar Basis (Std) [kJ/kgmole]	<empty>	<empty>
HHV Molar Basis (Std) [kJ/kgmole]	<empty>	<empty>
HHV Mass Basis (Std) [kJ/kg]	<empty>	<empty>
CO2 Loading	<empty>	<empty>
CO2 Apparent Mole Conc. [kgmole/m3]	<empty>	<empty>
CO2 Apparent Wt. Conc. [kgmol/kg]	<empty>	<empty>

LHV Mass Basis (Std) [kJ/kg]	<empty>	<empty>
Phase Fraction [Vol. Basis]	1	1
Phase Fraction [Mass Basis]	1	1
Phase Fraction [Act. Vol. Basis]	1	1
Mass Exergy [kJ/kg]	265.0435271	263.968138
Partial Pressure of CO2 [kPa]	129.0631369	127.694429
Cost Based on Flow [Cost/s]	0	0
Act. Gas Flow [ACT_m3/h]	545.2728763	551.2211761
Avg. Liq. Density [kgmole/m3]	17.86793622	17.86793622
Specific Heat [kJ/kgmole-C]	44.12249236	44.11215303
Std. Gas Flow [STD_m3/h]	4687.244785	4687.244785
Std. Ideal Liq. Mass Density [kg/m3]	423.526319	423.526319
Act. Liq. Flow [m3/s]	<empty>	<empty>
Z Factor	0.982173881	0.982358763
Watson K	14.94917915	14.94917915
User Property	<empty>	<empty>
Partial Pressure of H2S [kPa]	125.2760545	123.9475084
Cp/(Cp - R)	1.232190571	1.232257634
Cp/Cv	1.260914201	1.260669205
Ideal Gas Cp/Cv	1.238495619	1.238495623
Ideal Gas Cp [kJ/kgmole-C]	43.1758408	43.17584028
Mass Ideal Gas Cp [kJ/kg-C]	1.821523563	1.821523541
Heat of Vap. [kJ/kgmole]	20843.82418	20848.77632
Kinematic Viscosity [cSt]	1.708852782	1.727219239
Liq. Mass Density (Std. Cond) [kg/m3]	1.006525758	1.006525758
Liq. Vol. Flow (Std. Cond) [m3/h]	4668.418533	4668.418533
Liquid Fraction	0	0
Molar Volume [m3/kgmole]	2.750585995	2.780591724
Mass Heat of Vap. [kJ/kg]	879.3694848	879.578408
Phase Fraction [Molar Basis]	1	1
Surface Tension [dyne/cm]	<empty>	<empty>
Thermal Conductivity [W/m-K]	3.84E-02	3.84E-02
Bubble Point Pressure [kPa]	<empty>	<empty>
Viscosity [cP]	1.47E-02	1.47E-02
Cv (Semi-Ideal) [kJ/kgmole-C]	35.80817236	35.79783303
Mass Cv (Semi-Ideal) [kJ/kg-C]	1.51069275	1.51025655
Cv [kJ/kgmole-C]	34.99246207	34.99106098
Mass Cv [kJ/kg-C]	1.476279164	1.476220055
Cv (Ent. Method) [kJ/kgmole-C]	<empty>	<empty>
Mass Cv (Ent. Method) [kJ/kg-C]	<empty>	<empty>
Cp/Cv (Ent. Method)	<empty>	<empty>
Reid VP at 37.8 C [kPa]	<empty>	<empty>
True VP at 37.8 C [kPa]	<empty>	<empty>
Liq. Vol. Flow - Sum(Std. Cond) [m3/h]	4668.418533	4668.418533
Viscosity Index	-17.93752685	-17.82168875
Profiles		

Axial Length (m)	Elevation	Cells
0	0	
50000	0	10
Sizing		
Section	1	
Length	50000	
Elevation Change	0	
Cells	10	
Overall Dimensions		
Pipe Schedule	Pipe Schedule	
Material	Plastic Tubing	
Roughness	1.40E-02	
Nominal Diameter	<empty>	
External Diameter	500	
Internal Diameter	400	