MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

СӘТБАЕВ УНИВЕРСИТЕТІ SATBAYEV UNIVERSITY

School of Geology, Petroleum and mining engineering

Department of Petroleum Engineering

Yessenbolatov Kusman

Selection of equipment and selection of the optimal technological mode of equipment operation of the topsides at offshore fields

DIPLOMA PROJECT

5B070800 - Oil and gas engineering

Almaty 2021

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APPROVED FOR DEFENSE

Head of the Petroleum
Engineering Department,
Dairov Zh. K., MSc
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DIPLOMA PROJECT

Topic: «Selection of equipment and selection of the optimal technological mode of equipment operation of the topsides at offshore fields»

5B070800 - Oil and gas engineering

Performed by Yessenbolatov K.

Scientific adviser
PhD, lecturer
______________ Baimukhametov M. A.
15.05.2021

Almaty 2021

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Дата отчета 5/10/2021
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Метаданные

Название
Selection of equipment and selection of the optimal technological mode of equipment operation of the topsides at offshore fields

Автор
Есенболатов Кусман

Научный руководитель
Мурат Баймухаметов

Подразделение
ИГНиГД

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Обратите внимание!Высокие значения коэффициентов не означают плагиат. Отчет должен быть проанализирован экспертом.

КП1	КП2	КЦ
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25	7652	45988
Длина фразы для коэффициента подобия 2	Количество слов	Количество символов

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ПОРЯДКОВЫЙ НОМЕР	НАЗВАНИЕ И АДРЕС ИСТОЧНИКА URL (НАЗВАНИЕ БАЗЫ)	КОЛИЧЕСТВО ИДЕНТИЧНЫХ СЛОВ (ФРАГМЕНТОВ)	
1	http://www.oilngasprocess.com/oil-handling-surfacefacilities/compressors.html	30	0.39 %
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8	**«Formation of intercultural communicative competence in teaching foreign languages»** Исраилова Дильноза **5/14/2019** University of Foreign Languages and Professional Languages (Учебный отдел)	10	0.13 %
9	http://saujanamarine.com/board-of-director/	10	0.13 %
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Источник: Paperity			
1	**WELL-BEING INEQUALITY AND THE ECONOMIC CRISIS: EVIDENCE FROM LIFE IN TRANSITION SURVEYS IN EASTERN EUROPE** Alina Botezat, Livia Baciu;	12 (2)	0.16 %

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1	**EXTRACTION OF LEAD FROM LEAD SLAG** Galipauly Shyngys **4/22/2020** Satbayev University (ИМиПИ)	10 (1)	0.13 %

из программы обмена базами данных (0.43 %)

ПОРЯДКОВЫЙ НОМЕР	НАЗВАНИЕ	КОЛИЧЕСТВО ИДЕНТИЧНЫХ СЛОВ (ФРАГМЕНТОВ)	
1	**«Formation of intercultural communicative competence in teaching foreign languages»** Исраилова Дильноза **5/14/2019** University of Foreign Languages and Professional Languages (Учебный отдел)	20 (2)	0.26 %
2	**Isolation and identification of probiotic microorganisms from animal raw materials in the Almaty region** Nurdaulet Sungkar **5/21/2020** Kazakh National Agrarian University (КазНАУ)	13 (2)	0.17 %

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1	https://www.offshore-mag.com/production/article/16762343/platform-automation-remote-control-checklist-for-new-or-converted-unmanned-platforms	46 (3)	0.60 %
2	https://ru.scribd.com/book/282515909/Surface-Production-Operations-Volume-1-Design-of-Oil-Handling-Systems-and-Facilities	42 (4)	0.55 %
3	https://www.slideshare.net/TobiOmitola/crude-oil-production-system	32 (2)	0.42 %

4	http://www.oilngasprocess.com/oil-handling-surfacefacilities/compressors.html	30 (1)	0.39 %
5	http://saujanamarine.com/board-of-director/	10 (1)	0.13 %
6	https://gfzpublic.gfz-potsdam.de/rest/items/item_235442_1/component/file_235441/content?download=true	6 (1)	0.08 %
7	https://www.cheresources.com/invision/topic/7458-flashing-of-gas/	5 (1)	0.07 %

Список принятых фрагментов (нет принятых фрагментов)

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СӘТБАЕВ УНИВЕРСИТЕТІ SATBAYEV UNIVERSITY

School of Geology, Petroleum and mining engineering

Department of Petroleum Engineering

5B070800 - Oil and gas engineering

CONFIRM
Head of the Petroleum
Engineering Department,
Dairov Zh. K., MSc
____
____

TASK

for completing the diploma project

For student: Yessenbolatov Kusman

Topic: «Selection of equipment and selection of the optimal technological mode of equipment operation of the topsides at offshore fields».

Approved *by the order of university rector №2131-b from "24" December 2020*

Deadline for completion the work *"18" May 2021*

Initial data for the diploma project: data for modeling oil and gas processing on topsides.

Summary of the diploma project:

a) Building and considering possible options for construction and development of fields;
b) Calculation topsides weight for each development option;
c) Considering potential risks in environmental and occupational safety.

List of graphic material: presented 20 slides of the presentation

Recommended literature: 14 sources

THE SCHEDULE

For the diploma work preparation

Name of sections, list of issues being developed	Submission deadlines to the scientific adviser	Notes
Technical and technological part	10.03.2021	Task completed
Weight calculations	22.03.2021	Task completed
Cost calculations	10.04.2021	Task completed
Environmental and labor safety	15.04.2021	Task completed

Signatures

Of consultants and standard controller for the completed diploma work, indicating the relevant sections of the work (project).

The section titles	Consultant name (academic degree, title)	Date	Signature
Technical and technological part	PhD, Baimukhametov M. A.	10.03.2021	
Weight calculations	PhD, Baimukhametov M. A.	22.03.2021	
Cost calculations	PhD, Baimukhametov M. A.	10.04.2021	
Environmental and labor safety	PhD, Baimukhametov M. A.	15.04.2021	
Normcontroller	PhD, Baimukhametov M. A.	18.05.2021	

Scientific adviser ____________ PhD, Baimukhametov M. A.
Signature

The task was completed by the student: Yessenbolatov K.

Date: 25.01.2021

ANNOTATION

Today, offshore fields are being developed more and more often. This trend is increasing along with the depletion of onshore fields.

Difficulties in the design and development of offshore fields are associated with the economic profitability and safety of such projects. And often these two concepts limit each other to some extent.

The goal of this project is to select the best technological solution using UniSim software for the development of the K1 and K2 offshore fields.

In this work, the following steps were taken:

- There were considered possible options for construction and development of fields;
- Calculated topsides weight for each development option;
- Also were considered potential risks in environmental and occupational safety.

АННОТАЦИЯ

На сегодняшний день все чаще разрабатываются морские месторождения. Эта тенденция усиливается по мере истощения наземных месторождений.

Сложности при проектировании и разработке морских месторождений связаны с экономической рентабельностью и безопасностью таких проектов. И часто эти два понятия в той или иной степени ограничивают друг друга.

Целью данного проекта является выбор оптимального технологического решения с использованием программного обеспечения UniSim для разработки морских месторождений К1 и К2.

В этой работе были предприняты следующие шаги:

- Рассмотрены возможные варианты обустройства и разработки месторождений;
- Рассчитан вес верхнего строения для каждого варианта разработки;
- Также были рассмотрены потенциальные риски в области охраны окружающей среды и охраны труда.

АҢДАТПА

Бүгінгі күні теңіз кен орындары жиі игерілуде. Бұл үрдіс жер үсті кен орындары таусылған сайын күшейе түседі.

Теңіз кен орындарын жобалау мен игерудегі қиындықтар мұндай жобалардың экономикалық рентабельділігі мен қауіпсіздігімен байланысты. Көбінесе бұл екі ұғым бір-бірін белгілі бір дәрежеде шектейді.

Бұл жобаның мақсаты K1 және K2 теңіз кен орындарын игеру үшін UniSim бағдарламалық жасақтамасын қолдана отырып, оңтайлы технологиялық шешімді таңдау болып табылады.

Бұл жұмыста келесі қадамдар жасалды:

- Кен орындарын жайластыру мен игерудің ықтимал нұсқалары қаралды;
- Әрбір даму нұсқасы үшін жоғарғы құрылымның салмағы есептеледі;
- Сондай-ақ қоршаған ортаны қорғау және еңбекті қорғау саласындағы әлеуетті тәуекелдер қаралды.

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INTRODUCTION

About a third of the world's oil production comes from offshore areas. It was in Azerbaijan that the first in the world began to produce oil from the bottom of the sea. Currently, more than 90 countries are engaged in hydrocarbon exploration, and 30 countries are performing stable production.

The Caspian Sea is a unique natural site with significant potential resources for the development of the oil and gas industry. At present, hydrocarbon reservoirs have already been discovered in the offshore part of the Caspian. This project will focus on the development of such field. An important role in this project will be given to safety. Indeed, in history there are many cases of accidents and oil spills, which led to the largest environmental disasters. [1]

1.1. General information about K1 and K2 fields

The K1 and K2 fields are located in the shallow part of the Northern Caspian Sea, with a water depth of eight to nine meters. The nearest land area is the Buzachi demi-island, which is located about 75 km in a southeasterly direction. This part of the Caspian Sea is often icebound in winter, thus limiting the availability of normal operations between December and March each year.

The K1 field is planned to be developed jointly with the K2 field. The goal of joint development is to reduce capital costs and increase the profitability of the project.

1.2. Production profile

Below is the production profile of the joint development of the two fields.

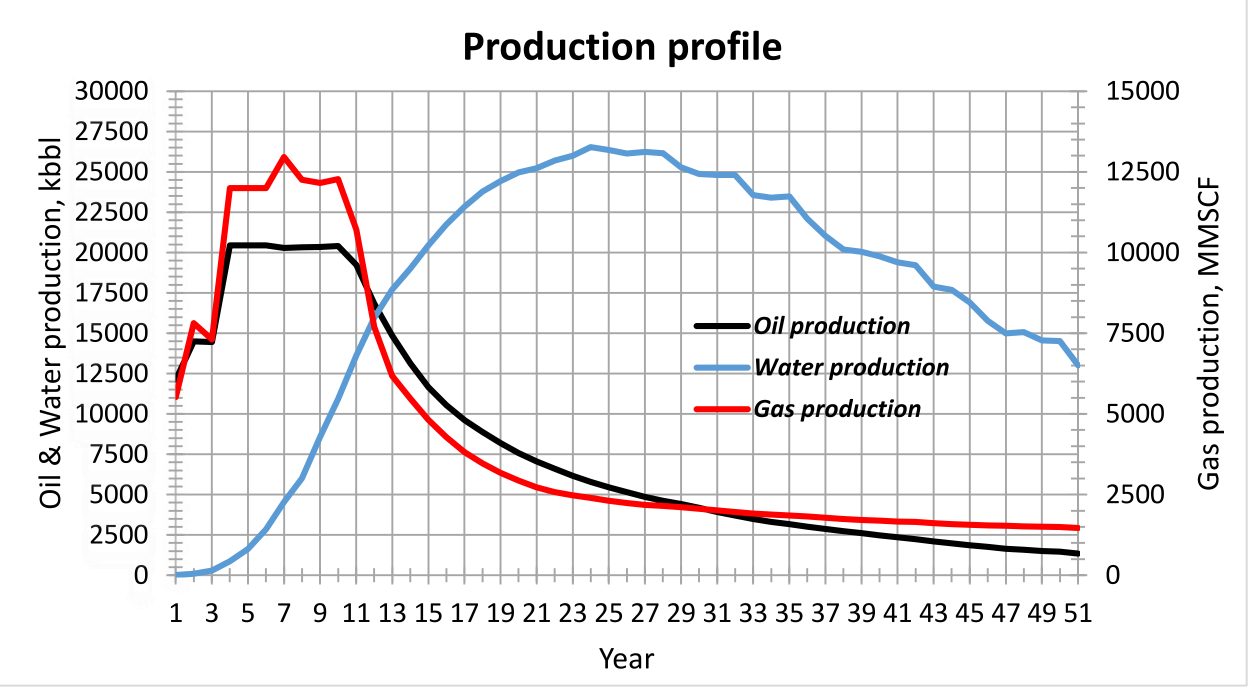

Figure 1. Production profile of Joint Development

The maximum volume of oil production will be 20,416 thousand barrels per year and will reach peak values in the 4th year of production. The duration of peak production will be six years, then there will be an exponential decline.

2 MAIN PART

2.1. Technical and technological part

There are several options for the development of these fields and we will consider some of them.

The development plan provides for the development of the K1 field as an offshore drilling satellite with a multiphase pipeline to the offshore processing hub located on the topside of K2 field. At the OPH, the crude oil will be prepared to marketable qualities. After the complete processing of hydrocarbons at OPH, the refined oil will be transported via a conventional oil pipeline to the Crude Oil Terminal at Buzachi, that is, 75 km by sea.

K1 field will be a satellite with minimal equipment, the substructure of which is a steel shell. Once the drilling process is completed, it is supposed that operations at K1 topside will not require maintenance in view of remote monitoring. The move to unmanned platforms is growing rapidly as offshore operators recognize the important benefits offered in terms of cost savings, efficiency and, above all, safety. An installation of this kind, recently completed by Siemens, has been on the Phillips Petroleum West Ekofisk platform in Norway, which has been converted to an unmanned platform.

The pipeline corridor between K2 and K1 includes an autonomous multiphase pipeline, and also reverse water injection and gas lift lines (gas lift only for the first development option). All produced products from K1, will be transported via a multiphase pipeline to an OPH, where they will be prepared to marketable qualities.

The OPH will be located on the artificial island. The design of the island will be U-shaped. The drilling module and modules for the technological preparation of oil and its further transportation to the COT will be located on the island.

Most often, at developing offshore fields after depletion of reservoir energy, gas lift is used in a mechanized production. Since the gas lift does not require large amounts of electricity and solves the problem of associated gas utilization. In the first of the two development options discussed below, it is planned to equip both fields with a gas lift, but this will require laying an additional gas lift pipeline to K1 field. The second option involves the abandonment of the gas lift on the K1 and its replacement with the ESP, which will work at the expense of electricity generated at the OPH.

Offshore operations are carried out all over the world because the oil industry finds most part of the world's hydrocarbon reserves under the oceans and seas. [2]

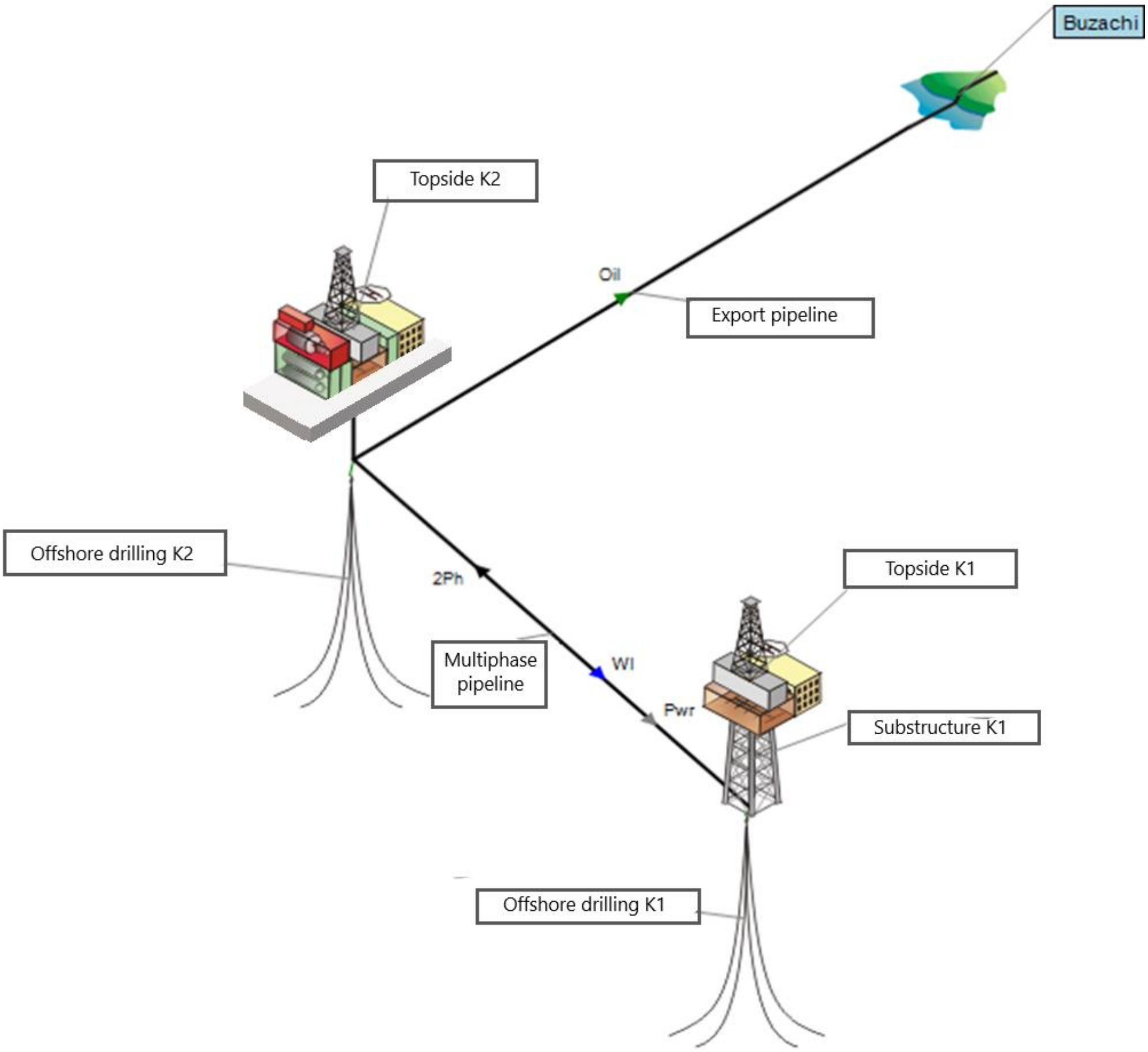

Figure 2. Field development scheme (from Questor software)

In this work, we will consider two of several possible options for the development of reservoirs. Simulation was carried out using the UniSim software, where the optimal oil and gas treatment scheme was selected. All parameters listed below were taken from the resulting models.

Option 1 includes a two-stage compression of the associated gas to further use in the gas lift system, as well as a stage with a RIGC (re-injection gas compressor) for injecting gas into the reservoir.

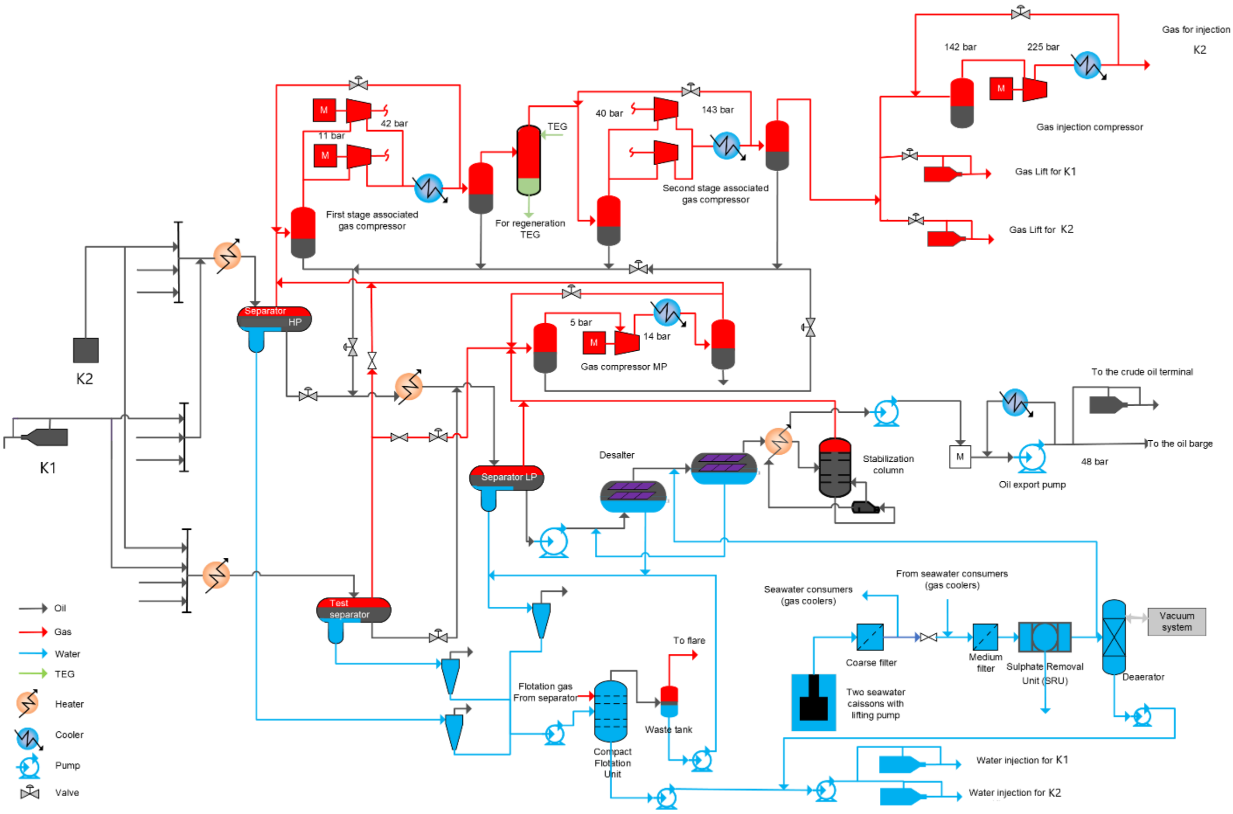

Figure 3. Principal scheme of the 1st option for Joint Development

Option 2 provides for the installation of a GTL system instead of re-injecting gas that will synthesize associated gas into liquid fuel and together with the oil, will be transported to the COT. Also, instead of a gas injection well, two gas production wells will be drilled for the needs of the gas lift. The scheme includes pre-treatment of gas for the GTL system.

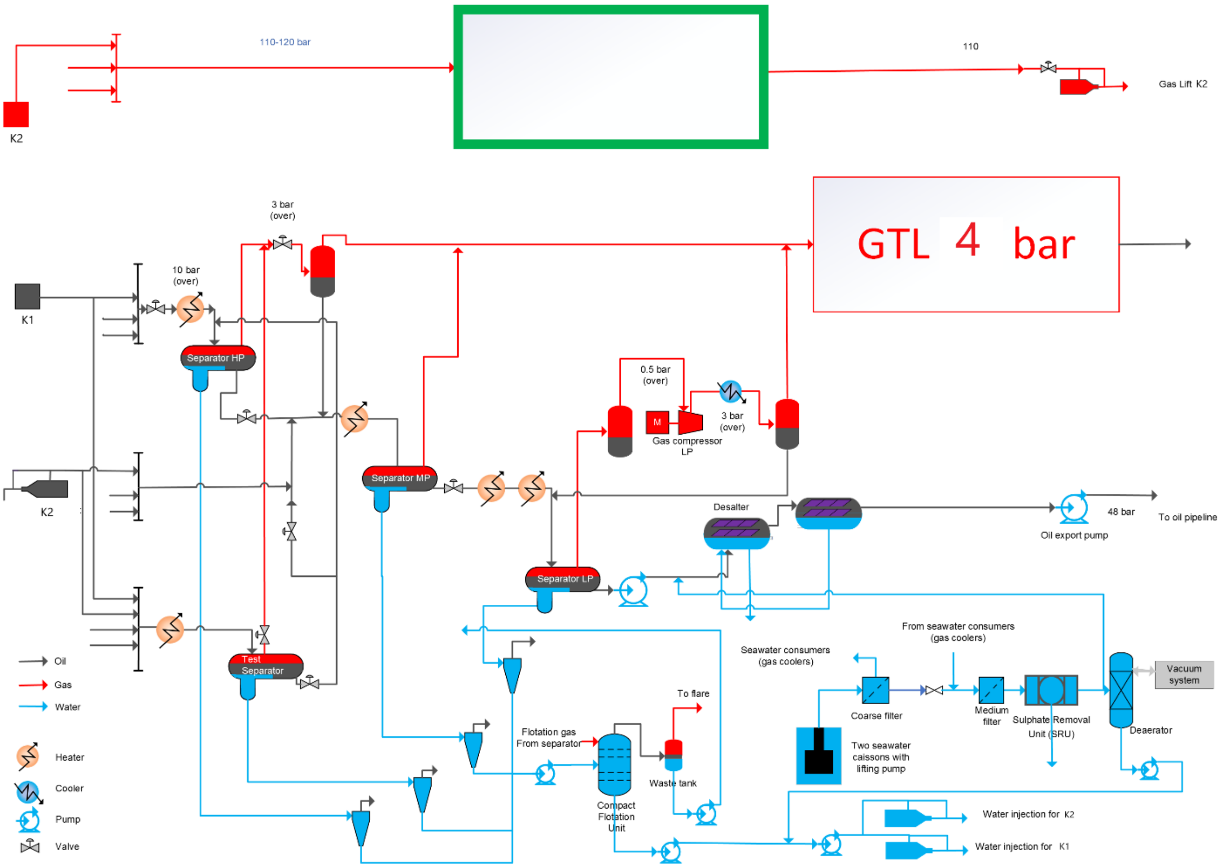

Figure 4. Principal scheme of the 2nd option for Joint Development

2.2. Oil processing and export

2.2.1. Oil separation

Each time when flows from two or more wells are combined at a central facility, a manifold is installed to ensure that the flow from all wells is extracted to any of the main or test processing systems.

Due to the multi-component nature of the production fluid than higher the pressure at which the initial separation occurs, the more fluid will be produced in the separator. If the pressure on the initial separation is too high, many lighter components will remain in the liquid phase in the separator. If the pressure is too low, not enough of these light components will be stabilized into the liquid in the separator, and they will be lost in the gas phase. The ability of any component of the technological flow to instantly pass into the gas phase depends on its partial pressure. That is why it is important to properly control the inlet pressure on the separators. [3]

To meet the technological requirements, separators are usually designed in stages, in which the first stage separator is used for primary phase separation, and the second and third stage separator is used for further processing. In our options, the separators are classified according to the pressure. [4]

In the first option, a two-stage separation scheme is used. The multiphase flow from the K1 and K2 manifolds is heated to a temperature of 50°C in the inlet heater at a pressure of 13 bar abs. After that, the flow enters the three-phase separator HP, where it is divided into three phases. The gas from the separator is directed to the first stage of the flash gas compressors (FGC). To measure the flow rate, a test separator is installed. The oil is sent to the second stage of the LP separation, and the water is sent to the hydrocyclones for cleaning.

Table 1. Separator operating parameters

Scheme	Properties	HP Separator	MP Separator	LP Separator
1 opt	Pressure, bar abs.	13	-	6
	Temperature, °C	50	-	60
2 opt	Pressure, bar over.	10	3	0,5
	Temperature, °C	50	50	72

In hydrocyclones, the reservoir water is separated from the oil, then the separated flow is sent to the CFU.

The oil flow from the HP separator is heated by an external heat carrier to 60℃ and enters the three-phase LP separator at a pressure of 6 bar abs. To prevent the release of gas in two sequentially operating desalters, the released gas sent to the off-gas compressor LP to increase the pressure to the values as at HP separator. As in the previous separator, the separated production water flows to the hydrocyclones. The oil flow is sent to the pump, where its pressure is increased to 12 bar abs.

In the option where we use GTL, there is a three-stage separation of oil, but there is no stabilization column. At first, the multiphase flow from the K1 manifold is heated in the heater to 50 ℃ at a pressure of 10 bars, and then it is going to the HP separator. Water from the separator enters the hydrocyclones, and the gas enters in the gas separator to prepare it for GTL. The oil flow is connected to the multiphase flow from the K2 manifold and is heated by an external heat carrier to 50℃ at a pressure of 3 bar from the pump and then enters the MP separator. The separated gas from the separator is going to the GTL unit, and the production water is going to the hydrocyclone. After that, the oil after the separator is heated in two consecutive heaters with a heat carrier to 72℃ and enters the LP separator at a pressure of 0.5 bar. The gas after the separator enters the single-stage LP compressor, and the production water goes to the hydrocyclone. The oil flow is further going to the pump, where its pressure rises to 10.5 bars.

2.2.2. Desalting

Any crude oil intended for pipeline transport must comply with strict regulations regarding water and salt content. Desalting involves mixing the heated crude oil with washing water. This is achieved by using a mixing valve to ensure proper contact between the crude oil and the wash water, and then passing it into the vessel, where phase separation is ensured. [5]

The requirements for salt and water content are even more stringent due to their negative impact on subsequent processes such as corrosion. The desalting process is necessary to achieve the required concentrations of salts and water in the oil (water <0.5% by weight, salt <100 mg / dm3). In both options, the desalting process is the same, using cleaned seawater after filtration and deaeration. The process uses two consecutive desalters. The first desalter is supplied with recirculating flushing recycled water, separated from the second desalter to reduce the concentration of salts in the oil. Further, after separation, the oil enters the second desalter, which is fed with fresh clean sea water. After the oil is separated from the second desalter, the required concentrations of salts and water in the oil are reached. The separated water from the desalter-2 is pressed by a booster pump to a pressure of approximately 10.5-11 bar abs. and enters the desalter-1 as recycled water.

Table 2. Desalter operating parameters

Scheme	Properties	Desalter 1	Desalter 2
1 opt	Pressure, bar abs.	10,5	9
	Temperature, °C	55	56
	Temperature of circulating water, °C	56	---
	Temperature of fresh sea water, °C	---	60
2 opt	Pressure, bar abs.	10,5	9
	Temperature, °C	72	71
	Temperature of circulating water, °C	71	---
	Temperature of fresh sea water, °C	---	60

Fresh washing water before being fed to the desalter-2 passes through two heat exchangers: in the first case, the heat carrier is water from the desalter-1, in the second case, it is heated to 60 ° C by a hot external heat carrier "TEG/water".

2.2.3. Oil stabilization

Since the scheme of the second option uses a three-stage oil separation, there is no need to install a stabilization column. The stabilization column is used only In the option where we use FGC.

The oil stabilizer is a poppet column consisting of seven stages. Heated in the lower part of reboiler, the temperature of which in the operating mode is 180℃. The flow after the desalter-2 is divided into two streams with a ratio of 30:70, part of the total flow (30%) is going to the upper part of the column, and the rest is heated in the heat exchanger and fed in the middle of the column. The separated gas from the upper part of the column is sent to the off-gas compressor LP. The oil heated in the reboiler is used as a heat carrier in the heat exchanger after the desalter-2 and going to the export.

Table 3. The main parameters of the stabilizer

Part of the column	Temperature, °C	Pressure, bar abs.
Top of column	58,2	6
Reboiler	175–180	6,5–7

2.2.4. Oil exports

In the option where we use flash gas compression (FGC) the export pump pumps the oil into the pipeline to the COT, after stabilization and use as a heat carrier.

In the option where we use GTL system, the oil after the desalter-2 is used as a heat carrier in the heat exchanger (LP Separator Preheater) and then, by using an export pump, it is pumped into the pipeline to the COT.

In both options, export oil is pumped at a pressure of 48 bar abs. Corrosion and paraffin inhibitors are introduced in front of the pumps. Regular cleaning is provided with scrapers to remove paraffin deposits in the pipeline.

On the shore, volume of oil is measured, and the quality of exported products (for the content of solid particles, water and salts) is monitored using a flow analyzer.

2.3. Compression, preparation and injection of gas, option 1 (FGC)

Compressors are used when it is necessary to direct gas from a lower pressure system to a higher pressure system. Oil wells often require a low surface pressure, and the gas released from the oil in the separator must be compressed in flash gas compressors. Flash gas compressors are usually characterized by a large pressure drop.

Often, a gas lift system is required to produce oil, after depletion of reservoir energy. The gas lift compressor needs to compress not only the associated gas produced with oil, but also the recirculating gas-lift gas. [6]

The gas from the HP and LP separators is sent to the OGC (off gas compressor) and FGC (flash gas compressors) gas compression lines to prepare it for use in the gas lift and as fuel gas. The excess gas will be re inject into the reservoir by using the re injection gas compressor.

2.3.1. Re-injection gas compressor (RIGC)

The RIGC receives gas from the LP separator, the oil stabilization column, and the flare system. It consists of two lines of 50% each. Each line has scrubbers at the inlet and outlet, a single-stage compressor, and a cooler after the compressor. The compressor will be powered by an electric motor.

Table 4. OGC parameters (1st opt)

	Temperature, °C	Pressure, bar abs.
Suction / discharge	41 – 65 / 110	5 / 14,0
Flange grade	ASME 150#	

2.3.2. *Flash gas compression system (FGC)*

In the first option, gas production is not provided, and the excess associated gas is re-inject into the reservoir through a gas injection well.

The gas is separated from the crude oil by flash evaporation at multiple pressure levels, which leads to gas flows at multiple pressure levels, flow rate and different gas composition. FGC consists of two lines of 50% each. Each with two compression stages driven by the use of electric motors. Each stage consists of inlet and outlet scrubbers, outlet coolers, and compressors. The gas is cooled by using seawater (water + TEG). Compression heats the gas, so there is a cooler after each compression stage. At a higher pressure, more liquid can separate, so the gas enters another scrubber before being compressed and cooled again. A glycol contactor is located between the two stages, which dewaters the gas by using a TEG absorber at a pressure of 42 bar abs. Dewatering is necessary to prevent the formation of hydrates in gas lift systems. After the TEG column, the gas can be used for fuel needs. Compressors in oil fields are equipped with recirculation valves. The recirculation valve allows the compressor to operate at low capacity, supporting the loaded compressor with the minimum required capacity. [7]

After the second stage of the FGC, gas is used for the gas lifts of K1 and K2 fields. The excess gas goes to the re-injection.

Table 5. Design and operating conditions of the flash gas compressor system

	Temperature, °C	Pressure, bar abs.
Designed	-46–180	60 / 165
Operational 1st stage (Suction / discharge)	41–65 / 144	окт.42
Operational 2nd stage (Suction / discharge)	42,5 / 153	41,5 / 143
Flange grade	ASME 1500#	

2.3.3. *Re-injection gas compression system (RIGC)*

The excess gas is fed to the RIGC and then pumped into the reservoir through the injection well. The system consists of three 33% compressors, a scrubber at the inlet and a cooler at the outlet. The maximum injection temperature is 120℃.

Table 6. Design and operating conditions of the gas injection system

	Temperature, °C	Pressure, bar abs.
Designed	-36–175	FV, 240
Operational (Suction / discharge)	42 / 80	141 / 224
Flange grade	ASME 2,500#	

2.4. Gas compression system, Option 2 (GTL)

The simulation was carried out in the UniSim software, where the optimal scheme of oil and gas processing was selected. All the parameters listed below were taken from the received models.

2.4.1. Gas preparation for GTL

The associated gas after separating from the oil in the HP separator is sent to the scrubber, where it is removed from the residual liquid. Then, together with the gas separated from MP separator, it is sent to the GTL.

The gas separated from the LP separator and the flare system enters a single-stage OGC compression system consisting of: inlet and outlet scrubbers, a compressor and a cooler. The gas is cooled to 50℃. After that, the gas is supplied to the GTL system.

Table 7. OGC parameters (2nd opt)

	Temperature, °C	Pressure, bar abs.
Suction / discharge	72 / 126	1,5 / 4,0

2.4.2. Gas preparation for the K2 gas lift

In the second option, it was decided to abandon the use of the gas lift on the K1 field, because of using the ESP. In this connection, there will be no need for a gas lift pipeline to K1. The injection gas well was also replaced with production gas wells, where the extracted gas from the gas cap will be used for the K2 gas lift.

Before using the gas for the gas lift, it is necessary in prepared it. At the initial stage using: a scrubber to separate the residual liquid and superheater. The superheater is necessary to raise the temperature from 60℃ to 120℃, in this temperature range, gas transportation is provided without the release of liquid it according to the technological requirements of gas lifting equipment.

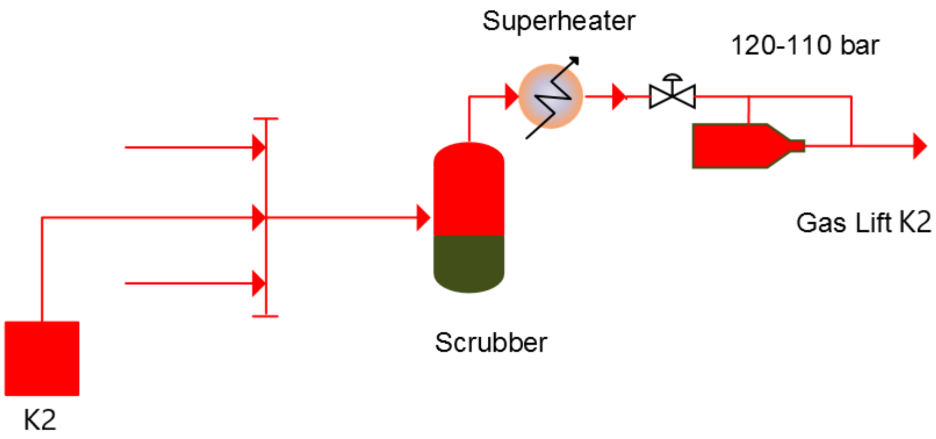

Figure 5. Gas to gas lift 1st stage (opt 2)

During further development of the field, the pressure of the gas cap is reduced to 80 bar abs., in this case, it is necessary to use the equipment: a scrubber and a compressor for raising the pressure to 120 bar abs..

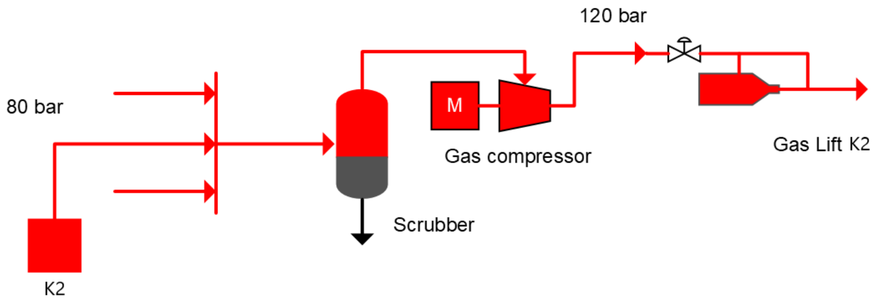

Figure 6. Gas to gas lift 2nd stage (opt 2)

Table 8. Compressor for gas lift (opt 2)

	Temperature, °C	Pressure, bar abs.
Suction / discharge	55 / 92	80 / 120

2.4.3. GTL system

GTL technology is widely used by many companies: Sasol, BP, Chevron and Shell. For example, Shell built the Pearl plant in Qatar.

The GTL system is based on the Fischer-Tropsch process and consists of synthesizing associated petroleum gas into fuels such as kerosene and gasoline. This transformation uses iron and cobalt-based catalysts. The resulting synthesized fuel can be mixed with natural oil produced in the field and delivered to the market by using the existing oil transportation infrastructure. In other words, the problem of gas utilization is solved and there is no need to build an export gas pipeline to the shore. Possible problems in the future design will only consist in the location of the system itself. It all depends on the overall dimensions.

The process itself consists of four stages:

- Stage 1: supply of gas and steam to the reformer, part of the gas is used for combustion for heating
- Stage 2: removing any water and compressing the gas stream
- Stage 3: supply of dry synthesis gas to the Fischer-Tropsch reactor
- Stage 4: separation of the resulting HC and water

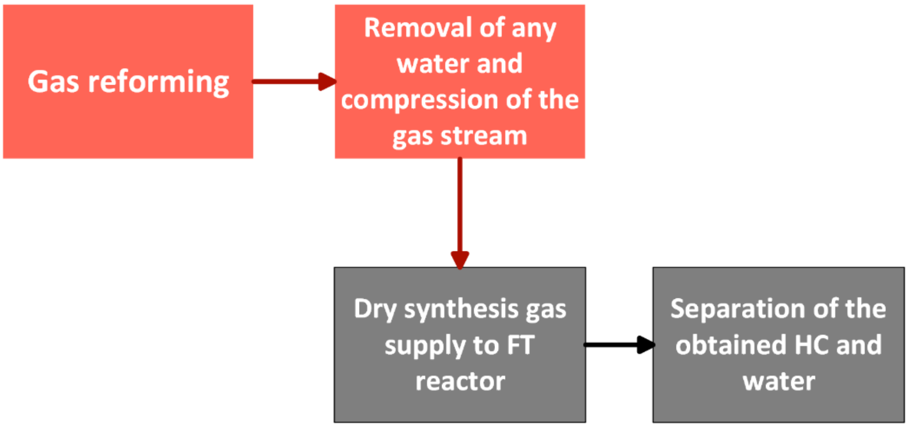

Figure 7. Stages of the GTL process

2.5. Flare system

A flare system is provided in both options. According to the existing legislation, to environmental protection, gas flaring is banned in normal or continuous mode. The system is used to prevent emergencies, only for emergency purposes for short periods of time. For example, when the compression systems are temporarily turned off. When a block is turned off, the flare system can be used for a short period of time, if the appropriate permissions are available. It burns gas until the problem or emergency is resolved.

The flare system consists of:

- LP systems, unloading gas from flotation and associated gas at pressures below 10 bar abs;
- HP systems, unloading the glycol regeneration system at a pressure above 10 bar abs.

Both systems consist of: a collection net, a drum, and a flare stack. The network of pipes that enters the liquid knockout drum, it is called the flare header. The liquid knockout drum separates the trapped liquid in the gas stream to prevent it from being released into the atmosphere. The HP and LP flare stacks are located on the same tower. The HP flare stack has a tip and due to the high pressure, the gas is burned at a speed close to the speed of sound. The LP stack has an open tip. The LP system includes a steam recovery blower. When the vapor capture system is switched off, the flare collectors are purged with fuel gas. In extreme cases, the reserve stock of inert gas is used. The purge gas is injected at a certain rate at points along the collector to prevent air from entering, which could create a flammable or explosive mixture. In the case of an explosion in the flare tube, the flashback seal drum prevents the flame from entering the flare collector. [8]

The flare pilots and the ignition system keep the pilot burners burning continuously while the flare is running. A rainwater drain tank is also provided to prevent liquid from entering the flare line.

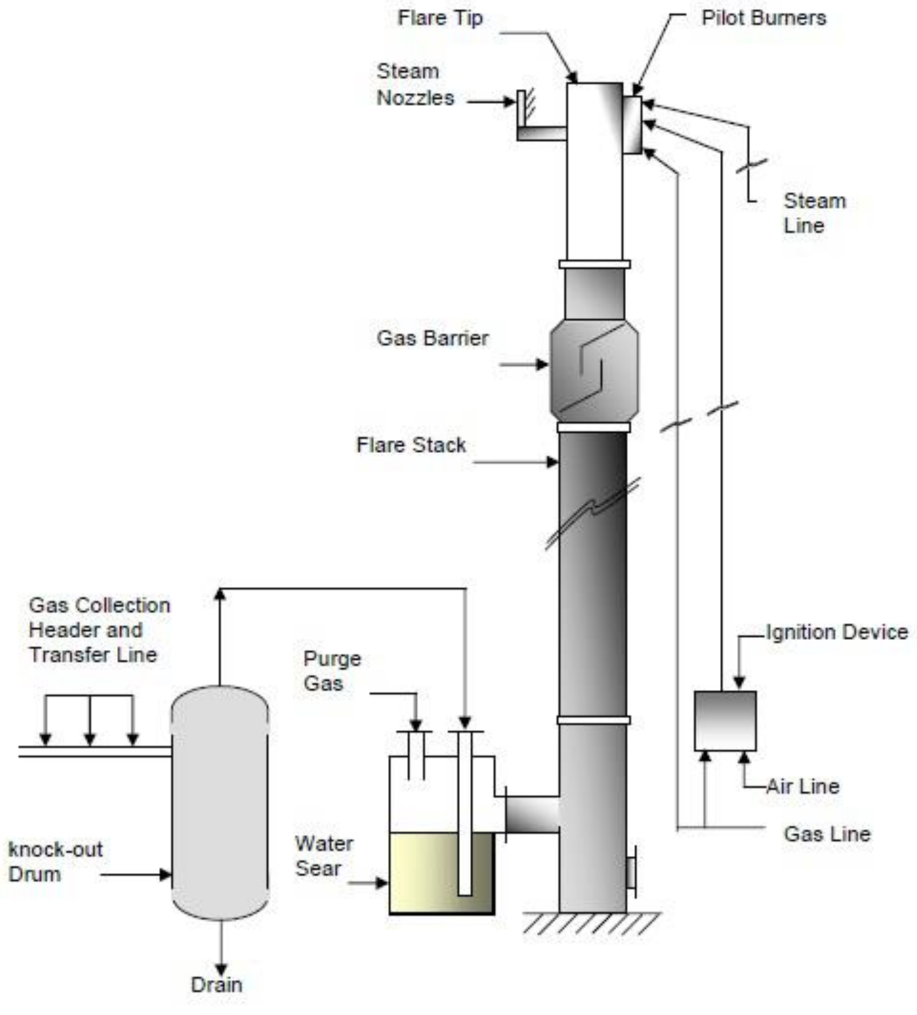

Figure 8. Schematic illustrates the components of a typical flare system [9]

2.6. Fuel gas

The fuel gas system is identical for both options. The fuel gas system provides dry gas for specific systems. High pressure fuel gas is used to generate electricity. Low-pressure gas is used for a purge of the flare network.

2.7. Preparation of produced and sea water

2.7.1. Preparation of produced water

The produced water, after separation from three separators for the first option and two for the second option, enters the system for the preparation of produced water. The system for both options consists of hydrocyclones, CFU and protective filters. The system provides water treatment to a concentration of oil <15 mg / l and mechanical impurities <15 mg / l. It also provides the installation of a produced water drum, into which the streams will drain from the LP separator and the desalter-1.

Due to the hydrocyclones of oil treatment, its concentration in the water is reduced to 100 ppm. While the hydrocyclones of sand treatment reduce the content of mechanical impurities to <15 mg/l.

Then the stream enters the CFU, where the flotation process takes place. It is achieved by introducing gas into the CFU, in the result suspended particles (mechanical impurities and oil) float to the surface. That's why, a constant supply of gas is necessary. Also, reagents such as coagulants and flocculants can be used in the flotation process, which promote the aggregation of suspended particles. After the water flow leaves the CFU, the oil content in it does not exceed 15 mg/l. The residual gas from the CFU will be directed to the LP flare unit.

The role of protective filters is to further reduce the concentration of mechanical impurities in water.

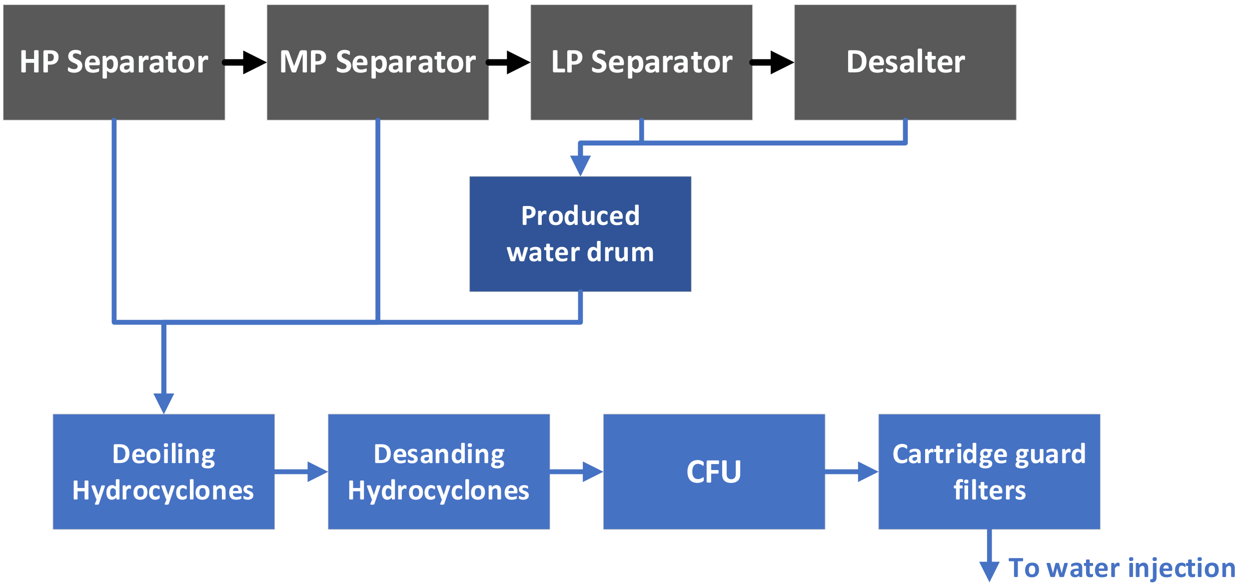

Figure 9. Produced water treatment scheme

2.7.2. Seawater intake and treatment

The use of seawater treatment and injection to increase oil recovery is widely practiced around the world. Seawater can be treated at different levels to provide the required water quality, compatible with the reservoir to maintain pressure. Insufficient water preparation can negatively affect the injection efficiency, change the wettability of the reservoir, or lead to clay swelling.

In both options, the seawater treatment system is the same. Seawater is injected into the reservoir along with produced water to maintain reservoir pressure. It is also used in the production of drinking water, as well as in the process of desalting oil.

In the Caspian Sea, the content of mechanical impurities exceeds 200 mg / l, and they have a fine particle size distribution. That is why the preparation of seawater is necessary.

The seawater treatment system consists of:

- Seawater pumps that pump water from the Caspian Sea. They are located in a pit for seawater intake. Hypochlorite is injected at the pump outlet to prevent the formation and accumulation of bioflora.
- Coarse and medium filters that greatly reduce the content of mechanical impurities in seawater.
- Deaeration columns, where the dissolved oxygen is removed. To improve the work, an antifoam agent is injected at the entrance to the deaerator. And oxygen absorber is injected down the column to reduce its concentration at the outlet from 20 to 10 ppm.
- Water injection pumps that pump part of the seawater at the outlet of the deaeration column together with produced water to inject them into the reservoir. The rest of the seawater is going through a reverse osmosis membrane and is used to desalting of oil.

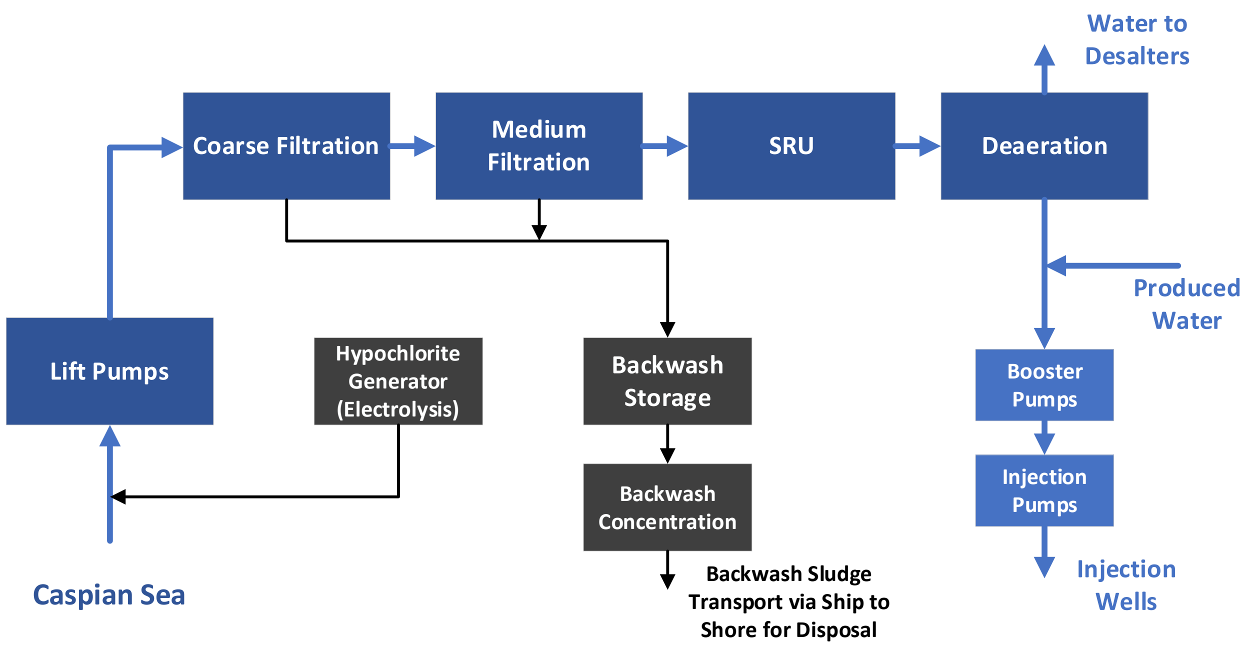

Figure 10. Seawater treatment scheme

2.8. Weights of OPH equipment

The MEL (Master Equipment List) is important in assessing weight. Regardless of the chosen method, the MEL will be the basis for weight estimation.

The MEL is used as a basis for determining the weights of other disciplines by applying the experience weight factors. This method is used in the feasibility study and concept development stages, as well as in the FEED stage. Based on the MEL information, you can determine the appropriate requirements for the area and volume of the upper structure, as well as creates drawings. Based on the drawings, the weight of bulk and structural elements can be calculated with the help of area / volume density coefficients. Based on the MEL information, you can find out the weight of the equipment for each module. [10]

The equipment was divided into modules according to their intended purpose. There is a difference in weight between both options, especially in the gas part. In the option where we use GTL system is almost no gas compression. When comparing the weights, the second option does not take into account the weight of the GTL system. The weights of some modules have been included in the calculations for the weights of other modules. For example, the weights of the M02 module are included in the M03 calculations.

Below are the dry weights of the equipment by module. However, when designing the substructure, operating weights are taken into account.

Table 9. Equipment dry weight for K2 OPH

Module	Description	Dry Weight 1st Option, Te	Dry Weight 2nd Option, Te
Module 1	LQ	259	259
Module 2	Compression/ Follow up compression	incl in M03	incl in M03
Module 3	Oil separation	2681	1106
Module 4	Water Treatment & Utilities	1459	1503
Module 5	Power generation	2205	2187
Module 6	Flare Knock-out	163	163
Module 6A	Export	573	477
Module 7	Pipe Rack	-	-
Module 8	Manifolds	114	114
Module 9	Flare Stack	7	7
Module 10	Gas Lift Compression	-	176
X1	Warehouse Steel	incl in M01	incl in M01
X2	Skid Beams	incl in M08	incl in M08
X3	Escape Route	-	-
X4	Closed Drain	incl in x7	incl in x7
X5	Fire Water Ring Main	incl in x7	incl in x7
X6	Flow Lines	incl in M07	incl in M08
X7	Other	604	544
X8	Stairtowers	-	-
K2 OPH Subtotal		**8 065**	**6 534**

2.9. Weights of topsides

The dry and operating weight and center of gravity of the topside must be monitored throughout its life. Data from the topsides weight database should be the primary document used by engineers when evaluating or re-analyzing structures.

The design allowance is 20%. It applies to individual weight elements and does not depend on the project phase, drawings or revision of technical data. Rather, they depend on the accuracy of the data at any given time. This principle reduces the coefficients and optimizes the load capacity of the platform at an early stage.

It is important to understand that design allowance - is a measure of the accuracy of the base dry weight of a product. Weight allowance should generally apply only to the base dry weight of each item and not to its contents. Since all operational increases must be accurately determined at the early stages of the detailed design of the project. [10]

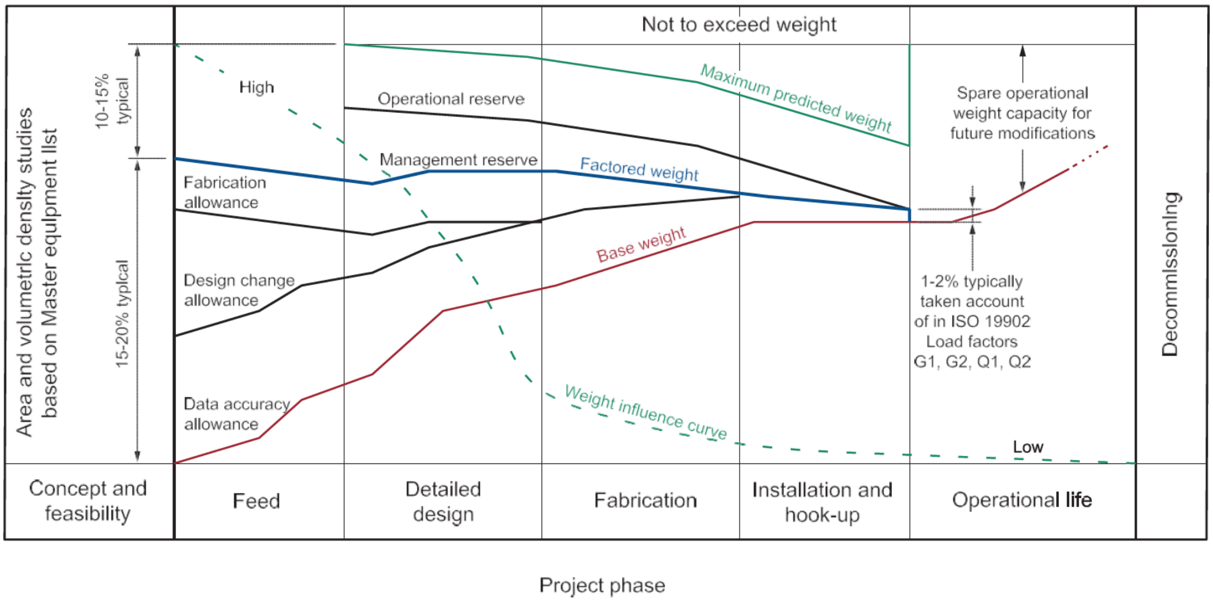

Figure 11. Allocation of topside allowances and reserves diagram [10]

When calculating the dry weights of the topsides for both options, take into account the weights of bulk materials, in addition to the main equipment, such as:

- Piping
- Instrumentation and telecommunications
- Electrical equipment
- Structure
- Utility room
- Fire protection
- Safety
- Insulation
- Painting
- HVAC (Heating, Ventilation and Air Conditioning)
- Fire wall

Since K1 is being developed as a remote drilling satellite, the living quarters in it is used only in the winter season when drilling in both options. In the summer, it is planned that the drillers will live in Flotel, and in the winter, due to the icebound Caspian Sea, they will live in living quarters. The reasons for using Flotel in the summer are due to the safety of drillers. Because of the risks of a blowout, since only in the summer is it planned to perforate wells. When designing the substructure, the operating weight of the modules is taken into account, while the dry weight of the modules is included in the calculations of transportation, hook-up and commissioning. The modular design is used to reduce the amount of work and labor required for installation and hook-up.

Figure 12. Dry weight for K1 and K2 Topsides

Module	Description	Dry Weight 1st Option, Te	*Dry Weight 2nd Option, Te
Module 1	LQ	3 773	3 773
Module 2	Compression/ Follow up compression	incl in M03	incl in M03
Module 3	Oil separation	9 555	2 070
Module 4	Water Treatment & Utilities	6 009	6 009
Module 5	Power generation	6 284	6 284
Module 6	Flare Knock-out	1 142	1 142
Module 6A	Export	1 998	1 908
Module 7	Pipe Rack	1 659	1 659
Module 8	Manifolds	2 985	2 985
Module 9	Flare Stack	369	369
Module 10	Gas Lift Compression	-	174
X1	Warehouse Steel	incl in M01	incl in M01
X2	Skid Beams	incl in M08	incl in M08
X3	Escape Route	50	50
X4	Closed Drain	incl in x7	incl in x7
X5	Fire Water Ring Main	incl in x7	incl in x7
X6	Flow Lines	incl in M07	incl in M07
X7	Other	1 900	1 900
X8	Stairtowers	197	197
K2 OPH Subtotal		**35 921**	**28 520**
K1 LQ	LQ	1019	1019
K1 Drilling	Drilling	1588	1588
K1 Topside	Upstream	5744	5533
K1 Subtotal		**8 351**	**8 140**

* Not included GTL system

2.10. Costs estimate

The capital cost calculations for topsides include: purchase, fabrication, construction, hook-up and commissioning (HUC), transportation and installation (T&I) costs. The cost of elements is determined by weight and evaluated for each module.

Methodology for calculating the cost of topsides:

Calculation of the cost of materials for topside modules

$$Design\ Allowance\ for\ Main\ Equipment\ 10\%$$

$$Design\ Allowance\ for\ Other\ materials\ 20\%$$

$$Material\ Cost\ =$$

$$((Net\ weight * \ Design\ Allowance\ on\ for\ Procurement\ Cost) * \ Unit\ rate)$$

Calculation of fabrication cost for topside modules

$$Total\ Manhours\ =\ Gross\ Dry\ Weight\ *\ Manhour\ Norm\ *\ PF$$

$$Total\ Fabrication\ Cost\ =\ Total\ Manhours\ *\ Hourly\ Rate$$

The fabrication of the modules will be done in the Caspian Sea area. Almost all topsides modules will be fabricated in RoK.

Calculating the cost of forwarding for topside modules

$$Freight\ Forwarding\ =\ (Total\ Fabrication\ Cost\ +\ Material\ Cost)\ *\ 10\%$$

The freight cost is 10% of the bulk and equipment cost transported to Caspian Sea.

Calculation of the hook-up & commissioning costs for topside modules

$$Total\ Manhours =$$
$$Manhour\ Norm * Modules\ complexity\ factor * Gross\ Dry\ Weight$$

The complexity factor of each module is defined by a qualitative approach. The man hours per Te of HUC between modules may vary significantly depending on:

- The number of interface connection (estimated by the construction manager).
- Size, type and location of each module

All modules are built in the Caspian Sea area. The modules will be transported by barge from the yards to the Island.

When comparing the costs for the two development options, it was defined that the second option is **13.6% more expensive** than the first. But taking into account the GTL system and the future increase in production due to its use, it can be concluded that both options require more detailed revision.

2.11. Environmental and labor safety

When designing the topsides takes into account various aspects that need to be considered for safe operation.

The structure and structural elements must be constructed and maintained in such a way as to withstand loads throughout their entire service life. [11]

In other words, they should:

- Withstand extreme impacts;
- Provide a good level of damage resistance

When designing the topsides, it is necessary to take into account possible emergency situations such as:

1) Fires;
2) Explosions;
3) Collisions with ships;
4) Impacts from falling and swinging objects, broken cables and wires;
5) Emergency landing and helicopter crash;
6) The effect of accidental flooding in cases of damage to compartments.

When using an ice-resistant unmanned satellite platform, some of the above emergencies can be minimized or avoided. In particular, problems such as collisions with ships and helicopter crashes can be minimized with the help of remote monitoring and absence of maintenance employees on the platform. It is also considering the possible risk of collision when the platform is located close to the shipping lanes.

The main solutions for the layout of block modules in technological areas are developed in order to minimize:

- Frequency and severity of the consequences of accidents;
- The possibility of spreading accidents to other modules

Design solutions should eliminate the emissions of explosive gases, flammable liquids, and toxic substances in the modules.

An open drainage system for hazardous effluents should exclude the possibility of:

- Accumulation of spilled hydrocarbons on the places;
- Spread of hydrocarbon spills

Solutions for drainage systems must ensure that it will work in all weather conditions. [12]

Living quarters should be located away from potentially hazardous systems.

2.11.1. Fire protection system

The fire protection system must perform the functions of alarm, detection, localization and elimination of fire. Also, emergency evacuation routes should be provided for such factors as ice formations on the sea surface, snowfall, snowstorm that complicate the evacuation. Platform maintenance employees must be provided with personal protective equipment and protective clothing in case of fire.

The exhaust devices of the ventilation systems are equipped with gas sensors and send signals to the control room. Dispatchers can remotely shut off the air intake in case of gas contamination.

The drainage system must work properly in all weather conditions to drain all foam and water used during in firefighting. [13]

CONCLUSION AND RECOMMENDATION

This project introduces a new concept and compares it with the existing one.

Evaluating the options under consideration, we can conclude that the GTL system is more promising in terms of applying new technologies. The only problem is the cost-effectiveness of its use. This technology brings a significant increase in production, but requires a significant area for placement. If it is possible to place GTL on the OPH, then there will be no need to build a gas pipeline to the COT, since the synthesized fuel will be transported along with the oil. This will significantly reduce the necessary capital investment. At this stage, there is no data on the exact parameters of the GTL system. That is why it is difficult to say whether this option is really better than with FGC. Only with further evaluation of the overall CAPEX will it become known which of the options are more profitable.

It is recommended to consider in more detail the international safety standards for FEED stage, for the development of offshore fields. Also, with more detailed design, it is possible to reduce the weight allowance according to the international standard.

LIST OF TERMS AND ABBREVIATIONS

OPH	Offshore Processing Hub
COT	Crude Oil Terminal
ESP	Electrical Submersible Pump
RIGC	Re-Injection Gas Compressor
GTL	Gas to Liquid
FGC	Flash Gas Compression
HP	High Pressure
MP	Medium Pressure
LP	Low Pressure
OGC	Off Gas Compression
CFU	Compact Flotation Unit
TEG	Triethylene Glycol
FT	Fischer-Tropsch
HC	Hydrocarbons
SRU	Sulphate Removal Unit
MEL	Master Equipment List
FEED	Front-End Engineering Design
LQ	Living Quarters
HVAC	Heating, Ventilation and Air Conditioning
HUC	Hook-Up and Commissioning
T&I	Transportation and Installation
CAPEX	Capital Expenditure
RoK	Republic of Kazakhstan

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