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PREDICTION MODELING FOR PLATFORMS' NETWORK VESSELS PERFORMANCE

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Abstract

Offshore platforms are required and designed to implement exploration, production at offshore oil fields. These platforms are equipped with a lot of equipment and processing vessels which are used to treat crude oils in order to reach specific or exporting criteria. In this article, a platforms' network vessels model is developed to predict performance conditions and behavior of the platforms when the central offshore treatment platform (COTP) is out of service and to investigate some process alternatives to select the optimum one. A stand-alone simulation has been implemented for each alternative to identify the optimum. The prediction model was developed based on the data received from an offshore company as a part of the installation activities of real projects carried out at different times along the offshore platforms: WP-A, WP-B, WP-C, WP-T, COTP, and main onshore facilities plant (MOPF). It was subsequently revised based on the new supplementary set of data from other companies. Accordingly, prediction is modified the study based on the additional data. Two scenarios with complete descriptions and cost analyses are recommended as optimal methods to operate platforms' networks in cases where COTP is not functioning properly. Finally, advantages and disadvantages are then presented for each scenario.

Keywords: *Offshore platforms; Predicting model; Network processing problem, Optimum solution.*

1. Introduction

Offshore platforms are used to perform exploration and production at offshore oil fields. An offshore platform is structurally divided into two parts: the topsides and the substructure [1]. The topsides are steel structures providing spaces to hold various kinds of facilities for exploration, production and human activities. Substructures are necessary to support the topsides "sitting" at an elevation safely above the ocean free surface [1]. Generally, the topsides and the substructure of a platform are designed and manufactured separately. All topsides and the substructure are therefore integrated at onshore or offshore sites with a network called platforms' network.

As mentioned earlier, an offshore platform is specifically designed to cater to the needs of the corresponding oil field development. Platforms can be designed for oilfield exploration as the drilling rigs, for oil and gas production as floating production structures or as the oil field service units. However, the three main topsides design elements are [1]:

a. Holding all equipment needed for operations
b. Optimization of dimension and weights
c. Providing a safe and sustainable healthy living environment

A platforms' network should have complete system integrity in order to monitor and maintain these design elements, while having contingencies in place when or if the integrity fails during the production life cycle of the network's wells [1-2]. Due to the importance of platforms' vessels integrity during the produced life cycle of the network, integrity is considered to be the heart of the platforms integrity management system.

One of the vessels installed in the platform is a separator. Separators are available in three forms: horizontal, vertical, and spherical [3-4,6-8]. These vessels have a great impact on the platforms' network production during normal and abnormal conditions. In addition to the separator, the subsea pipeline, pumps, costs, integration methodology, COTP, and MOFP also greatly influence the production network system.

Therefore, extensive platforms' data analytics are applied in the petroleum industry to leverage data collection, modeling, processing and analysis. A better understanding of oil production platform systems' abnormal behavior or potential problems, such as our malfunctioning COTP case, is provided. This knowledge is important for the adoption of a proactive oil production and maintenance approach instead of conventional time-based strategies or plans. This approach leads to a paradigm shift towards condition-based maintenance since a decision is now based on the unitization of big, diverse, and dynamic amounts of data as a method of optimizing operational costs of platforms' vessels.

In order to solve COTP problem, keep platforms' network integrity, select the optimum and the least cost equipment, develop a combination model for platforms' network simulation, our article will model, address and explain the main purposes of selecting the best operating scenario:

a. Proposing different process alternatives.
b. Comparing between the recommended alternatives that have been proposed.
c. Determining the required facilities for each alternative.
d. Performing preliminary sizing for the required facilities.
e. Presenting the simulation results for each scenario.
f. Implementing pressure elevation profiles for the subsea pipeline to MOFP
g. Displaying the flow assurance results for the main pipeline from WP-C to MOFP

2. Platforms' network developed modelling

Fig. 1 shows a flow diagram of the platforms' network developed model procedures.

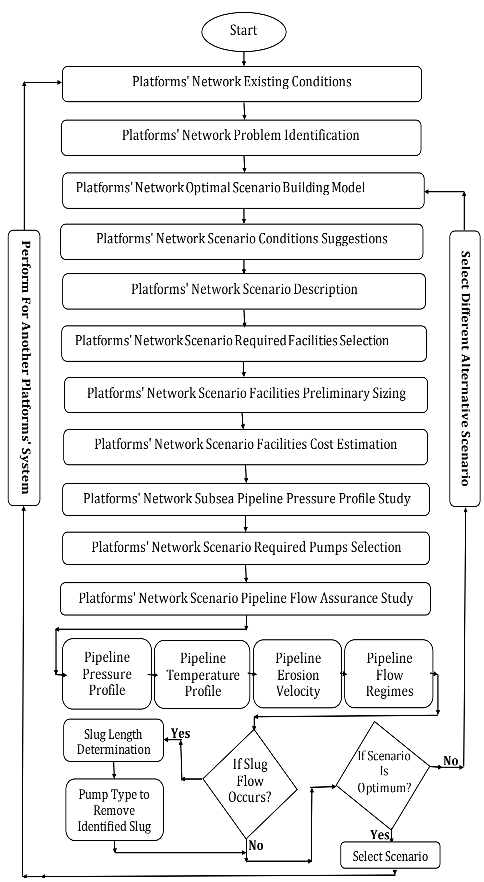

Fig. 1. Platforms' developed modelling flow diagram

3. Normal operations for platforms' network

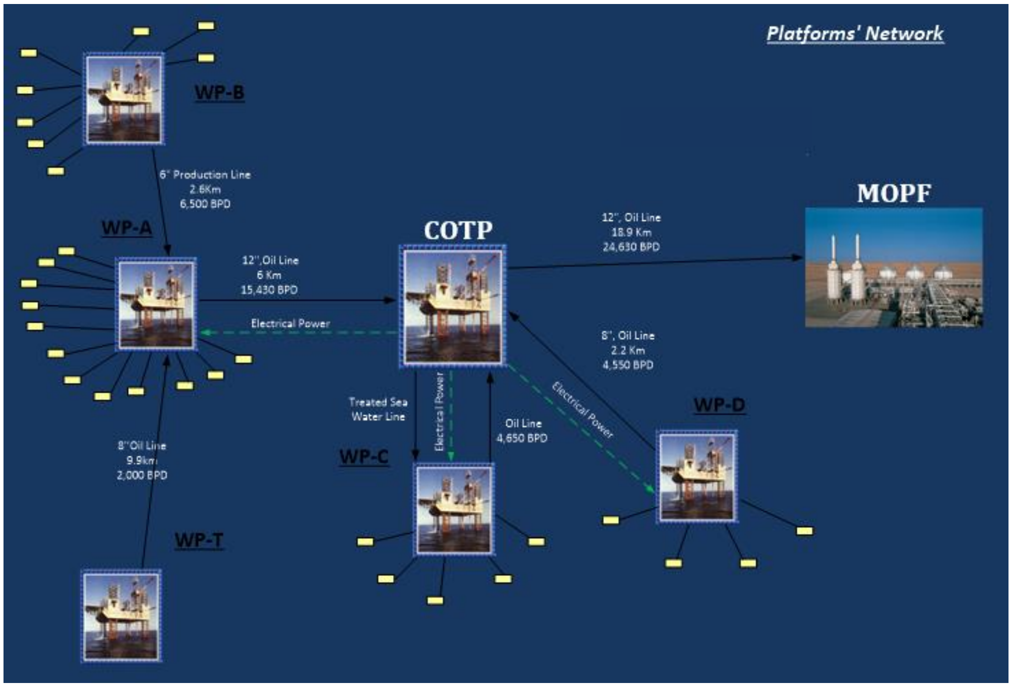

Fig. 2. Offshore platforms' network system

An offshore company operates a group of off-shore crude oil fields, include a set of platforms in the sea. It has five main platforms which are: WP-A, WP-B, WP-C, WP-D and WP-T in addition to the remote wells (Fig. 2). The production from these platforms is routed through a network of subsea pipelines to a central off-shore treatment platform (COTP). COTP supplies the platforms with the following:

- Power fluid for WP-C.
- Flare to handle excess gas.
- Electric power to WP-C and WP-D and standby electric power for WP-A.

The production from COTP is then pumped to the main onshore facilities plant (MOFP) by transfer pump via subsea line for further processing and shipping.

3.1. Platform WP-B description

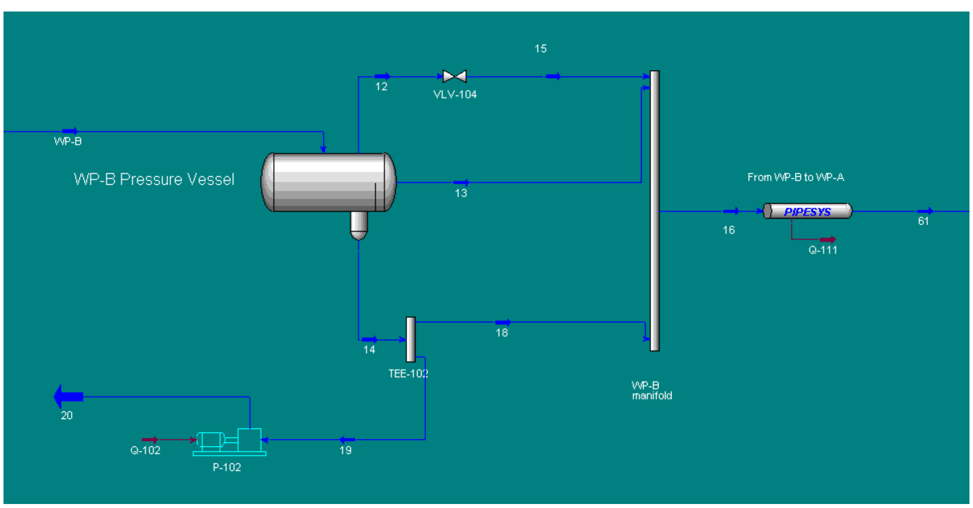

Fig. 3. WP-B platform system

The crude produced from WP-B wells is directed to a pressure vessel located on WP-B platform. The water produced from the separator is directed to the HPS pump to be used as a power fluid. The excess water is mixed with the oil and gas produced from the pressure vessel, then directed to WP-A platform. Table 1 shows the WP-B platform (Fig. 3) feed and product conditions.

Table 1. WP-B Platform feed and operating conditions

WP-B	Total flow, bbl/d	Oil Flow, bbl/d	GOR, Scf/bbl	WC %	Operating press, psig	Operating temp, °C
Vessel conditions	16,500	4,220	250	73	170	25
Manifold conditions	6,500	4,220	250	30	170	25

3.2. Platform WP-A description

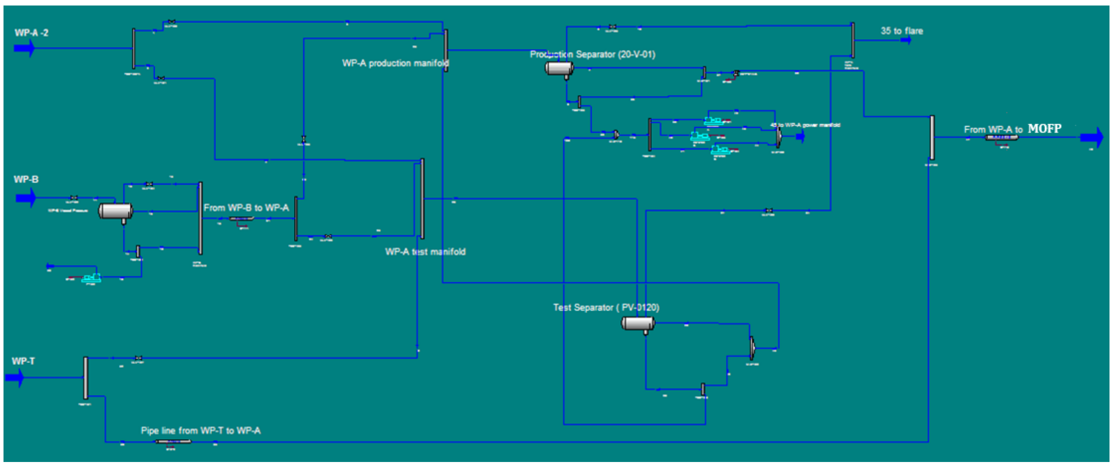

Fig. 4. WP-A platform system

The crude produced from WP-A wells (Fig. 4) is mixed with production from WP-B platform. The combined feed is directed to the three phase production separator located on WP-A. The gas produced from the production separator is directed to the gas treatment system for power generation and to the flare. The water produced from the production separator is directed to the HPS Pumps to be used as a power fluid. The excess formation water and the oil produced from the WP-A production separator are then pumped to the slug catcher located on COTP via a pipeline. WP-T platform production is directed to WP-A platform. Due to the production separator capacity limitation, WP-T production bypasses the production separator and combines with the separator products. Table (2) shows WP-A platform feeds and operating conditions.

Table 2. WP-A platform feeds and operating conditions

Platform	Total Flow, bbl/d	Oil Flow, bbl/d	GOR, Scf/bbl	WC, %	Operating Press, psig	Operating Temp, °C
WP-A	21 700	3 100	205	85	54	35
Remote wells	950	280	250	70	56	35
WP-T	2 000	1 000	2 100	9	130	30
WP-B	6 500	4 180	275	30	63	20
WP-A total production	16 350	8 600	-	44	100	33

3.3. Platform WP-C and WP-D description

The crude produced from WP-C and WP-D wells is directed to the production manifold located on COTP platform. The manifold pressure shall operate at 72 psig. Table 3 shows WP-C and WP-D platforms' feed specifications.

Table 3. WP-C and WP-D platforms' feed and operating conditions

Platform	Total flow bl/d	Oil flow bl/d	GOR cf/bbl	WC %
WP-D	4 550	1 800	257	58
WP-C	16 650	1 800	250	90

4. Platforms' developed recommended scenarios

4.1. Scenario 1 WP-A and WP-C gas separation

4.1.1. Scenario description

In order to increase the separation capacity and efficiency, a new three phase separator shall be added in addition to the existing Production Separator on WP-A (Fig. 5), hence minimizing the possibility of having sluggy flow in the subsea pipeline between WP-A and WP-C. With the construction of the new separator, a shelter for the personnel must be considered.

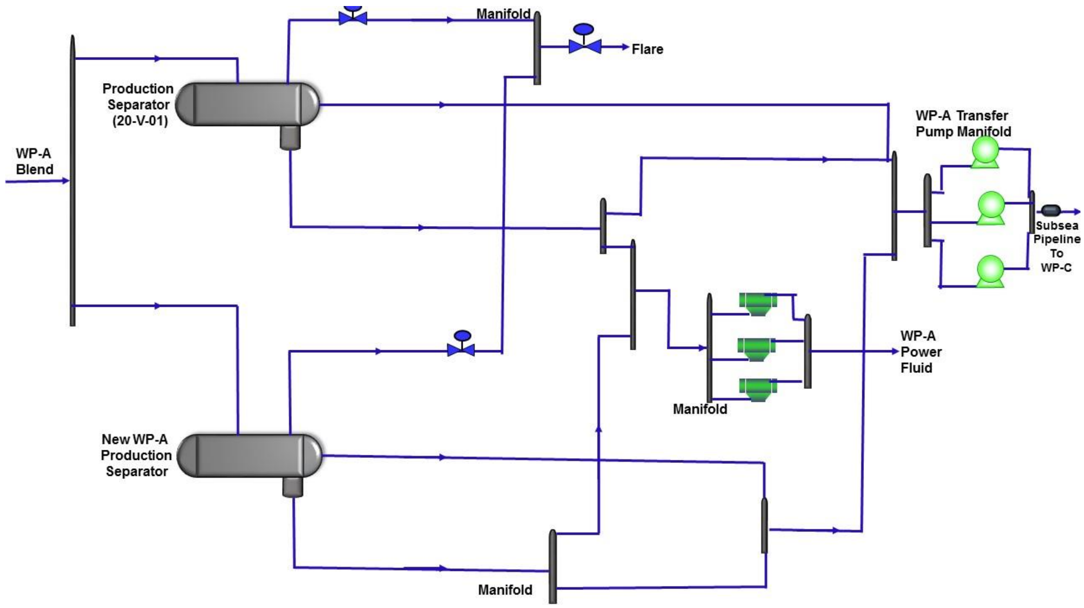

Fig. 5. WP-A platform future processing system

A new three phase separator shall be installed on WP-C platform to receive the production of WP-C and WP-D wells. The gas produced from the new three phase separator shall be routed to the flare located on COTP platform or a new one on WP-C in case of a malfunctioning COTP. A new production manifold shall be installed on WP-C to receive the oil and excess water produced from WP-C new separator and WP-A production. From the drawing in Fig. 6, it shows that WP-A transfer pumps will pump directly to MOFP (oil and water) as it is connected to the WP-C new transfer pump discharge. The blend is then directed to MOFP through the subsea pipeline for further processing.

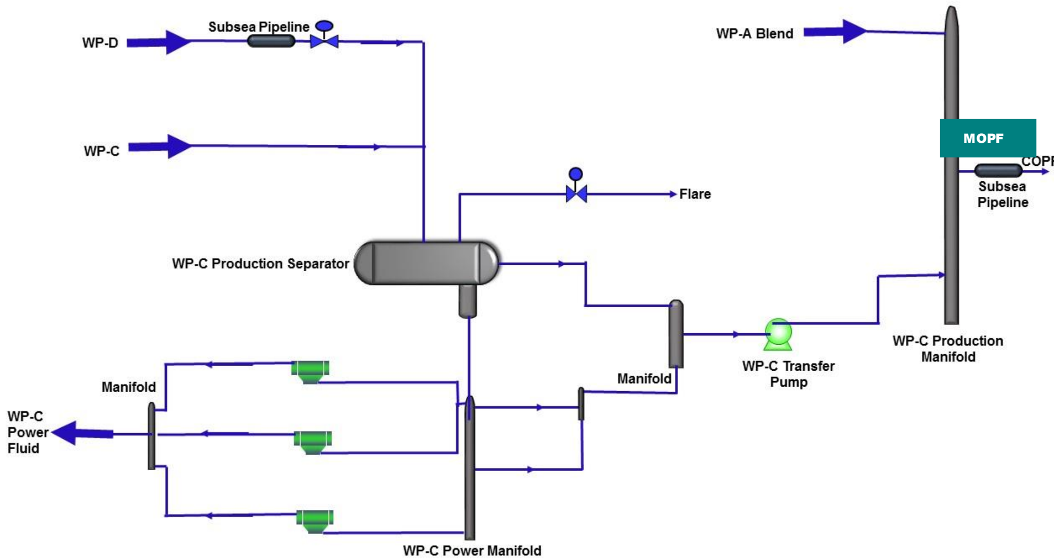

Fig. 6. WP-C platform future processing system

4.1.2. Required facilities

In order to implement the first recommended scenario, WP-A platform should be provided with a new three phase separator while WP-C should also be provided with another three phase separator, transfer pumps, and production manifold (Table 4).

Table 4. Required facilities for the first scenario

Platform	WP-A	WP-C
Required Equipment	New three phase separator	New three phase separator Transfer pumps WP-C production manifold

4.1.3. Preliminary sizing

The separator sizing calculations in the first developed scenario model are based on the software default which assumes certain ranges for liquid and gas residence time, L/D ratio and liquid level inside the vessel. All the sizing calculations are preliminary and shall be confirmed by detailed engineering calculation and vendors. Firstly, for separators, two horizontal separators operating at 30°C are required for WP-A and WP-C platforms. However, they will work at various operating pressures, 54 psig and 72 psig for WP-A and WP-C platforms respectively. WP-C separator pressure is higher than what we usually operate at in normal conditions, which will back pressure WP-D and WP-C wells (Table 5). Secondly, for new separators sizing at different retention times (Table 6), the developed model results in, for WP-A platform separator dimensions,

- 1.2 m x 4.2 m (diameter x length) at 5 min. residence time with 8720 bbl/d
- 1.5 m x 5.3 m at 10 min. residence time with 8525 bbl/d capacityand, for WP-C platform separator dimensions,
- 1.8 m x 6.4 m at 5 min. retention time with 29485 bbl/d capacity
- 2.2 m x 8 m at 10 min. retention time 27530 bbl/d capacity

Finally, the existing transfer pumps on WP-A will not pump to the discharge pressure therefore transfer pumps are required to be installed on WP-C platform in order to provide 8800 bbl/d flow rate and 105 psig discharge pressure (Table 7).

Table 5. Operating separators conditions for the first scenario

Equipment	WP-A Separator	WP-C Separator
Operating Press, psig	54	72
Operating Temp, C	30	30
Orientation	Horizontal	Horizontal

Table 6. New platforms' separators parameters for the first scenario

Equipment	Residence time, min	Length , m	Diameter, m	Capacity bbl/d
New WP-A Separator	5	4.2	1.2	8 720
	10	5.3	1.5	8 525
New WP-C Separator	5	6.4	1.8	29 485
	10	8	2.2	27 530

Table 7. WP-C Platform transfer pumps for the first scenario

Equipment	Flow rate, bbl/d	Suction pressure, psig	Discharge pressure, psig
WP-C Transfer Pumps	8 800	72	105

4.1.4. Preliminary cost estimate

In order to choose the optimum equipment, they should perform the required rates and capacity with minimum costs. Therefore, Table 8 is the estimated prices/weights (full packages) deduced from the developed model for the vessels. The transportation costs are excluded. These prices are based on available old offers and subject to market conditions and petroleum industry fluctuations.

Table 8. Estimated prices for platforms' vessels for the first scenario

Equipment	WP-A Separator	WP-A Separator	WP-C Separator	WP-C Separator	WP-C Transfer pumps
Position	Horizontal	Horizontal	Horizontal	Horizontal	-
Residence time, min	5	10	5	10	-
Steel grade	A 516 GR70	A 516 GR70	A 516 GR70	A 516 GR70	-
Design pressure, psig	90	90	100	100	135
ID, m	1.5	1.5	2	2.5	-
L, m	4.5	5.5	6.5	8	-
TH, inch	0.30	0.30	0.40	0.42	-
Volume , m^3	8	10	20	40	-
Estimated weight, kg	1 646	1 943	4 166	6 747	-
Total price, USD	76 625	81 972	102 990	134 000	150 000

4.1.5. Transfer line from WP-C to MOFP

The production from WP-C manifold (24,230 bbl/d) is directed to MOFP through the subsea pipeline. Table 9 shows the transfer line from WP-C to MOFP conditions resulting from the developed model. The following charts plotted from the model results (Figs. 7 and 8) show the elevation and pressure profiles along the pipeline. The behavior of the pipeline pressure profile is normal as elevation decreases from sea level, the higher the flowing pressure of the pipeline and vice versa.

Table 9. Transfer pipeline from WP-C to MOFP conditions for the first scenario

Transfer line from WP-C to MOFP	Manifold	MOFP
Pressure, psig	105	1
Temp,°C	25	20

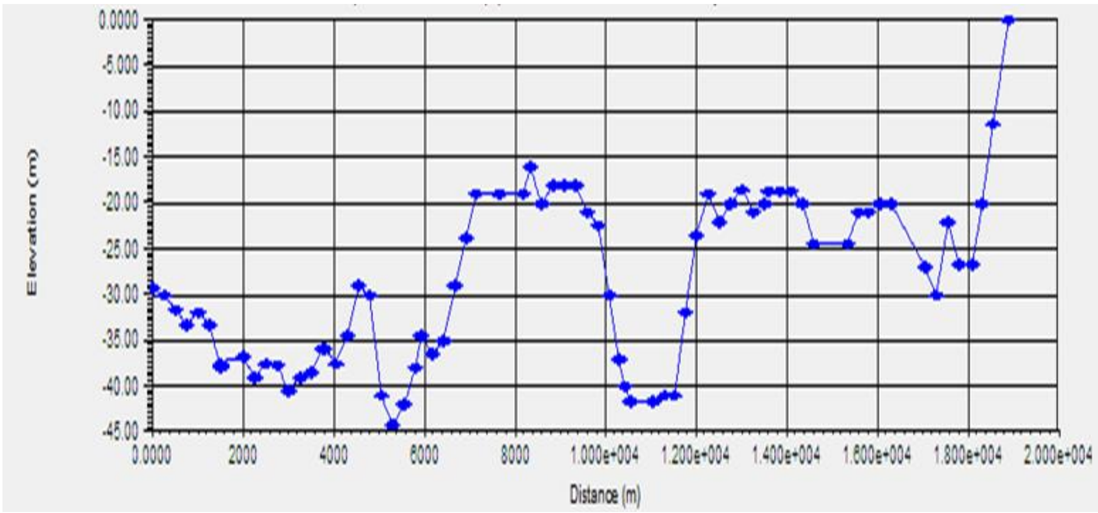

Fig.7. Pipeline elevation profile from WP-C to MOFP for the first scenario

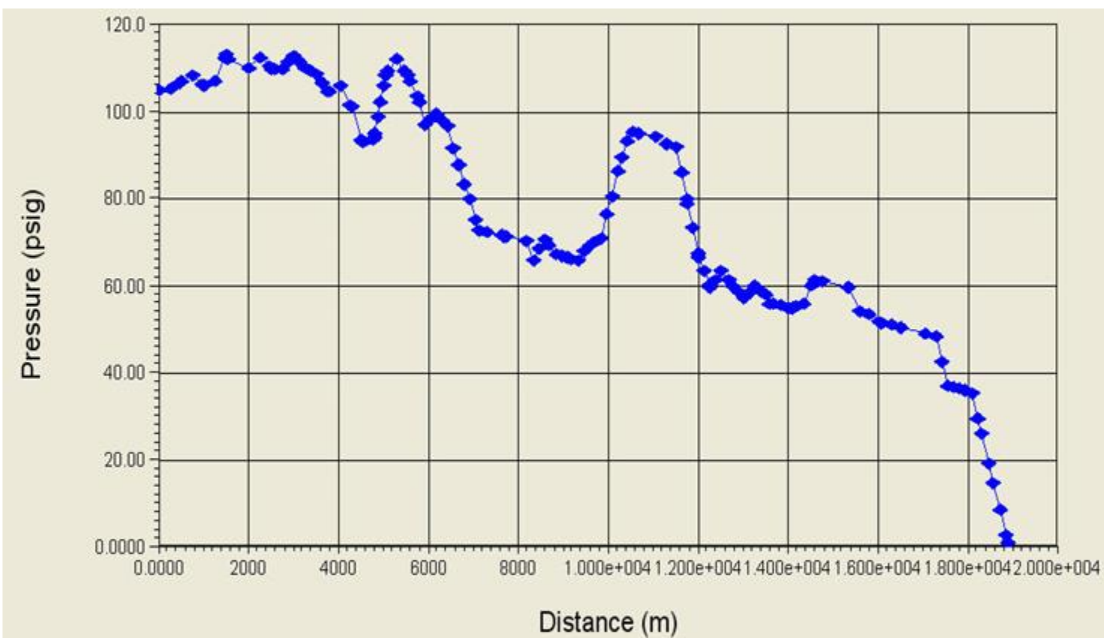

Fig. 8. Pipeline flowing pressure profile from WP-C to MOFP for the first scenario

4.2. Scenario 2 WP-A Gas separation/WP-C and WP-D direct flow to MOFP

4.2.1. Scenario description

In order to increase the separation capacity and efficiency, a new three phase production separator shall be installed in addition to the existing production separator on WP-A platform (Fig. 9), hence minimizing the possibility of having sluggy flow in the subsea pipeline between

WP-A and WP-C. With the construction of the new separator a shelter for the personnel must be considered.

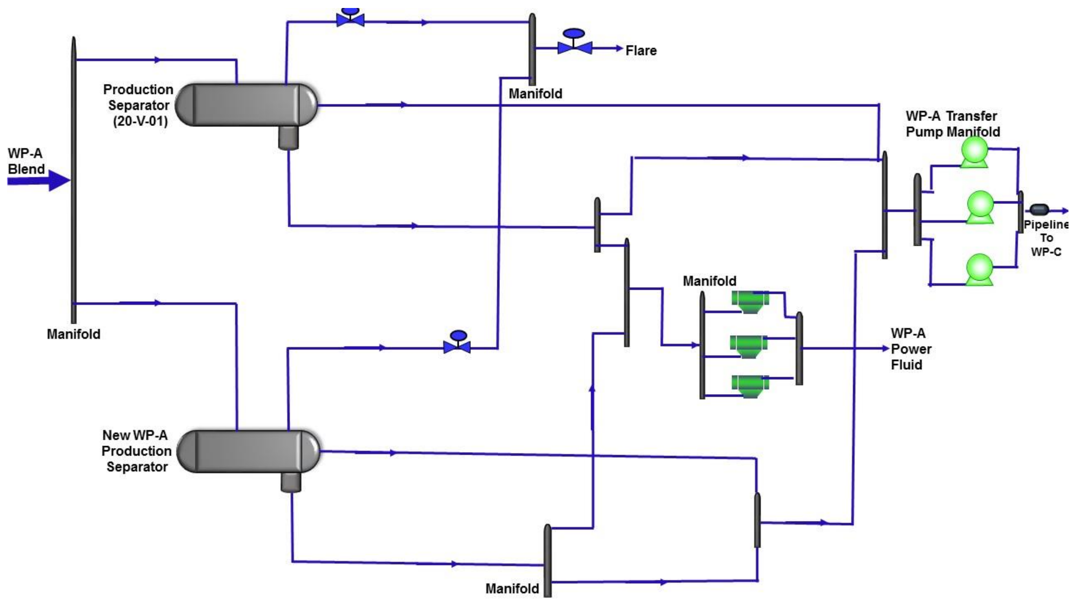

Fig.9. WP-A platform future processing system

The production from WP-C wells is directed to a new vessel, similar to WP-B system. The water produced from WP-C new vessel is directed to the power fluid pumps. A new production manifold shall be installed on WP-C to receive the oil and gas and excess water produced from WP-C new separator and WP-A and WP-D production (Fig. 10) (Is it a manifold or a vessel to deliver the outlet to the facility on COTP). A new artificial lifting system shall be required on WP-D to deliver the gross production at a certain pressure to be able to deliver the flow directly to the new WP-C production manifold. The blend is then directed to MOFP through the subsea pipeline for further processing (Fig. 10). As there is no gas separation on WP-C, sluggy flow may occur in the subsea pipeline from WP-C to MOFP. Slug tracking calculation has been performed and included in the developed model to calculate the required vessel (slug catcher) volume needed at MOFP to handle the slugs that may occur through the subsea line.

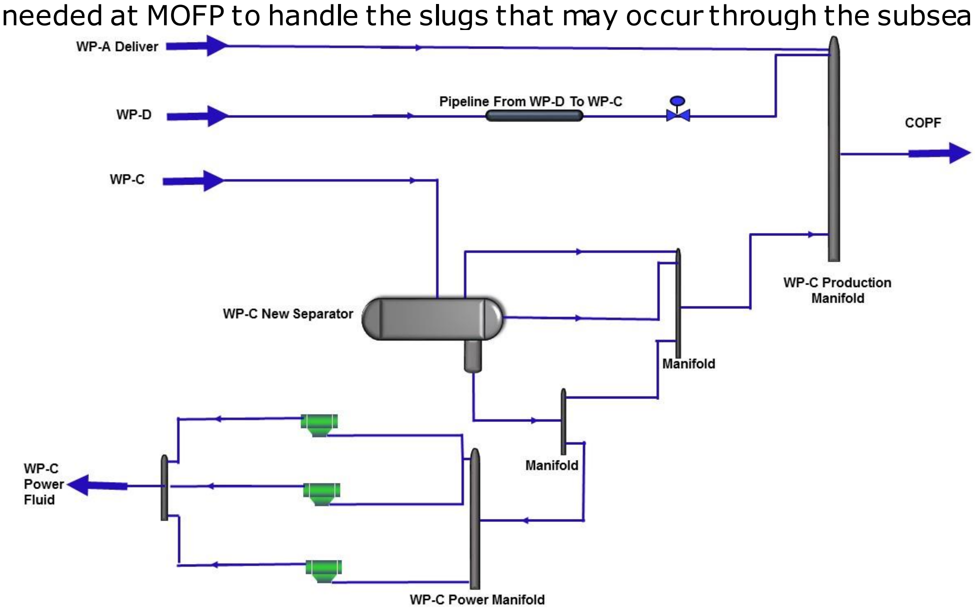

Fig. 10. WP-C platform future processing system

4.2.2. Required facilities

In order to implement the second developed recommended scenario, the recommended equipment are tabled in Table 10. Additional equipment are required for the second scenario, contrary to the first one, such as pressure vessels, injection pumps, artificial lifting pumps, and slug catcher.

Table 10. Required facilities for the second scenario

Platform	Required equipment	
WP-A	Three phase production separator	-
WP-C	Pressure vessel	Injection Pumps
WP-C	WP-C production manifold	
WP-D	Pressure vessel	Artificial lifting pumps
MOFP	Slug catcher	Transfer pumps

4.2.3. Preliminary sizing

The separator sizing modeling results are also based on the software default for the second developed scenario which assumes certain ranges for liquid and gas residence time, and L/D ratio. All the sizing calculations are preliminary and shall also be confirmed by detailed engineering calculation and vendors. For the required separator types in the second scenario, a horizontal separator operating at 30°C and 54 psig is proposed for WP-A platform while a vertical vessel operating at 32°C and 187 psig is recommended for WP-C platform (Table 11). The recommended separators are sizing at various retention times in order to determine separator length, diameter, and capacity as shown in Table (12). Additionally, the recommended pumps are transferable, injections, and artificial lifting pumps with 202 psig discharge pressure (Table 13).

Table 11. Operating separators conditions for the second scenario

Equipment	WP-A Separator	WP-C Vessel
Operating Press, psig	54	187
Operating Temp, °C	30	32
Orientation	Horizontal	Vertical

Table 12. New platforms' separators for the second scenario

Equipment	Residence time, min	Length, m	Diameter, m	Capacity, bbl/d
New WP-A Separator	5	4.2	1.2	8 720
	10	5.3	1.5	8 525
New WP-C Vessel	1	3	1	21 330

Table 13. WP-D Platform pump for the second scenario

Equipment	Flow rate, bbl/d	Discharge pressure, psig
WP-D Artificial lifting pump	-	202

4.2.4. Preliminary cost estimate

In order to select the optimum equipment, the estimated prices / weights (full packages) are determined as shown in Table 14. The transportation costs & assembly fees are excluded. The suggested costs are subject to change according to companies' offers and the industry market because they were calculated based on the available old offers.

Table 14. Estimated prices for platforms' vessels for the first scenario

Equipment	WP-A Separator	WP-A Separator	WP-C Vessel	Onshore Vessel	Onshore Vessel
Position	Horizontal	Horizontal	Vertical	Vertical	Vertical
Residence time, min	5	10	1	5	10
Steel grade	A 516 GR70	A 516 GR70	A 516 GR70	A 516 GR70	A 516 GR70
Design pressure, psig	90	90	225	50	50
ID, m	1.5	1.5	1	5	5.5
L, m	4.5	5.5	3	14.5	17
Th, inch	0.30	0.30	0.40	0.45	0.50
Volume, m^3	8	10	2.5	285	400
Estimated weight, kg	1,646	1,943	976	26,688	37,787
Total price, USD	76 625	81 972	66 506	250 000	320 000

4.2.5. Transfer line from WP-C to MOFP

The production from WP-C manifold (24,630 bbl/d) is directed to MOFP through the subsea pipeline. Table 15 shows that the pipeline will be recommended to operate at 23°C and 187 psig at manifold suction and 20°C and 6 psig MOFP discharge conditions.

Table 15. Transfer pipeline from WP-C to MOFP conditions for the second scenario

Transfer Line from WP-C to MOFP	Manifold	MOFP
Pressure, psig	187	6
Temp,°C	23	20

4.2.6. Flow assurance calculations

Further investigation has been performed and included in the developed model to study the fluid behavior in the subsea pipeline from WP-C to MOFP in order to check the ability of sluggy flow occurrence. The slug tracking models are implemented and verified using flow assurance software (OLGA). Figures 12 through 16 show the slug tracking calculations and the temperature, pressure and erosion velocity profiles across the pipeline.

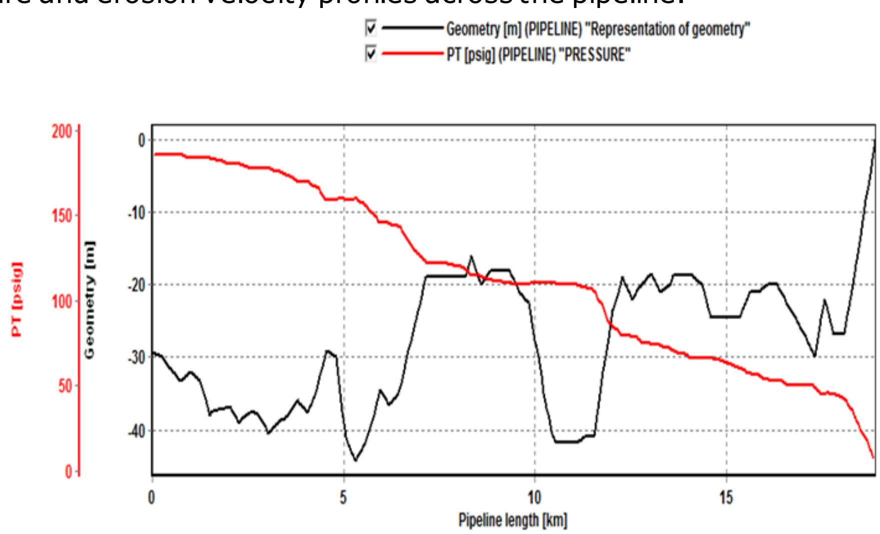

Fig.11. Subsea pipeline pressure profile from WP-C to MOFP for the second scenario

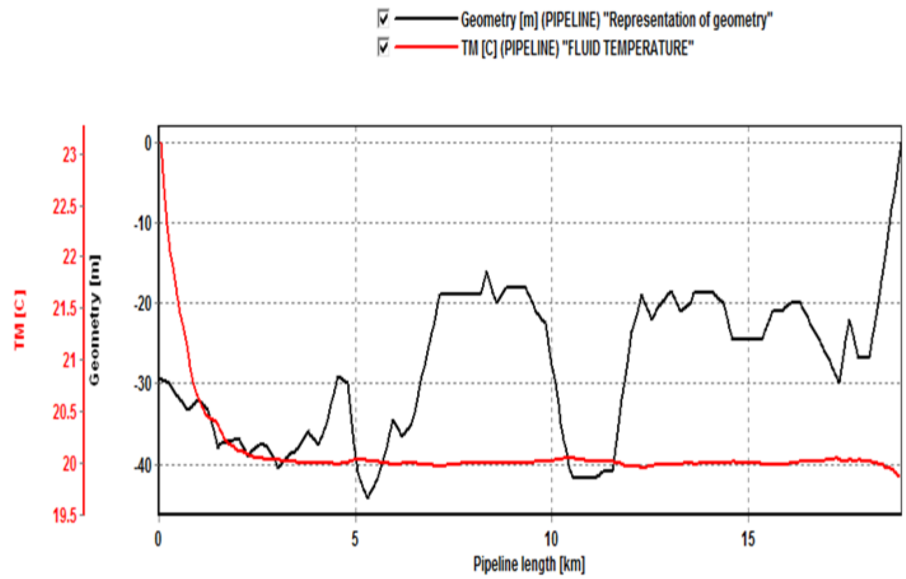

Fig.12. Subsea pipeline temperature profile from WP-C to MOFP for the second scenario

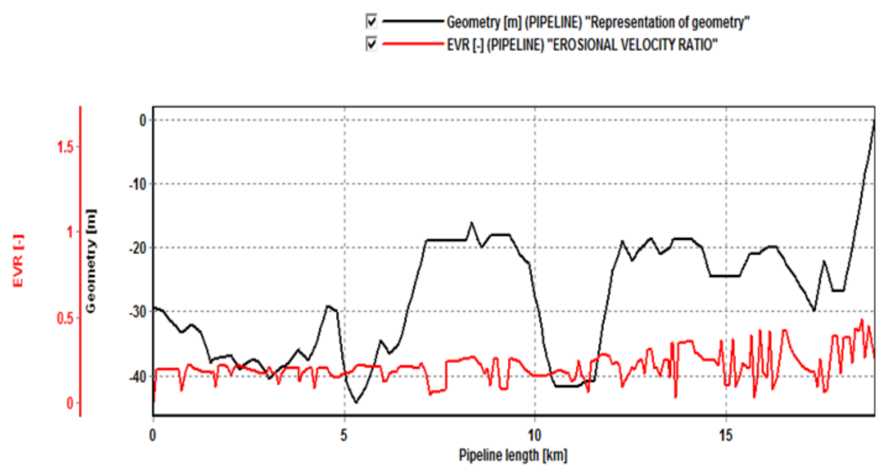

Fig.13. Subsea pipeline erosion velocity profile from WP-C to MOFP for the second scenario

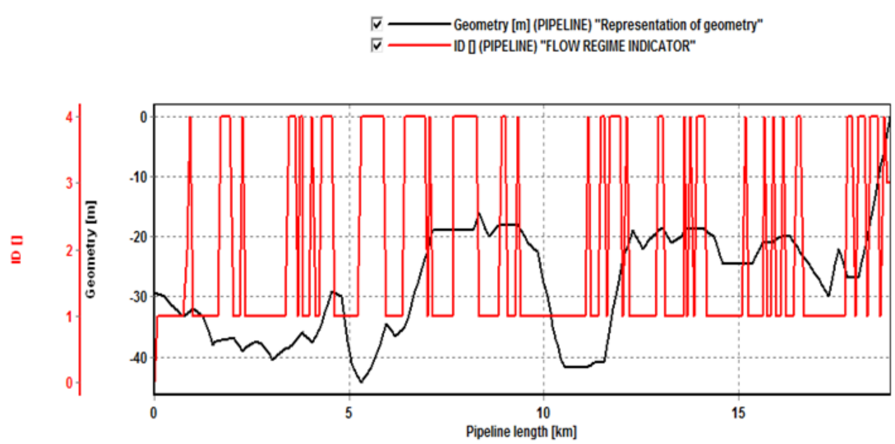

Fig.14. Subsea pipeline flow regime profile from WP-C to MOFP for the second scenario

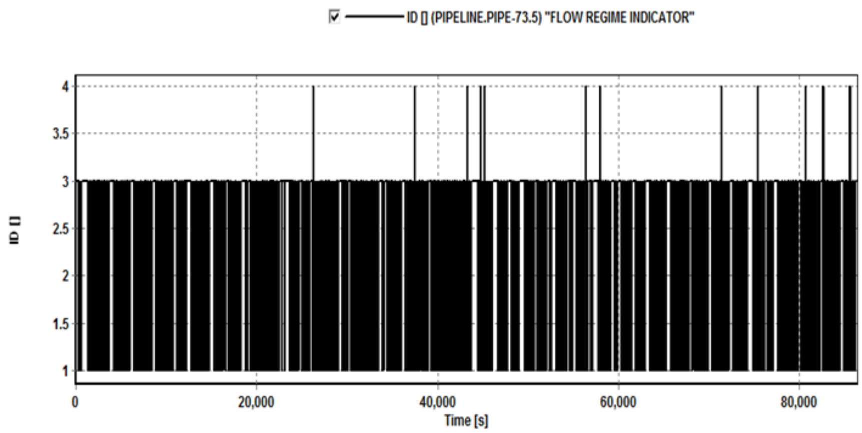

Fig. 15. Subsea pipeline flow regime at the end of the pipe for the second scenario

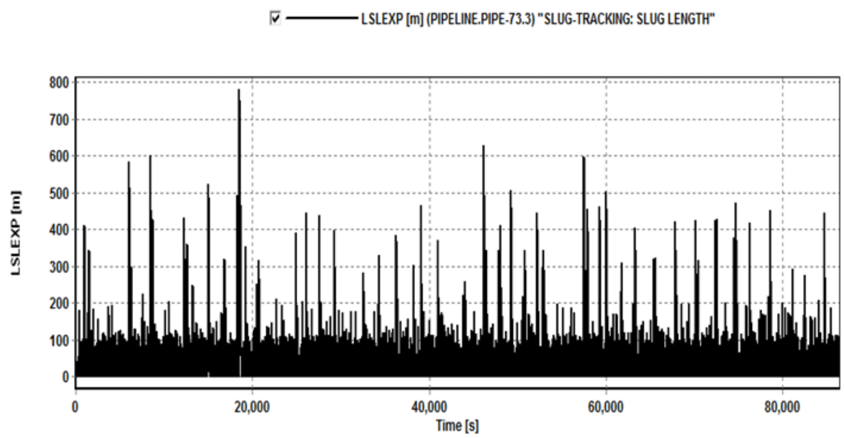

Fig.16. Subsea pipeline slug length for the second scenario

The previous profiles show that the flow regime is within normal flow (wavy and dispersed bubble) across the pipeline and sluggy at the end of the pipe. Based on the slug tracking calculations, a new vessel (slug catcher) shall be installed on MOFP to handle the slugs that may occur in the pipeline. The slug catcher sizing calculations are based on the software default which assumes certain ranges for liquid and gas retention time, L/D ratio and liquid level inside the vessel. All the model slug catcher sizing calculations are preliminary and shall be confirmed by detailed engineering calculation and vendors. Table 16 shows the onshore vessel (Slug catcher) sizing at different residence time.

Table 16. Onshore slug catcher in the second scenario

Equipment	Orientation	Volume, m^3	Residence time, min	Length, m	Diameter, m
Onshore slug catcher	Vertical	262	5	14.5	5
		426	10	17	5.6

5. Advantages and disadvantages of the developed recommended scenarios

Table 17 shows the advantages and disadvantages for the suggested scenarios through which a complete picture with the preceded model results is presently shown for the decision maker in the company.

Table 17. Pros and cons of the developed scenarios

Scenario	WP-A and WP-C gas separation	WP-A Gas separation / WP-C and WP-D direct flow to MOFP
Advantages	Availability of the electric power supply at WP-C.	Smaller area will be required on WP-C due to non gas separation. The pipeline integrity won't be affected.
	More stability at the pipe line due to the gas separation.	Full independence on WP-C from COTP
		Gas utilization at MOFP
		Minimize the man power
		Improve the company environmental compatibility.
		Reduce the running cost
Disadvantages	Due to the area limitation on WP-C a wide extension for this platform may be required.	Sluggy flow will occur.
	Higher investment cost.	Onshore Transfer pumps will be required

6. Summary

Based on the model simulation results, the new required facilities for each alternative are summarized in the Table 18

Table 18. Summary of new required facilities for platforms' network

Platform	WP-A and WP-C gas separation	WP-A Gas separation /WP-C and WP-D direct flow to MOFP
WP-A	Three phase production separator	Three phase production separator
WP-C	Three phase production separator	WP-C Pressure vessel
		Injection pump
	Transfer pump	
WP-D	-	Artificial lifting system
Onshore	-	Slug Catcher Transfer Pumps

7. Conclusions

Additionally, the following conclusions are extracted based on the analyses and results:

Platforms' production network can successfully be operated when COTP is out of service. The developed predicting model proved its effectiveness as a proactive oil production and maintenance tool instead of traditional time-based strategies.

Flow assurance and pipeline calculations are key parameters for providing and selecting the required pumps for platforms' network. Cost analysis of vessels is absolutely the main issue for selecting the optimum producing scenario. Differentiating between the recommended scenarios by utilizing the identified advantages and disadvantages of each is considerably easier for a company's decision-maker.

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