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"Application of Hydraulic Jet Pump Technology in MEL Field"

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Abstract

MEL Field is located onshore in the northern part of the South Sumatra Basin producing oil from the Lower Talang Akar Formation. It is characterized as multilayer sandstone reservoirs with complex reservoir connectivity. Declining well performance due to increasing water cut necessitated the need of artificial lift to maintain production. Different types of artificial lift were evaluated considering technical and economic parameters. Hydraulic Jet Pump was selected as artificial lift for MEL Field. This paper discussed the implementation of the hydraulic jet pump system, including the selection process, equipment design, and actual results and the key surveillance parameters.

Introduction

MEL Field is located onshore in the northern part of South Sumatra Basin and producing oil from Lower Talang Akar Formation. It is characterized as multilayer sandstone reservoirs with complex reservoir connectivity **(Figure 1).** A total of 11 wells have been drilled from 4 well pads penetrating more than 10 reservoir layers with inclination varying from 0 to 50 degrees. Initial flow rates ranged from 100 to 2000 BOPD with 0 – 90% water cut. Oil density varies from 33 to 40^0 API, while initial GOR varied from 400 to 1000 scf/bbl.

Production from wells drilled from pad A and B experienced rapid production decline along with sharp increase in water cut, hence artificial lift is required.

Artificial Lift Overview

In most oil field developments, artificial lift is required at some point as most producing oil wells will experience increased water production and/or declining reservoir pressure. Selection of artificial lift technique is therefore critical to ensuring continued production and recovery, taking into account field and well characteristics to obtain optimum results. A combination of one or more of the following factors may provide justification for installing an artificial lift system:

- Expected reservoir pressure with time
- Expected reservoir drive mechanism.
- To optimize production from a well struggling to produce under natural flow.

Following are artificial lift methods that were evaluated:

- **Rod Pump / Beam Pump** is a reciprocating positive displacement pump and consists of surface unit (beam pump), sucker rod and downhole piston pump. It is mainly used onshore for relatively low production rate wells. It offers low OPEX and CAPEX but has limitations in gas handling and deviated wells.
- **Progressive Cavity Pump** is a rotary positive displacement pump and consists of a surface drive, drive string (rod) and downhole pump, which is comprised of a single helical-shaped rotor that rotates inside a double helical elastomer-lined or metal stator. It is a common form of artificial lift for low-to-moderate rate wells especially onshore for viscous oil and is able to handle limited sand production. OPEX and CAPEX are generally low but might vary depending on completion type. Limited application is driven by reduced performance at higher GOR (poor gas handling) and high reservoir temperature which were seen as potential issues if PCP being installed in MEL field.
- **Gas Lift** is a method of artificial lift by injecting gas through into the annulus between the production tubing and casing. A side-pocket mandrel with an orifice valve is incorporated into the tubing string to allow the injected gas from the annulus to enter the production tubing, thereby reducing the weight of the column. Produced gas at surface is reinjected back to annulus which makes this a closed system. Gas lift method can be differentiated based on intensity to have continuous or intermittent injection. As an option for artificial lift, gas lift

comes with wide compatibility and some tolerance to solid/sand production. OPEX is relatively low, but might require high CAPEX if surface facility is not initially designed to have some gas processing units. Moreover, additional CAPEX would be required if existing completion type are not premium connection to prevent from well integrity risks. Gas resource in MEL field is available which makes this method feasible. However, the existing wells do not have premium connection in the completion which would require workover.

- **Electrical Submersible Pump (ESP)** is used in high production, high water-cut wells with rates up to 60,000 BFPD. It can be utilized onshore, offshore and subsea. The pump's reliability is dependent on application and location. The ESP consists of a three-phase induction motor, multistage centrifugal pump and surface controls powered by electric generator. The ESP is commonly deployed downhole of tubing with the pump on top and the motor attached below. The power cable, from the surface power supply, is strapped to the tubing down to the induction motor. Completion design using an ESP can vary considerably depending on well requirements. With a simple design, if no access to the well is required, the ESP is run below the production packer. If access to the reservoir is required, the ESP is run with a Y block which allows the bypass tubing to be run below the ESP and provide intervention access to the reservoir. In some cases, ESP can be equipped with gas handling technology for high GOR wells. ESP offers high production rate by achieving high drawdown, but it comes with relatively short life time and high maintenance cost for workover if pump replacement required.
- **Hydraulic Jet Pump** is the only form of artificial lift that has no moving parts finding wide application in low (100 BFPD) to high rate wells (20,000 BFPD). The Jet Pump is compact, reliable, and easy to install / retrieve with or without slickline. The Jet Pump System consists of downhole jet pump and surface facilities for power fluid circulation. The Jet Pump can be deployed by slickline into either a Sliding Side Door (SSD) or Ported Nipple. The jet pump can also be retrofitted by punching a hole in the tubing and setting a straddle packer. Power fluid is either injected down the annulus with commingled production up the tubing or injected down the tubing with commingled production up the annulus. Jet Pump is applicable to deviated well with low maintenance cost by using slickline intervention.

Artificial Lift Selection

The selection of artificial lift in the MEL field takes into consideration cost, compatibility with well and (already installed) surface facilities, intervention constraints, operational risks and lead time. In order to ensure a fit for purpose artificial lift method, the following selection process was developed:

- Initial screening of all methods to eliminate unsuitable candidates.
- Select the top 2-3 applicable methods for detailed scoring
- Determine the most feasible artificial lift method to continue with design and implementation

The initial screening is summarized in **Figure 2.** Rod pump is not applicable for MEL field as most of the wells are deviated and completed with 2-7/8 tubing. PCP's are also not applicable for the MEL field due to high GOR and high reservoir temperature.

The applicable artificial lift method for MEL field are:

- Gas Lift – This option requires installation of gas lift mandrels and replacement to tubing connections which therefore requiring some workovers to modify the existing completion strings. Furthermore, existing surface facilities were not designed to have gas lift system which require additional CAPEX for gas compressor and high pressure gas lines.
- Hydraulic Jet Pump – This option provides flexible operation, usage in deviated and small ID completion wells, and is not materially affected by higher gas rates. Another major advantage is

that no workover (pulling of the existing completion string) is required.

A scoring-based evaluation was performed to further compare gas lift and hydraulic jet pump by taking into consideration the expected deliverability, economics, and compatibility with existing completion and facilities. Despite of each artificial lift method has its own strengths and weaknesses, the total scoring results indicate relatively small difference between gas lift and hydraulic jet pump. Hydraulic jet pump was selected as the artificial lift method based on its higher score as shown in **Figure 3**. particularly on its ability to meet first oil delivery schedule and the massive amount of CAPEX and timing associated with gas lift to modify existing completion and surface facilities.

Downhole Jet Pump Design

Hydraulic Jet Pump uses high-pressure power fluid injected down the tubing which then flows through a nozzle (venturi design) to create drawdown on the formation below and produce reservoir fluids through the annulus. The jet pump downhole assembly consists of jet pump housing to hold jet pump carrier and direct the reservoir fluid to flow through to the annulus, and jet pump carrier to grip and direct the flow through the nozzle as shown in **Figure 4**. Standing valve can be installed to prevent injecting the formation in case of jet pump system leak. The downhole jet pump installation requires slickline unit by initially setting the housing at the SSD then followed by running the carrier to sit on the housing. In the case of maintenance, jet pump nozzle can be retrieved either by slickline as the most effective way or reverse circulation which requires higher pumping pressure to displace the annulus.

Reservoir parameters from each well were used to design the jet pump configuration as shown by **Figure 5**. Sensitivity analysis on setting depth using available SSD’s, injection rate, and nozzle type were performed to obtain optimum design. It was concluded that the deeper the setting depth and the higher the injection rate, the more liquid gain can be produced. However, higher injection pressure will be required as the consequence as well as an appropriate nozzle to convert the inlet rate and pressure to the desired drawdown on the formation.

Jet Pump Surface Facilities

Surface facilities for Jet Pump system consists of high-pressure surface pumps, knock out drum and power fluid separator. Optionally, a test separator can be used for more accurate and direct measurement from the well. The specification for surface pump is driven by the required injection rate and pressure required based on selected nozzle type. Diesel engine type was used for surface pumps due to availability and the required diesel consumption can be high and needs to be taken into account in the economic evaluation. A spare hydraulic surface pump was available to ensure the desired high availability of the entire system. A knock out drum is used as first separation of gas from total liquids returned from the well. Power fluid separator is used to separate power fluid and liquid gain from the well which results in most of produced water returns as power fluid and left oil with some water to be transferred as liquid gain to processing facility. The surface block diagram is illustrated by **Figure 6.**

Hydraulic Jet Pump Performance

During commissioning, the jet pump operating conditions needs to be fine-tuned. This was achieved by gradually increasing the surface pump RPM to achieve the target injection rate while also checking the pump discharge pressure. Once achieved, the jet pump system may require time before floe from the formation is obtained, indicated by a decreasing water cut in the overall jet pump system.

The Jet Pump system was implemented in well pad A and B of MEL Field. Wells **W3** in Pad A and **W5** in Pad B had jet pumps installed. Well **W3** initially produced at 400 BLPD of liquid rate during comingled production utilizing a shallower gas zone. The production declined at 20%/month resulting in 200 BLPD prior to hydraulic jet pump installation. Post hydraulic jet pump installation, total liquid rate increased 100% resulting in additional oil production by 100 BOPD as shown in **Figure 7.**

Well **W5** initially produced at 1800 BLPD during natural flow, then sharply declined at 40%/month due to increasing water cut to 900 BLPD before installing hydraulic jet pump. Post hydraulic jet pump installation, the total liquid rate increased by 30% to 1200 BLPD with slower decline rate as shown in **Figure 8.**

Key Surveillance Parameters

In order to maintain optimum jet pump performance, the following key parameters need to be monitored on a regularly basis:

Surface Pump Injection Rate is critical as it controls the downhole pressure drawdown created by jet pump system. Any problem on surface would therefore reduce potential liquid gain from the jet pump system

- **Surface Pump Injection Pressure** is critical as combined with the injection rate controls the downhole pressure drawdown on the formation generated by the nozzle. Decrease to injection pressure followed by no liquid gain could be the indication of leak in the jet pump system. While an increase to injection pressure could be an indication of plugging in the system.

- **Liquid Gain** is the main outcome to understand if the jet pump system configured correctly assuming there is no productivity issue in the formation. Reduction to liquid gain followed by increasing injection pressure could indicate plugging to jet pump system (i.e. scale build up, surface filter problem). While absence of liquid gain followed by decreasing injection pressure are indications of leak in the jet pump system which could be caused by nozzle inadvertently unset from the jet pump carrier or nozzle get damaged during the operations.

In addition to the continuous surveillance, a regular jet pump diagnostic program was implemented to prevent scale build up. This involves retrieval of the jet pump nozzle and housing and carrier if required using a slickline unit for visual inspection.

Summary

- Hydraulic Jet Pump was selected to provide artificial lift for the MEL field based on screening and scoring evaluating considering the ability to deliver high liquid rate, compatibility with existing facilities, and economical analysis.
- In designing the downhole jet pump system and configuration, it was concluded that the deeper the setting depth and the higher the injection rate, the more liquid gain can be produced, but higher injection pressure is required to achieve this. Therefore, optimum configuration needs to be defined by installing suitable nozzle type and also taking into consideration surface facility condition.
- Injection rate, injection pressure and liquid gain are the key surveillance parameters to ensure optimum jet pump performance. In addition to the continuous surveillance, a regular jet pump diagnostic program was implemented to prevent scale build up
- Jet pump system had been able to increase liquid rate by 30 – 100% and extended well life in MEL field. However, the overall oil gain was below initial expectation due to reservoir complexity and larger gas reservoirs.

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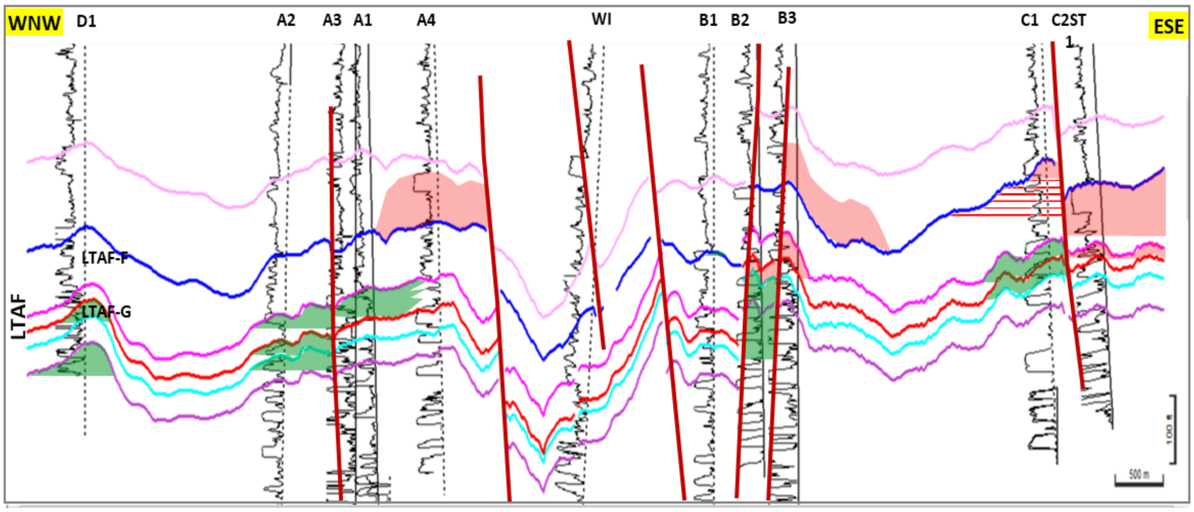

Figure 1 – MEL Field showing complex LTAF reservoir connectivity

	Install Cost	Op. Costs	>1,000 BPD Lift	Efficiency	Noise Level	Gas Handling	Slim Hole (2-7/8" comp)	Deviated wells	Solids handling
Sucker Rod Pump	Good / Moderate	Good	Moderate	Good	Moderate	Moderate	Poor / Moderate	Moderate	Poor / Moderate
PCP	Good	Good / Moderate	Poor	Good	Good / Moderate	Poor	No Known Installs	Poor / Moderate	Good
ESP	Moderate	Moderate	Good	Good / Moderate	Good	Poor	No Known Installs	Moderate	Poor
Hydraulic Jet Pump	Good / Moderate	Moderate	Good	Moderate	Good / Moderate	Good / Moderate	Moderate	Good	Good / Moderate
Continuous Gas Lift	Good / Moderate	Moderate	Good	Moderate	Good	Good	Good / Moderate	Good	Good
Intermittent Gas Lift	Good / Moderate	Moderate	Poor	Poor	Good	Good	Good / Moderate	Good	Moderate

Key: (green) Good; (yellow/green) Good / Moderate; (yellow) Moderate; (yellow/red) Poor / Moderate; (red) Poor

Figure 2 – Artifial Lift Screening Matrix

SCORING PARAMETER	Weighted Point	SCORE (0-100)		WEIGHTED AVERAGE SCORE	
		HJP	Gas Lift	HJP	Gas Lift
> 1000 BLPD rate	15%	80	70	12.0	10.5
Operational Envelop for Wide PI, GOR and Wcut	5%	70	80	3.5	4.0
Well Intervention Operation	5%	80	80	4.0	4.0
Sand/Solid/Contaminants Handling	5%	50	60	2.5	3.0
Power Consumption	10%	60	80	6.0	8.0
Black Start/ Start Up	10%	90	50	9.0	5.0
Reliability	10%	60	70	6.0	7.0
Compatibility with Surface Facilities	10%	70	60	7.0	6.0
Availability to Meet Schedule Requirement	10%	70	50	7.0	5.0
CAPEX	10%	80	70	8.0	7.0
OPEX	10%	70	90	7.0	9.0
TOTAL	**100%**			**72.00**	**68.50**

SCORE CODE BAR
0
2
4
6
8
10
12
14
16

Figure 3 – Hydraulic Jet Pump vs. Gas Lift Evaluation

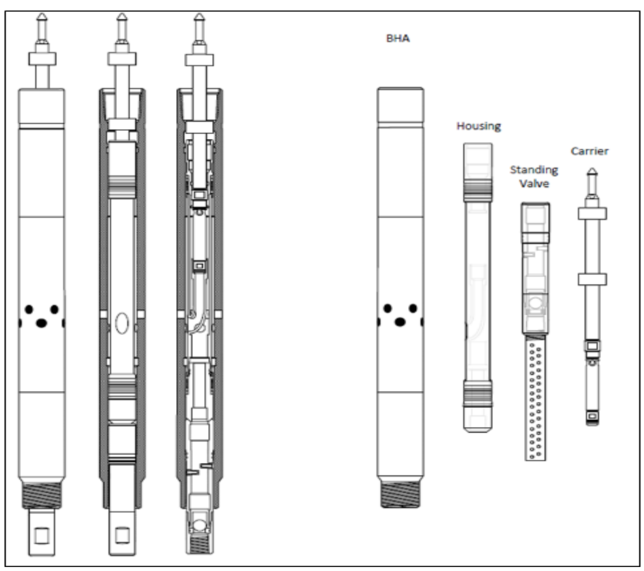

Figure 4 – Downhole Jet Pump Assembly ~~possible standing valve~~

Design Input

No	Parameters	Well W3	Well W5
1	Mid Perforation (MD ft)	6232	5791
2	Reservoir Pressure (psia)	2000	2065
3	Productivity Index (STB/day/psia)	0.42	0.77
4	Casing ID (in)	8.755	8.755
5	Production Tubing OD (in)	2.875	2.875
6	Production Tubing ID (in)	2.441	2.441
7	Tubing length (MD ft)	6202	5780
8	Oil Gravity (API)	34.3	37.9
9	Produced Water Cut (%)	40	60
10	Water Salinity	15000	15000
11	GOR (scf/stb)	464	559
12	Gas Gravity	0.979	1.011
13	Nozzle Type	D7	E11

Sensitivity Result

Injection Rate	Pump Depth	Well W3	Well W5
		Liquid Gain	Liquid Gain
BLPD	ft	BLPD	BLPD
1,000	4,000	350	710
1,200	4,000	380	780
1,500	4,000	405	850
1,000	5,000	375	770
1,200	5,000	400	840
1,500	5,000	425	910

Figure 5 – Design Input & Sensitivity Result

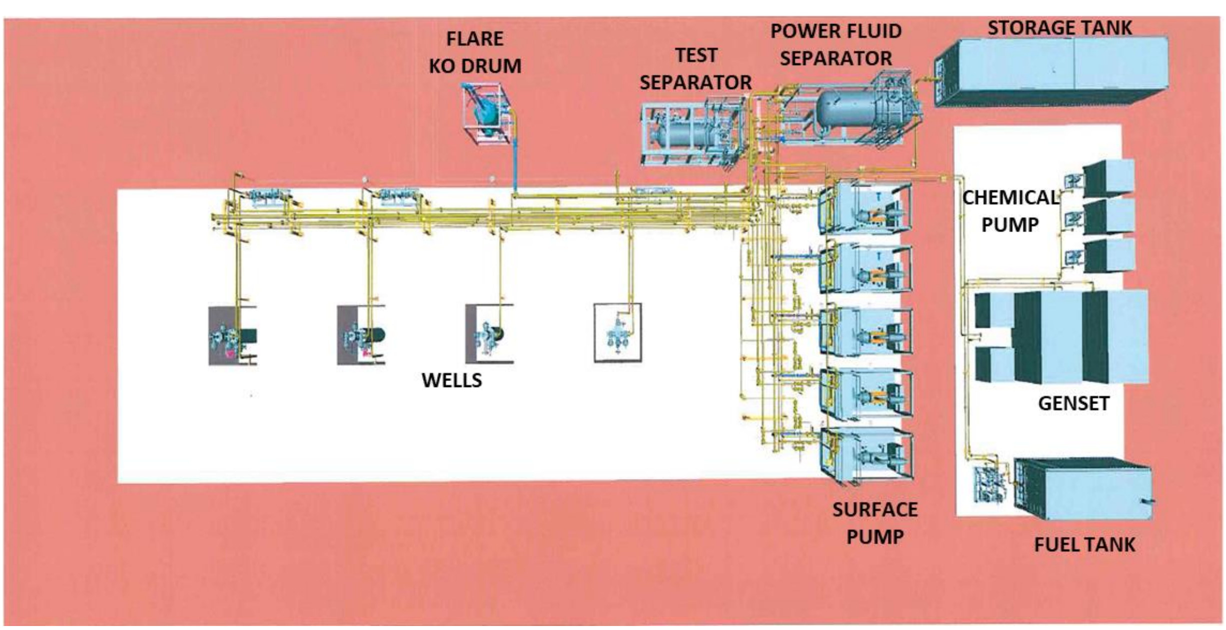

Figure 6 – Jet Pump Surface Facilities

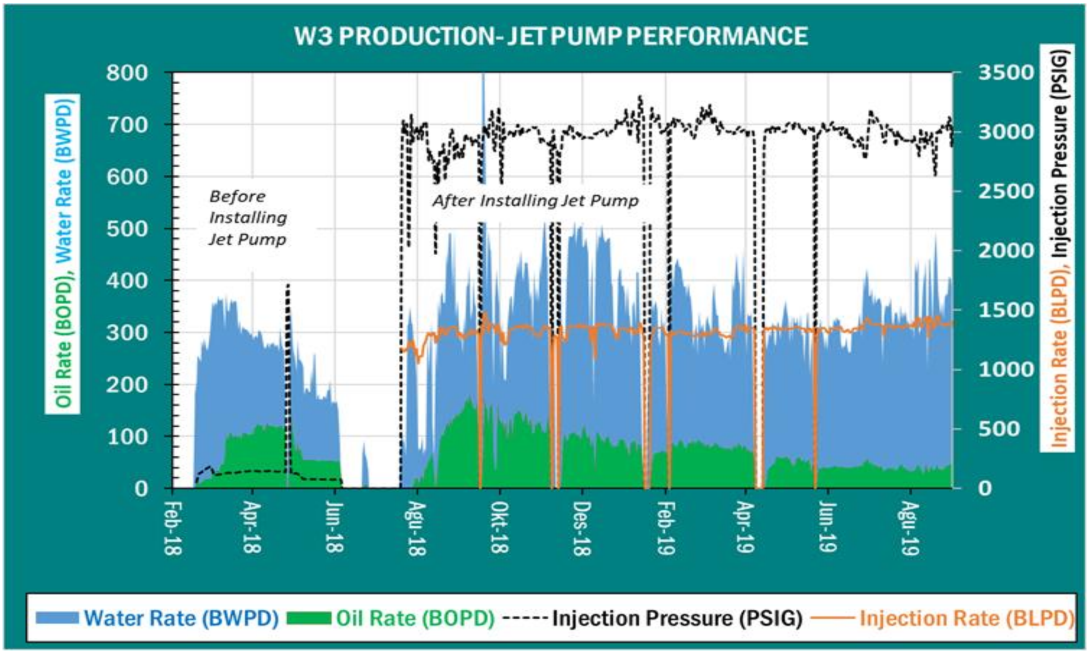

Figure 7 – Well W3 Jet Pump Performance

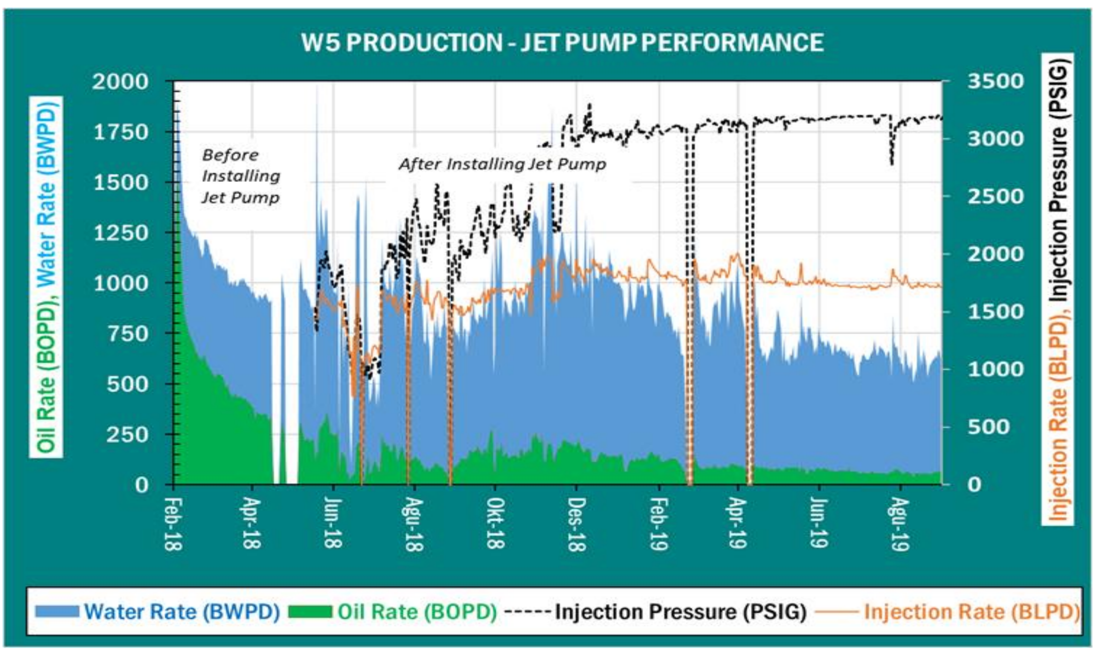

Figure 8 – Well W5 Jet Pump Performance