Production Optimization of High Pour Point Oil in Lindai Field by Thorough Flow Assurance Enhancement

Dias Anugrah Massewa[1*], Rizaldi Winant[1], Bomantara Zaelani[1], Fertian Eka Purnama[1], and Fahmi Nugraha[1]

[1]Pertamina Hulu Energi Siak
* Email: dias.massewa@pertamina.com

Abstract. Thorough flow assurance simulation study has been conducted to find the most optimum solution to overcome the congealing problem for production optimization in this field based on technical and economical aspect. Previously, three wells in Lindai field were found shut off for eight hours every night due to congealing caused by temperature drop. Three options were tested using software simulation, laboratory study, and field trial to overcome the congealing problem. The first option was to implement back flow method which improve the flow assurance by pumping produced water from the gathering station using piston pump back to three wells that regularly effected by congealing problem and flow it back together with the oil production from these wells. The second option was to inject pour point depressant to the wells flow line and perform laboratory test. The last alternative was to install heater to the wells flow line to increase the temperature until above pour point. The observation outcomes for all three selections were gathered. The first outcome was implementing back flow method which only needed minor flow line modification resulted in improved flow assurance because the fluid temperature from these three wells could be maintained above its pour point by continuous flow from the pumped produced water thus preventing the oil from congealing even when ambience temperature drop at night. The second outcome was injecting pour point depressant needed large amount of chemical and continuous injection was needed to reduce the pour point. The last outcome was installing heater to the wells flow line, which in turn, huge power consumption was required to activate the heater continuously. This study concluded that back flow method was the most optimum method to improve flow assurance of high pour point oil from these three wells.

Keyword: High pour point; production optimization; flow assurance

1 Introduction

1.1 Lindai Field Characteristic

PHE Siak have three fields which are Lindai, Menggala South, and Batang field as seen in Figure 1. Lindai field has around 20 producing wells with average field production in 2019 was 631 BOPD. The artificial lift used in 2019 were Electrical Submersible Pump (ESP) dan Sucker Rod Pump (SRP). However, in 2020, some of Lindai field wells are using Progressive Cavity Pump (PCP) as the artificial lift.

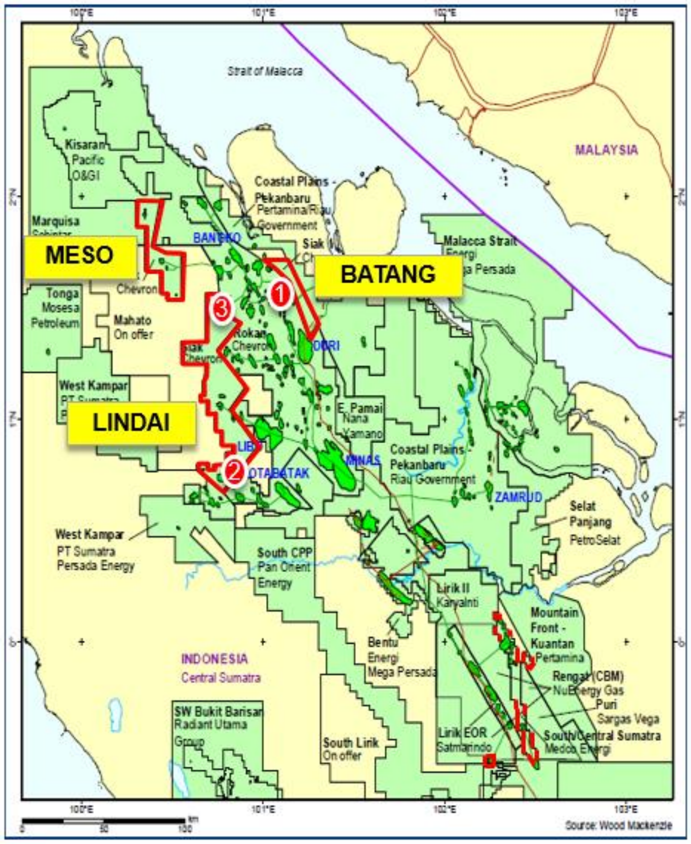

Figure 1: PHE Siak field map

Fluid characteristic in Lindai field is categorized as High Pour Point Oil (HPPO) with detail as stated below.

API Gravity	:	31.2
Specific Gravity at 60/60°F	:	0.8696
Pour Point	:	97°F
Sulphur Content	:	0,133%wt
Asphalt Content	:	0,062%wt
Wax Content	:	17.13%wt

Prior to receiving any treatment to the oil production, three out of 20 wells which were LDI 02, LDI 12, and LDI 16 were found automatically shut off for approximately 8 hours every night due to high pressure in the flow line caused by temperature drop below pour point and congealing. The well test result and estimate LPO for these three wells are shown in

Table 1.

Table 1: Base well production

		Base Well Production			
Wells	**Pump Type**	**Gross (BFPD)**	**Net (BOPD)**	**Hours Down**	**Est. LPO (BOPD)**
LDI 02	SRP	50	22	8	7
LDI 12	SRP	82	21	8	7
LDI 16	SRP	43	41	8	14
			Total Est. LPO (BOPD)		28

1.2 Causing Factors

The causing factor of the congealing problem was analyzed using fishbone analysis as described in Figure 2.

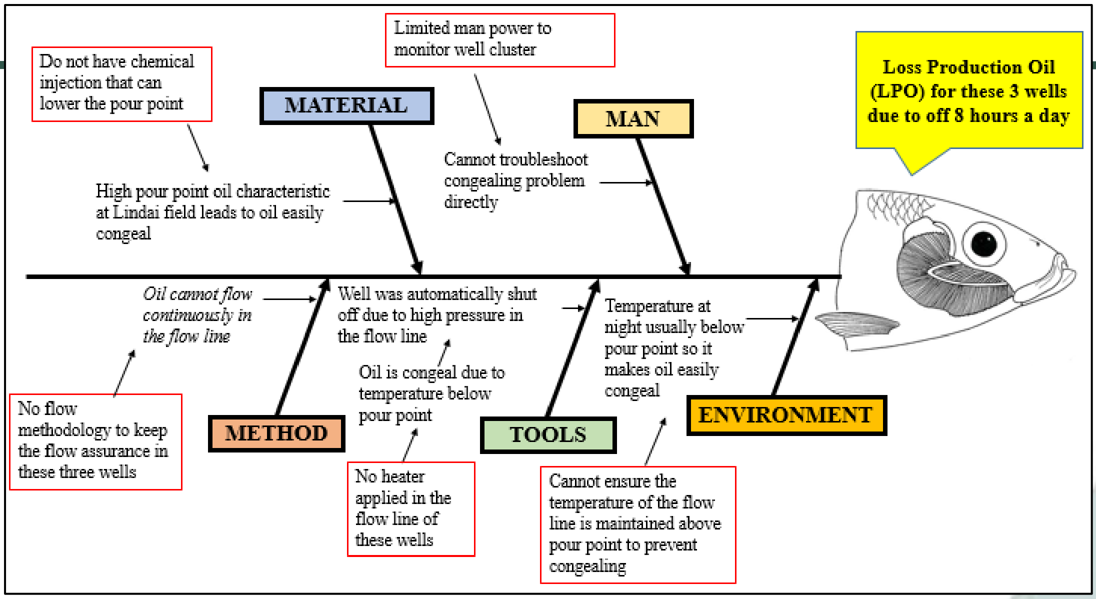

Figure 2: Fishbone analysis

By this fishbone analysis, it was found out that there were five causing factors which consisted of material, man, method, tools, and environment that leaded to the problem of Loss Production Oil (LPO) for the three wells due to off condition for approximately 8 hours a day.

The analysis of cause and effect can be seen in Table 2 which shows the causing factor that correlates with the main problem of the fishbone.

Table 2: Causing Factors

No.	Causing Factor	Analysis	On Field Verification	Correlation (Yes/No)
1	Environment	Fluid characteristic is categorized as HPPO which will congeal at temperature below 97°F.	From the PVT of Lindai field, it is stated that the pour point is 97°F.	Yes
2	Man	Limited man power that caused the monitoring in cluster 2 is difficult especially at night.	Lower frequency of surveillance at night shift due to limited man power compared to the day shift.	No
3	Tools	Heater is needed to	No heater currently	Yes

		increase the temperature of oil in the flow line of the three wells so it can be maintained above pour point.	available in this field. The type of heater that is suitable for the flow line is cable heater.	
4	Material	Pour point depressant (PPD) is required to lower the pour point so oil cannot easily congeal	In the current chemical availability in Lindai field, PPD has not been included. Additional procurement is needed to use this chemical	Yes
5	Method	New method for production flow assurance in Lindai is needed to prevent oil from congealing	Flowing water from the gathering station to the three wells has been proven by field trial can prevent the oil from congealing	Yes

After looking deeper into the field result, the factors that correlates into the shut off condition for the three wells due to congealing problem are environment, tools, material, and method.

1.3 Root Cause Analysis

To find the root cause, analysis was done using Failure Mode and Effects Analysis (FMEA) to find the most contributing cause of the shut off conditions during the night for these three wells. The calculation of FMEA using Risk Priority Number (RPN) is shown in Table 3.

Table 3: FMEA Calculation

Problems List	Process Description	Causes of Failure	Severity (S)	Occurrence (O)	Detection (D)	Risk Priority Number (RPN)	% Rel	% Cum
A	No flow methodology to keep the flow assurance in these three wells	If the oil congeals due to low tempereature then the wellhead temperature will increase due to restricted flow and the pressure switch will shut off the well	8	8	7	448	61%	61%
B	Do not have chemical injection that can lower the pour point	Not yet have the availability of pour point chemical injection at the field	6	5	5	150	20%	81%
C	No heater applied in the flow line of these wells	Not yet have specific heater for the wells flowline to maintain the temperature	5	5	5	125	17%	98%
D	Cannot ensure the temperature of the flowline is maintained above pour point to prevent congealing	If temperature drop below pour point (92°F), then the oil will congeal and cannot flow	3	2	2	12	2%	100%
		Summary				**723**	**100%**	

The pareto chart is developed in Figure 3 to show the root cause ranked by RPN that is calculated from Table 3 consisted of severity, occurrence, and detection to find the most contributing cause to the problem.

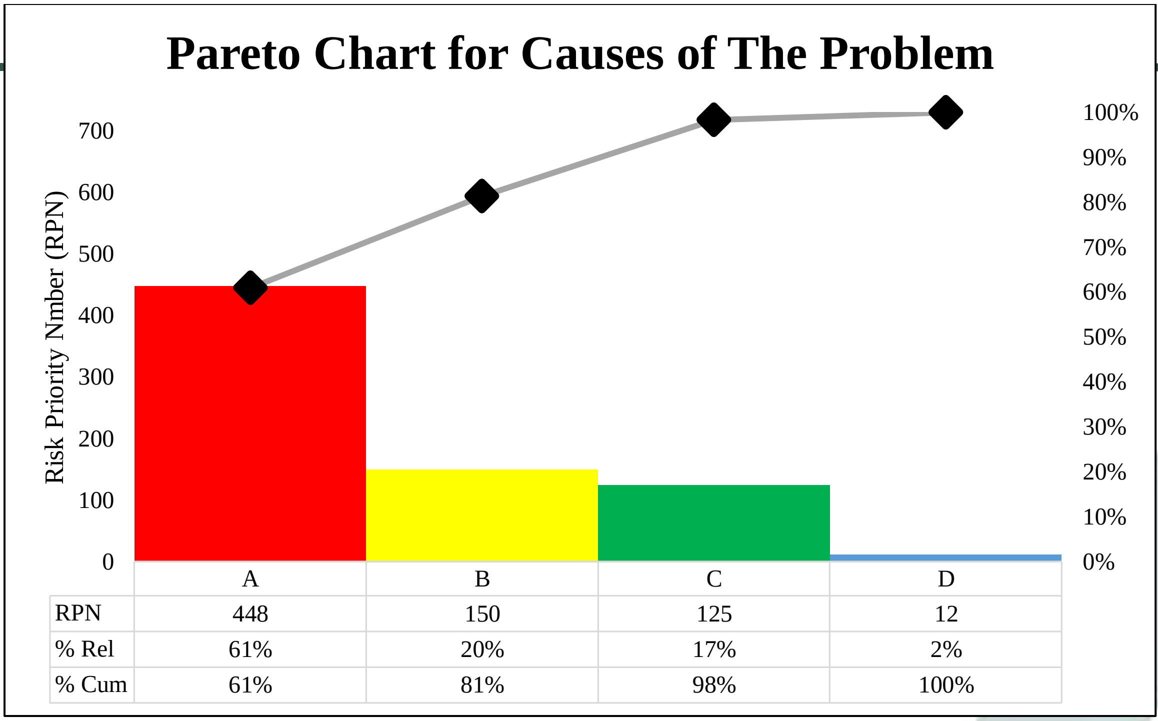

Figure 3: Pareto Chart for Causes of The Problem

It is found that problem A which was “No flow methodology to keep the flow assurance in these three wells” came up on top as the main root cause for the shut off for the three wells due to congealing problem. Therefore it is needed to find the solution to overcome the root cause.

2 Methodology

From the top three of the causing factors, it is essential to compare the applicability of the solutions to tackle the main problem. In this analysis, the causing factor that would like to be compared are new innovative flow method which is called “backflow method”, PPD chemical injection, and clamp heater application.

2.1 Backflow Method

The condition of the previous production flow process in Lindai field is illustrated in Figure 4. In this figure oil from LDI 02, 12, and 16 was produced straight to the production flow line and continued to the gathering station which was combined with any other wells in Lindai field. In this condition, these wells were found off for 8 hours at night due to congealing problem.

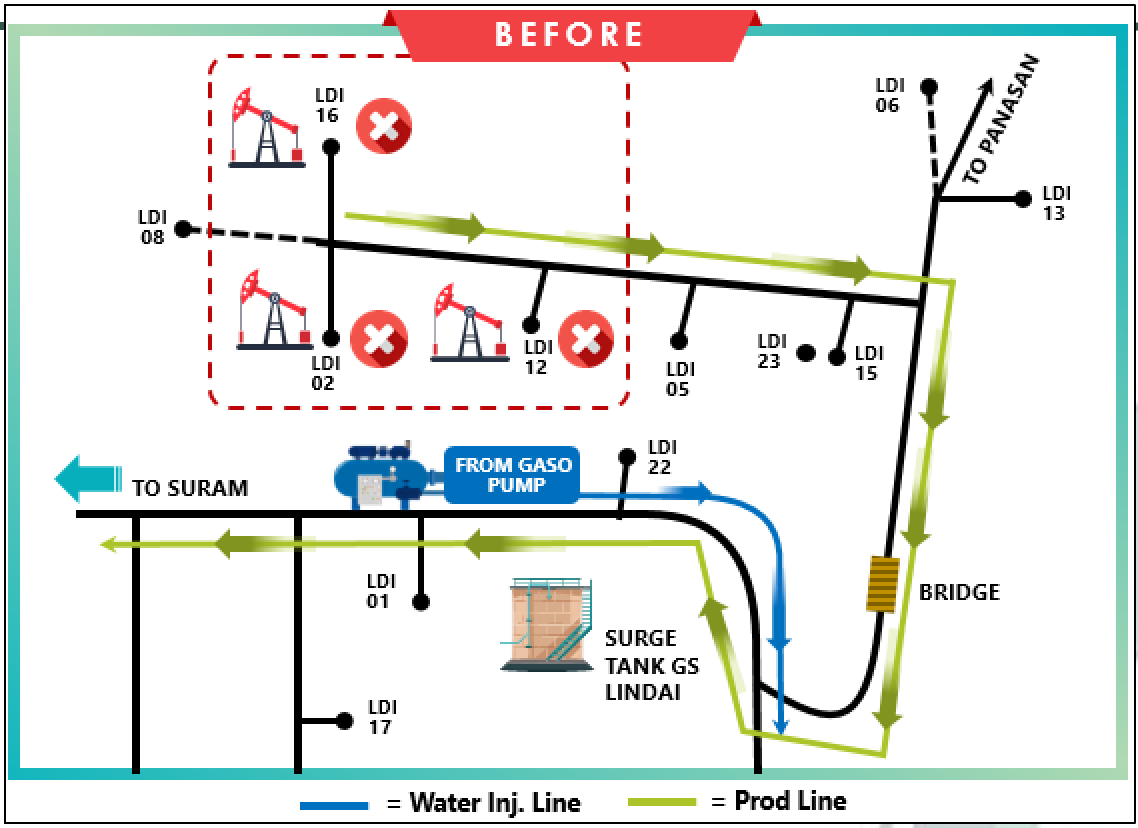

Figure 4: Before Backflow Activation

The new method that wanted to be applied was Backflow method. It was an innovative flow method in Lindai field by pumping produced water from the gathering station using Gaso Pump from the surge tank to the water injection line and test line then going into the flow line of the three wells back to the gathering station again that could be seen in Figure 5.

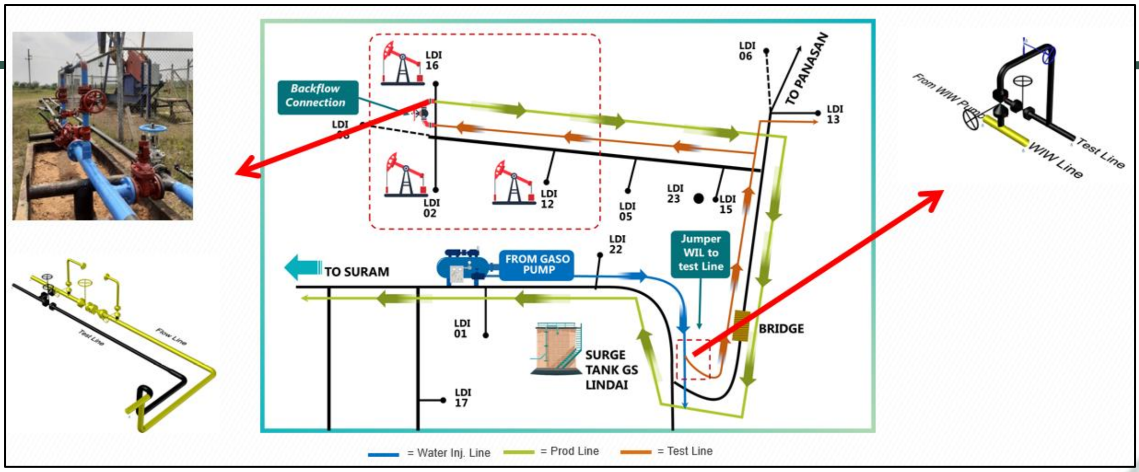

Figure 5: Backflow activation with equipement modification

This method was activated by utilizing idle test line that has not been used anymore. Additionally, two modifications were needed on two sections of the flow line. The first one was for the connection in the jumper water injection line (WIL) to the test line. It was used as the transition for the flow of the pump produced water from the WIL to the test line. The second one was for the backflow connection on LDI-16. Both modification could be seen in Figure 5. The backflow connection was needed as the transfer connection for the pumped produced water to be combined with the produced fluid from LDI-02, LDI-12, and LDI-16. The purpose was to maintain the temperature of the produced fluid to be above the pour point so the oil will not congeal anymore.

2.2 PPD Chemical Injection

PPD chemical injection is a method to lower pour point by injecting some dosage of chemical to the agreed point in the flow line. In this case, PPD was injected to the wing line of LDI-16 as shown in Figure 6.

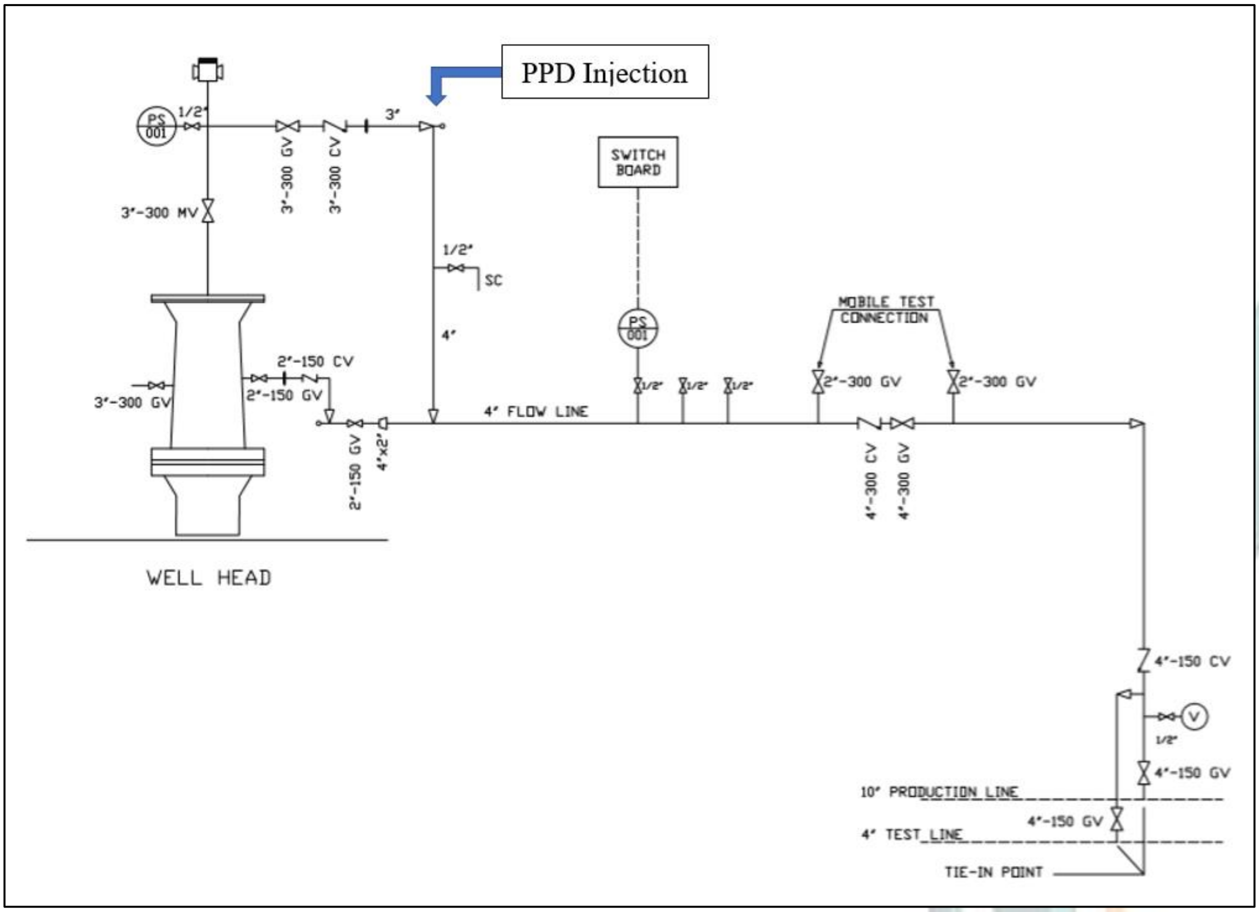

Figure 6: PPD Injection

By injecting PPD, oil could be transported more easily in the flow line and could flow with less trouble after a shutdown or power trip. Prior to find the dosage of PPD that needs to be injected, pour point test of

LDI-16 well was performed to confirm the pour point of the oil. The pour point test was referencing to ASTM D97 (Standard Test Method for Pour Point of Crude Oil) and it was found that the pour point in Lindai field was 97°F. After that, sensitivity bottle test to mix the oil sample of LDI-16 with the PPD chemical is performed to calculate the dosage needed to lower the pour point based on the flow temperature in the system. In the field implementation, continuous PPD injection is obligatory to constantly maintain the designed pour point.

2.3 Heater Application

Heater is one of electrical methods to increase temperature to be above pour point while also reducing the viscosity thus increasing the flow assurance in the well and flow line. In this paper, the type of the heater that will be installed in the flow line of LDI-16 is clamp heater. The selection of the well that suits to be chosen to install clamp heater is a low water cut well with water cut less than 50%.

The principal work of this clamp heater is shown in Figure 7.

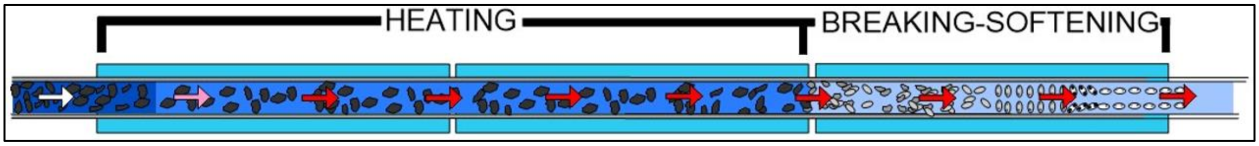

Figure 7: Principal work of clamp heater

- The working principle of this clamp heater is heating, breaking, and softening to the oil in the flow line with the purpose to increase the temperature and reduce viscosity to enhance the flow assurance in the flow line.
- The heating process is using induction heating. Electromagnetic wave on the flow line causing to Eddy Currents concentration which leads to heating effect with pole's polarisation on the fluid.
- Breaking is using high frequency acoustic vibration method. This will make uniformity and stretch the fluid molecule that leads to viscosity reduction.
- Softening is using electromagnetic complex modulated frequency pulse with the purpose of interfering the forming of solids by fluid polarisation. This mainly effect to the drag force reduction of fluid to the flow line.

3 Result and Discussion

3.1 Technical Result

3.1.1 Backflow Method

The illustration of the flow model after activating backflow is shown in Figure 8. This method was using a gaso pump (piston pump) to pump water from the gathering station to the water line then connect to the test line and then returning back to the production line thru the backflow connection in LDI-16. The pumped water is divided to the backflow connection and for water injection well. Therefore, choke adjustment was needed on the water delivery to the backflow so the temperature can be maintained above pour point.

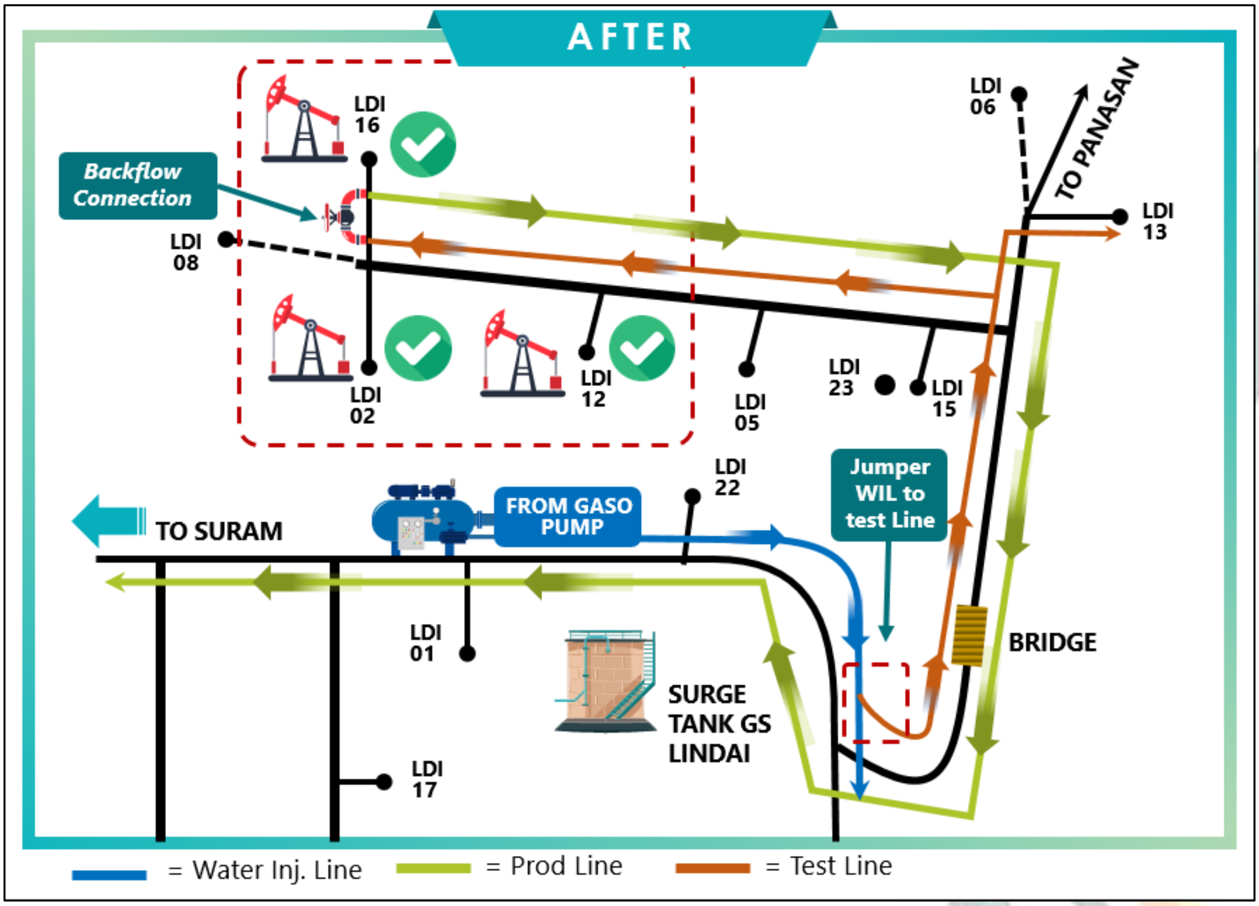

Figure 8: After backflow activation

The piston pump specification is:

- Pump capacity : 5829 BWPD; 4080 BWPD in 70% efficiency
- Piston size : 5 inch
- Liner size : 5 inch
- Maximum working pressure : 667 psi

The flow line specification from the piston pump to the backflow connection is:

- Size : 4 inch
- Material : Carbon steel
- Schedule : 40
- Distance : 9384 ft

Prior to activating backflow, simulation was performed using PIPESIM software simulation to know the temperature drop along the flow line so that the fluid temperature can be maintained above the pour point.

From the simulation, the temperature drop from the piston pump to the backflow connection is depicted in Figure 9.

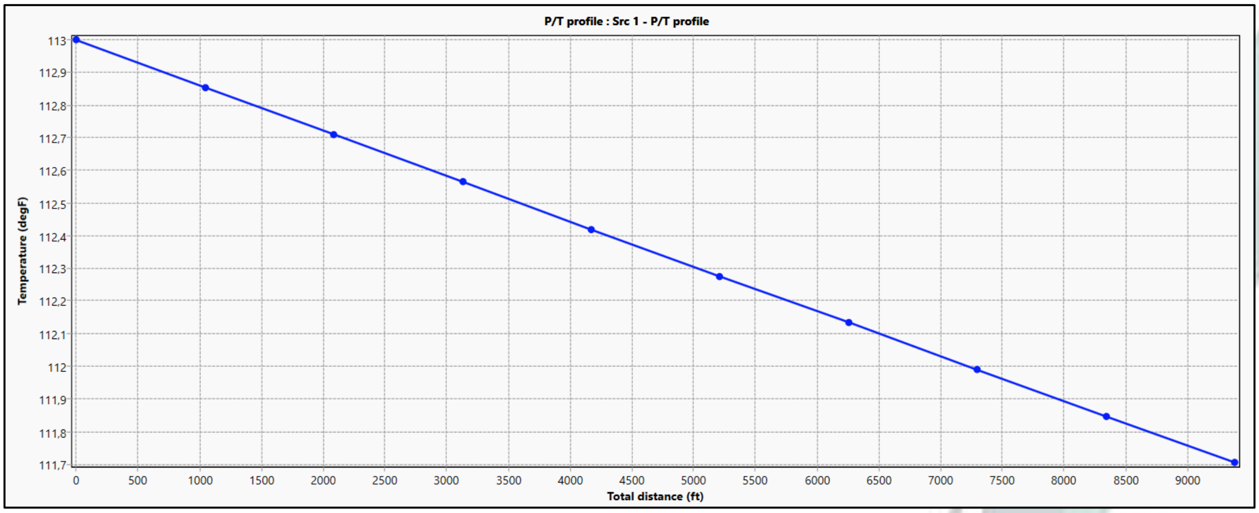

Figure 9: Temperature drop from gathering station to backflow connection

After the water from the gaso pump in the gathering station flowed thru the water line and test line from the piston pump to the backflow connection, the temperature dropped from 113°F to 111,7°F. Then the water was mixed with the fluid from LDI-16. After the dilution, the temperature was checked and it was dropped to 109°F. Simulation was performed again to see the temperature drop from the backflow connection to the gathering station. The result of the temperature drop is shown in

Figure *10*

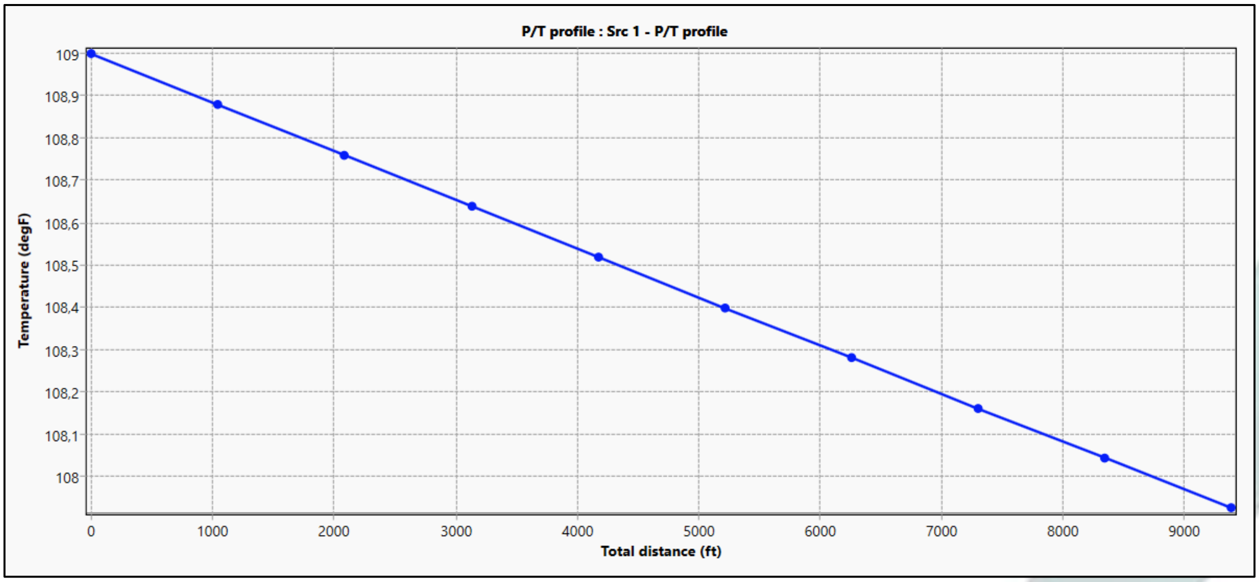

Figure 10: Temperature drop from backflow connection back to gathering station

From the simulation, the temperature from the backflow connection to the gathering station dropped from 109°F to 108°F. By this simulation, the temperature could be maintained above the pour point which is 97°F.

After that, field test was performed to see the execution of backflow method as depicted in Figure 8. The result of backflow method execution was that the three wells were not found shut off anymore.

3.1.2 PPD Chemical Injection

The pour point test was performed by heating the crude oil in the laboratory until the temperature reached 176°F then when it reduced until 118°F PPD chemical was injected with various dosage, then perform agitation until both fluid are mixed. After that, the decrease in temperature was monitored until the pour point value was found, which was until the crude oil sample could not flow anymore when the tube was facing down in 45° angle.

The result of the pour point test is shown in Table 4 below.

Table 4: PPD sensitivity test

No	Chemical	Dosage (ppm)	Pour Point (°F)

1	Blank	-	97
2	PPD	1000	93
3		2000	91
4		3000	91
5		4000	91
6		5000	90
7		6000	88
8		7000	88
9		8000	86
10		9000	86
11		10000	86

From this table, adding PPD with 8000 ppm dosage could reduce the pour point of crude oil in LDI-16 from 97°F to 86°F which was safe for the flow process so the oil will not be congealed anymore.

Additional pump was needed to inject PPD that will be installed in the wing line LDI-16.

The specification of the pump is:

- Pump capacity : 1932 BFPD; 1352 BFPD in 70% efficiency
- Plunger size : 1/2 inch
- Maximum working pressure : 600 psi

3.1.3 Heater Application

Clamp heater has been used in PHE Siak to increase the fluid temperature to be above pour point, hence reducing the viscosity and increasing the flow assurance on the production flow line system.

This clamp heater has been used on the flow line with specification as follows:
- Size : 4 inch
- Material : Carbon steel
- Schedule : 40

Electrical requirement:
- Voltage : 5-10 kVa

The installation of the clamp heater can be seen in Figure 11:

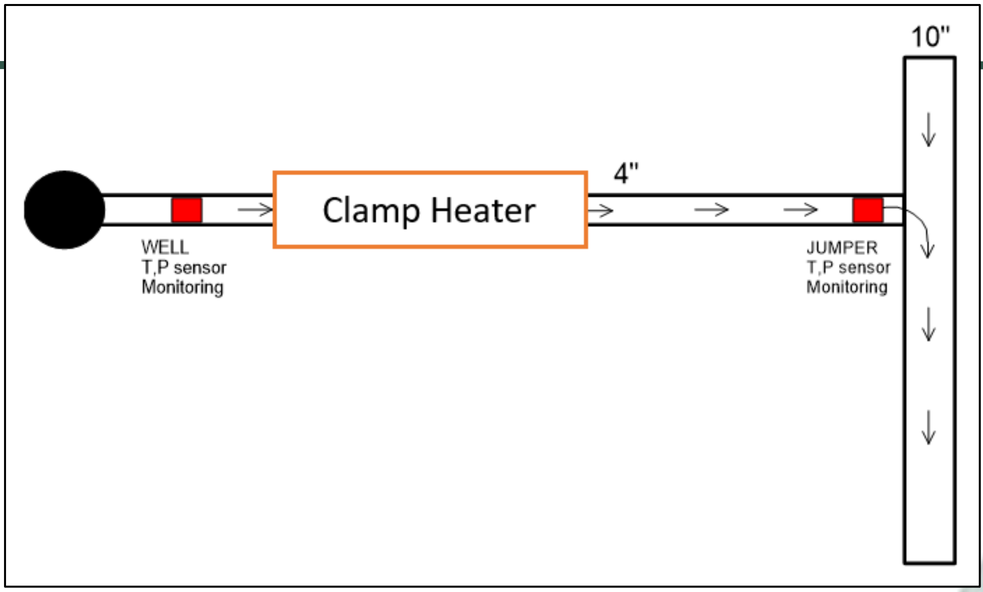

Figure 11: Clamp heater installation

The result of the observation is shown in Figure 12:

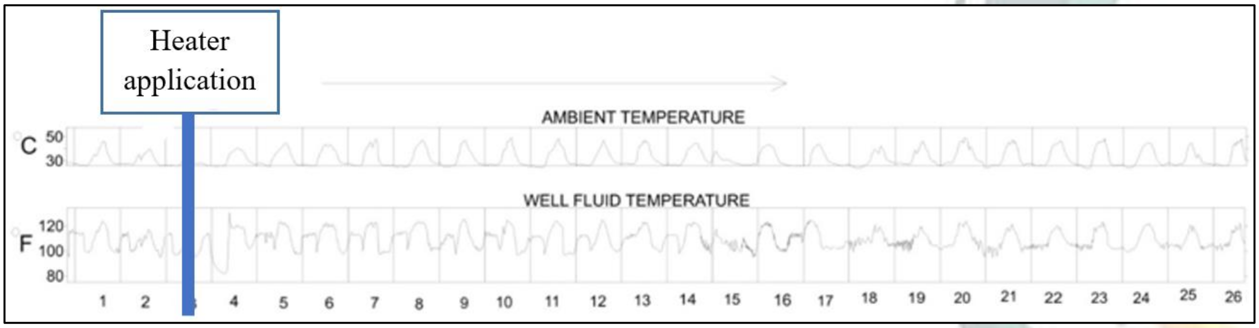

Figure 12: Observation of clamp heater

From this data, the well flow line temperature increased from average of 105°F to 115°F so the flow assurance could be maintained to be above the pour point. By maintaining the temperature of the flow line to be above pour point with heater application, the three wells can keep producing and eliminate congealing problem.

3.2 Economic Evaluation

The economic evaluation is based on the need to purchase any additional equipment, installation cost, electrical cost, and other necessary material. The timeline of evaluation is one year activation of each method.

- Backflow method

Item	Cost	
Material for jumper water injection line to test line and backflow connection	1.759	USD
Installation	300	USD
Total	**2.059**	**USD**

- PPD Injection

Item	Cost	
PPD Material	119.400	USD
Electrical cost for pump	5.472	USD
Chemical pump	2.399	USD
Total	**127.271**	**USD**

- Heater application

Item	Cost	
Rent	113.880	USD
Material	4.264	USD
Installation	1.093	USD
Electrical	285.662	USD
Total	**404.899**	**USD**

The graphical result of economic evaluation is captured in Figure 13:

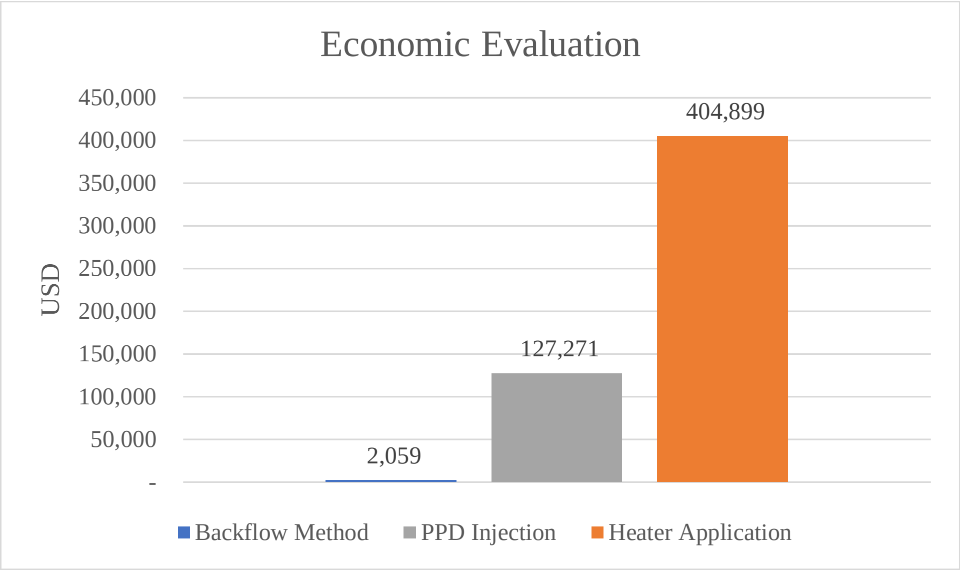

Figure 13: Application cost for each method

From the figure, backflow method is the most efficient method based on application cost to be implemented to overcome congealing in LDI-16, LDI-12, and LDI-02.

4 Conclusion

Based on the technical and economical aspect, backflow method is selected as the most efficient and reliable option to tackle congealing problem in LDI-16 with overall cost for 2,059 USD.

The benefit of using backflow method are:

- Minor modification on the production flow line.
- Only one time installation and does not need routine additional cost such as purchasing chemical or rental cost for additional equipment.
- Do not need additional contract to activate the method.
- Minimal supervision from the operation crew.

Things that needs to be considered in backflow method:

- Water rate adjustment from the gathering station because the water from the gaso pump is divided for backflow and water injection.
- Electricity back up because backflow method relies on pump availability. If the pump goes off then backflow method is inactive

References

[1] Slater, G and Davis, A. 1986. Pipeline Transportation of High Pour Point New Zealand Crude Using Pour Point Depressants. Paper SPE 15656. Presented at the 61st Annual Technical Conference and Exhibition of the Society of Petroleum Engineers held in New Orleans, LA October 5-8, 1986

[2] Cardoso C, Alves I, Ribeiro G. 2003. Management of Flow Assurance Constraints. Paper OTC-15222. Presented at Offshore Technology Conference held in Houston, Texas, USA May 5-8. 2003

[3] Kulkami, M and K, Iyer. 2005. Effects of Pour-Point Depressants on Indian Crude Oils. Paper SPE-95976. Presented at SPE Annual Technical Conference and Exhibition held in Dallas, Texas, U.S.A October 9-12, 2005.