Coiled Tubing Asphaltene Inhibitor Squeeze Program Evaluation for Production Optimization of High Gas Oil Ratio Wells: Case Study in HPS Field

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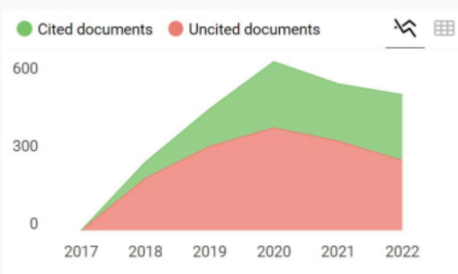

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Coiled Tubing Asphaltene Inhibitor Squeeze Program Evaluation for Production Optimization of High Gas Oil Ratio Wells: Case Study in HPS Field

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ABSTRACT

Asphaltene deposition in a reservoir or a production tubing is a formation damage issue that could occur at the primary recovery of the oil reservoir. The problem leads to a decline in oil production, which also occurs in high gas oil ratio (GOR) wells H-01, H-02, and H-03 of the HPS Field. An advanced coiled tubing asphaltene inhibitor (AI) squeeze program was designed to solve the problem. This paper is focused on evaluating the success of the AI program in delaying scale deposition and increasing oil production. The methodology of this paper begins with data preparation on production performance data, well data, reservoir fluid data, and the AI program data. The remaining reserve evaluation is done to make sure the AI program will provide an optimal result in the gain production. The asphaltene problem identification was carried out by evaluating the production performance and the fluid sample analysis of the gauge cutter slickline. The evaluation of the success of the asphaltene inhibitor program is reviewed from two aspects: technical (asphaltene deposition removal) and production (increasing oil production). The main results shows that the AI program in wells H-01, H-02, and H-03 of the HPS Field has successfully removed asphaltene deposition and increased the oil production with an average 72.02% improvement on decline rate and the average 5.09 on oil rate fold of increase (FOI).

1. INTRODUCTION

Asphaltene deposition in reservoir rocks is very difficult to overcome. When precipitated, asphaltene can become trapped in rock pores, plugging porosity, and reducing reservoir permeability. Asphaltene deposition can also occur in the wellbore, particularly in oil wells with high gas production. The mixing of gas with oil changes the fluid composition in the wellbore and produces deposits when the pressure reaches bubble point pressure. The rate of asphaltene deposition depends on fluid composition, particle size, fluid viscosity, and shear rate [1- 5]. Although difficult to overcome, several studies [1- 7] have suggested that asphaltene deposition can be returned to the liquid phase if the shear rate of asphaltene is increased beyond the shear rate before asphaltene was deposited, adsorbed, and trapped in the reservoir rock.

The reservoir fluid characteristics of the HPS field are typical of black oil characteristics. The bubble point pressure value at a reservoir temperature of 225 ^{0}F is 1,320 Psia. The value of gas dissolved in oil is 365 SCF/STB with an oil-specific gravity of 40.4 ^{0}API. The wax and asphaltene content in the crude oil of the HPS field is an indication that there is a possibility of asphaltene deposition problems forming [8].

Wells H-01, H-02, and H-03 are oil wells located in the HPS Field. The wells were produced in a natural flow with high gas production. The identification of the production problem was carried out after the oil production rate had decreased. Formation fluid analysis in the laboratory revealed that there were organic and inorganic material deposits contained in the production fluid. The material deposition was a strong indication that there was an asphaltene deposition problem in wells H-01, H-02, and H-03. Therefore, an Asphaltene Inhibitor (AI) program was designed to overcome the asphaltene deposition problem and increase the oil production in wells H-01, H-02, and H-03.

Asphaltene inhibitor squeeze operation in the HPS Field were conducted to overcome and prevent the asphaltene deposition around the wellbore that could lead to a decrease in production rate. The squeeze operation is performed with advanced coiled tubing in three stages: pre-flush, main treatment, and post-flush. With proper design and monitoring, the asphaltene inhibitor program is expected to overcome the asphaltene deposition problem and increase the oil production rate in wells H-01, H-02, and H-03 of HPS Field. This paper shows how the Asphaltene Inhibitor (AI) program is performed and how to evaluate the success ratio of the program.

2. LITERATURE REVIEW

2.1 Production Problem

Asphaltene deposition in reservoir rocks is very difficult to clean. If it settles, asphaltene can become trapped in rock pores, where asphaltene particles precipitate and clog the porous media and reduce rock permeability. However, hypothetically, asphaltene deposits can be returned to the liquid phase if the shear rate is high enough before the asphaltene is deposited, adsorbed, and trapped in rock pores. [1] carried out several multi-rate tests and pressure transient analyses to understand the behavior of asphaltene deposits both around the drill hole and in areas quite far from the drill hole. This research concluded that the production rate is a significant factor in the asphaltene formation mechanism. Production rates need to be maintained as high as possible to prevent the formation of asphaltene deposits in the wellbore. The accumulation of asphaltene in porous media can be considered as an issue of formation damage, which can occur during the production process which can have an impact on reducing the oil production rate. [9] discuss the modeling of asphaltene deposits in porous media, and its effect on lowering permeability values, as well as the amount and influence of asphaltene deposits on production rates.

Wells with a history of organic scale deposition can be produced economically if an appropriate identification, testing, and chemical application program is implemented. With proper stimulation, organic scale deposits can be removed, allowing oil to flow into the wellbore. [6] also stated that it was more economical to remove sediment that was blocking the production line compared to opening a new production line through hydraulic fracturing activities. There are two different types of organic scale: paraffin and asphaltene. A rapid decline in production is often caused by the presence of organic deposits both in the wellbore and in the formation. Paraffin deposits can be caused by the heating process so that gas

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is released from the oil. Asphaltene deposits can be caused by acidizing activities. Identifying the type of deposit is a very crucial first step. A specific chemical injection program is needed to overcome the problem of scale deposits efficiently and economically.

Furthermore, the sour reservoir conditions result in various production problems, such as scale deposits, corrosion, and erosion of production equipment. These conditions make well-monitoring activities very important, and workover and well-intervention activities become unconventional activities with more significant risks. The research results of [10] recommend several things to avoid unwanted incidents, which include dealing with iron sulfide deposits, avoiding using acid solutions, descaling treatment in sour reservoir conditions must be carried out in balanced conditions to reduce the release of H2S gas; the selection of corrosion inhibitors and scavengers must be adjusted to the wellbore conditions; check tubing and analyze fluid samples during production activities to find indications of the need to remove iron sulfide deposits; The recommended fluids for removing iron sulfide deposits are water and diesel, especially for reservoirs with high H2S content.

2.2 Asphaltene Inhibitor

Asphaltene is a problem of concern in the oil and gas industry because the effects of asphaltene deposition can cause issues for production, storage, transportation, and even the refinery process. [5] explained a non-ionic surfactant that was developed to prevent asphaltene deposition in crude oil. Surfactants with a low concentration of 25 ppm can keep asphaltene dispersed close to 100%. A group consisting of 5 types of surfactants was developed to be soluble, non-flammable, and not to affect reservoir fluid performance. Asphaltene inhibitor performance was tested according to the procedures described in ASTM D7061-06. With a concentration of 200 ppm, the five surfactants prevented asphaltene deposition. With a concentration of 100 ppm or below, polymer type E is the most efficient and consistently high-performance asphaltene inhibitor.

To provide an understanding of the benefits of asphaltene inhibitor laboratory tests is required to guide or give an overview of inhibitor performance in the field [4]. There are two methods used to compare the performance of asphaltene inhibitors: (1) dead-oil analytical centrifuge and (2) high-pressure live-fluid test. The centrifuge analytical method was developed as a simple laboratory test with conditions close to field conditions. The high-pressure test is carried out with a Solids Detection System (SDS) apparatus, designed to measure asphaltene pressure and the amount of asphaltene deposits. [4] found that in their research, the centrifuge method could accurately and consistently predict inhibitor performance in the field. However, predicting inhibitor performance in the field on a laboratory scale will always have a relatively high level of uncertainty.

Asphaltene inhibitors (AI) are commonly used to mitigate asphaltene deposition issues. AI is believed to change asphaltene formation behavior, including dispersion, aging (deposition formation time), electrostatic interactions, and other parameters, influencing the asphaltene deposition rate. [3] show AI performance in various methods for identifying occurring mechanisms. Various AI performance profiles using multiple methods reveal the characteristics of the two AI chemicals and the asphaltene deposition behavior. Traditional Turbiscan tests show that AI-1 and AI-2 operate in high heptane ratios. The modified Turbiscan test shows that AI-1 can delay the growth of asphaltene particles up to 70-80% heptane ratio, but this does not apply to AI-2. The Indirect method shows that AI-1 causes asphaltene deposits to be more aggregated than dispersed. In contrast, AI-2 helps disperse asphaltene deposits. Both AIs change the growth of asphaltene deposit particles kinetically but in different stages.

2.3 Coiled Tubing

Increasing water production in offshore wells can cause many problems for oil and gas operators. Problems that can occur include decreased oil production rates, scale formation, problems handling production water, and corrosion of production equipment. Workover work with coiled tubing for water shut-off activities offers a more economical solution compared to carrying out well completion with an offshore rig. [11] explain the application of resin squeeze to mitigate excess water production in offshore oil wells in the Gulf of Mexico. Workover activities using resin squeeze through coiled tubing can close non-productive zones and increase oil production with the same tubing flow pressure before the workover is carried out.

The innovative perforation technique used for this case, namely by using electric-line-enabled coiled tubing, where the depth can be monitored and controlled precisely in combination with an advanced gun development system. The technique used is a combination of detonation shock-resistant subsurface equipment; two safety emergency disconnect tools; software to predict and evaluate shock loads and dynamic underbalance; pressure and H2S gauges; rounded scallop guns; and high-tensile coiled tubing. This advanced coiled tubing technology was successfully applied to 10 wells in the Caspian basin and succeeded in providing efficient, economical, and safe results [12].

The technology that helps the success of advanced horizontal drilling and multi-stage hydraulic fracturing in producing shale oil and shale gas economically in Vaca Muerta. One of the technologies in question is custom-engineered coiled tubing, which is designed to work in several complex well intervention techniques to provide efficient and economical results in shale reservoir development. Coiled tubing is able to anticipate extreme well deviations so that it can reach horizontal sections of production wells. Several experiments were carried out using spiral tubing technology so that some information was obtained, including we can increase the ability of coiled tubing to reach the wellbore by designing oval tubing walls for specific applications; understanding the friction force relationship that occurs is very important to reduce the vibration of tools using certain injection fluids; the need to improve job accuracy through pre-job simulation; and we can increase the efficiency of the cleanout operation by increasing the size of the coiled tubing [13].

2.4 Asphaltene Inhibitor Evaluation

Asphaltenes-Analytical Centrifuge Stability Analysis (Asphaltene-ACSA/A-ACSA) as a new method for analyzing asphaltene stability, which is being developed and introduced to the oil and gas industry [14]. This method uses an analytical centrifuge to evaluate the stability of asphaltenes in crude oil. Simultaneously, it is added to a solvent that destabilizes the asphaltene, accompanied by centrifugal force. [14] explained A-ACSA as a method that is simple, fast, and capable of providing accurate results in providing asphaltene stability levels in crude oil. A-ACSA is recommended for use in monitoring programs for the implementation of asphaltene inhibitor injection in the future.

To improve asphaltene risk evaluation using data available in the past and present. Modeling was carried out for reservoirs in offshore fields with natural depletion and gas injection conditions. Models created in 2016 were compared with models made in 2008 to understand changes over time in the risk of asphaltene deposition. Risk factor updates include changes in reservoir conditions/reservoir fluid conditions that have occurred during the 8 years of production. In general, a comparison between the model in 2008 and the model in 2016 shows that changes in fluid composition caused by gas injection are one of the reasons for the differences in modeling results. The 2016 model shows that the risk of asphaltene deposition is higher than the 2008 model [15].

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Asphaltene deposition in oil wells is a phenomenon that affects production rates, project economics, and operational safety. Asphaltene deposition is influenced by the complexity of the behavior and characteristics of the hydrodynamic flow. [16] conducted the study to evaluate and compare the performance of existing asphaltene deposition models and improve theoretical understanding of asphaltene deposition phenomena by creating a more accurate asphaltene deposition prediction model. This study used an experimental database of transport coefficients collected from four literature studies to evaluate fives transport coefficient models. This study reveals that the Kor and Karrat (2016) model is the most accurate, but the model fails to predict the direction of transport of large particles. To investigate the asphaltene deposition flow, the model of Jamialahmadi et al. (2009) analyzed and found that the calculation of deposition flow gave more significant results than actual conditions. [16] made modifications to complement the deficiencies in the previous model and obtained an average error of 6.8% and a standard deviation of 11.4%.

3. METHODOLOGY

The research began with the inventory and quality control of the required data, which included production performance data, well data, reservoir fluid analysis data, and asphaltene inhibitor data. Production performance data consists of oil, water, and gas production rate data; cumulative oil, water, and gas production; pressure data (well bottom hole pressure and tubing head pressure); and water cut data. Well data includes well diagram; well history; well trajectory; and well completion (tubing and perforation). Formation fluid analysis data includes formation water analysis data as one of the problem scale indicators and PVT analysis data. Asphaltene inhibitor (AI) data includes chemical AI data; AI program design data; and the wellsite execution of asphaltene inhibitor program.

The next step is the analysis of production data. Production data analysis includes well potential analysis and production performance analysis. Well potential analysis is conducted to determine the remaining reserves that can be produced in an oil well. If there are no remaining reserves that are potential enough to be produced, then the asphaltene inhibitor program will not provide optimal or economic results. Production performance analysis includes the decline in production performance as an indication of scale (asphaltene) deposition problems in the wellbore. The production analysis will also be used to evaluate the success of the asphaltene inhibitor program. Furthermore, the scale problem identification was carried out by evaluating the production performance, formation water analysis, and asphaltene deposition analysis of the gauge cutter slickline during the production well monitoring process. Decreased production performance, the presence of organic material deposits in the formation water from laboratory analysis, and the presence of asphaltene deposits on the gauge cutter slickline are strong indications that there is an asphaltene deposition problem in the production well.

The asphaltene inhibitor program includes the selection of chemical asphaltene inhibitor; design of asphaltene inhibitor program for pre-flush, main treatment, and post-flush stages with crude oil; calculation of squeeze volume for each stage; implementation of squeeze using advanced coiled tubing; and monitoring gauge cutter slickline and production performance after asphaltene inhibitor program is conducted. The evaluation of the success of the asphaltene inhibitor program is reviewed from two aspects: the success of the AI program in removing asphaltene deposits and the success of the AI program in increasing oil production rates. The evaluation of asphaltene deposits was conducted from the analysis of asphaltene deposits from the slickline cutter gauge during the production well monitoring process. Evaluation of the increase in production rate was carried out by comparing the decline rate and fold of increase in oil production rate before and after the asphaltene inhibitor program was performed. If the decline rate after the asphaltene inhibitor program is smaller than the decline rate before the asphaltene inhibitor program, and if the fold of increase in oil production rate is greater than 1.2, it can be concluded that the asphaltene inhibitor program has successfully increased the oil production rate. A detailed flowchart of the research methodology can be seen in Figure 1.

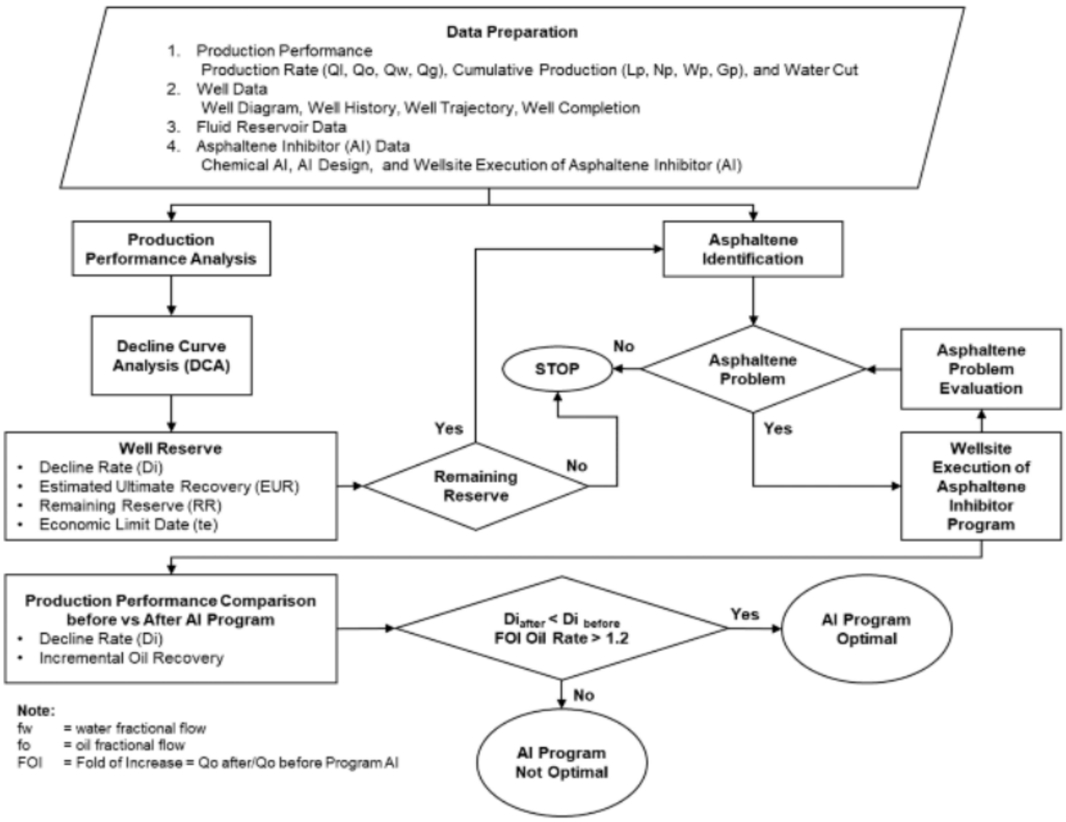

Figure 1. Methodology of Asphaltene Inhibitor Squeeze Program Evaluation

4. RESULTS AND DISCUSSION

4.1 Decline Curve Analysis (DCA) for Well's Reserve Evaluation

The first step in every production optimization program of a well/reservoir/field is to determine the remaining reserve. The remaining reserve determination of H-01, H-02, and H-03 were determined using decline curve analysis [17], [18]. The decline type used in this study is exponential decline (b=0).

The decline curve analysis results of H-01 shown in Figure 2. The decline rate of H-01 is 14.89% per year with 9.39 MMSTB of Estimated Ultimate Recovery (EUR). The cumulative oil production of H-01 is 8.35 MMSTB. Therefore, there is 1.04 MMSTB of remaining reserve in H-01. The decline curve analysis of H-02 shown in Figure 3. The decline rate of H-02 is 17.88% per year with 4.26 MMSTB of EUR. The cumulative oil production of H-02 is 2.56 MMSTB. Hence, the remaining reserve of H-02 is 1.70 MMSTB. The decline curve analysis of H-03 shown in Figure 4. The decline rate of H-03 is 16.73% per year with 3.34 MMSTB of Estimated Ultimate Recovery (EUR). The cumulative oil production of H-03 is 1.04 MMSTB. Therefore, there is 2.30 MMSTB of remaining reserve in H-03.

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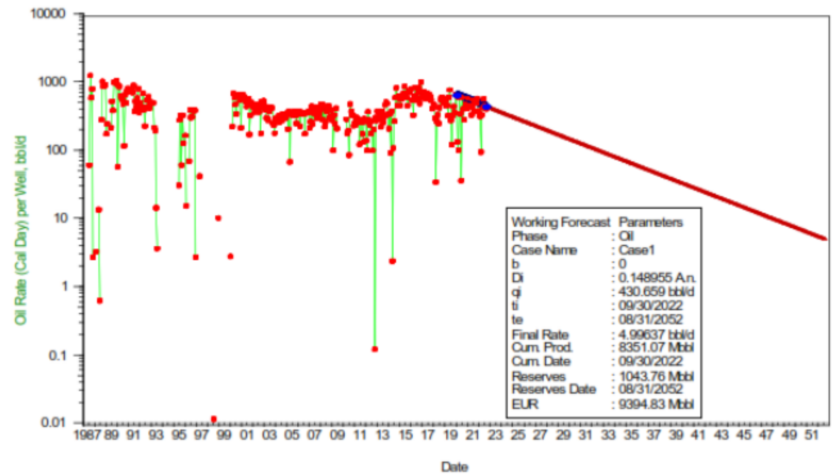

Figure 2. Decline Curve Analysis of H-01

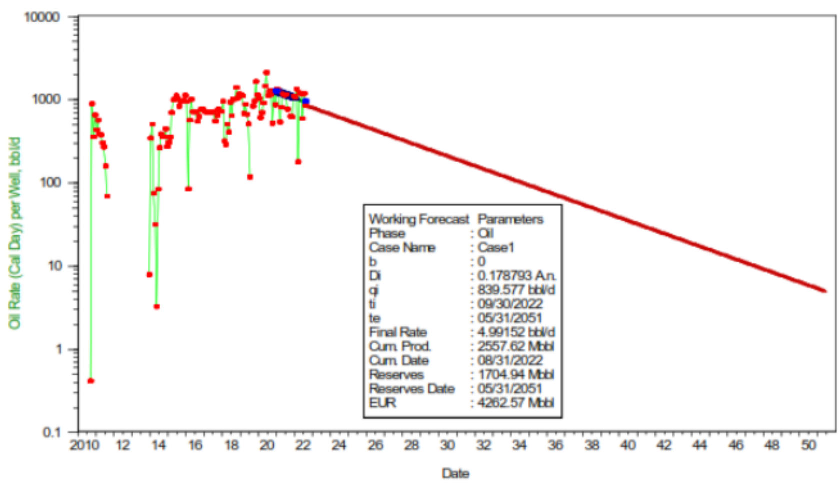

Figure 3. Decline Curve Analysis of H-02

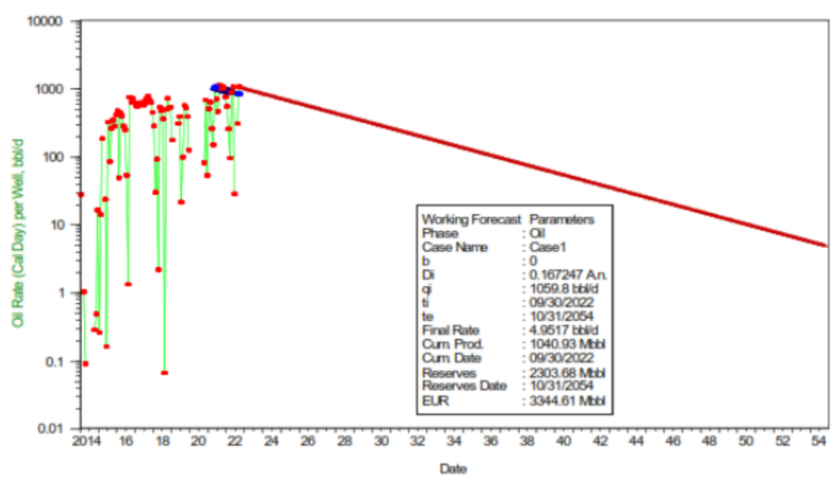

Figure 4. Decline Curve Analysis of H-03

4.2 Asphaltene Problem Identification

4.2.1 Asphaltene Problem Identification based on Well History Data

There are several indicators of asphaltene deposition problems based on production data and well history data [19- 22]. The initial indicator of an asphaltene deposition problem was the significant decline in production rates at wells H-01, H-02, and H-03. Slickline was then run into the wellbore through the production tubing to identify the cause of the decline in production rate. Scale deposits were found on the cutter gauge of the slickline in wells H-01, H-02, and H-03. Based on the decrease in production rate and the discovery of scale deposits on the slickline cutter gauge, it can be concluded that there are indications of asphaltene deposition problems in the production tubing in wells H-01, H-02, and H-03. Figure 5 shows an indication of a scale deposition problem in the production tubing based on sampling from the slickline. Further reservoir fluid analysis needs to be conducted to validate these indications.

Figure 5. Scale Deposition on Cutter Gauge Slickline at HPS Field

4.2.2 Identification of Asphaltene Problem based on Reservoir Fluid Analysis Data

Reservoir fluid analysis was conducted on scale sediment samples obtained from well intervention with slickline. Table 1 shows the results of the laboratory analysis of scale samples from well H-01, H-02 and H-03. In well H-01 sampling and analysis were conducted in February 2022. From the analysis, it is known that 92.58% of the composition of scale deposits is organic material. In well H-02 sampling and analysis were conducted in December 2021. The 94.60% organic material in the composition of scale deposits is a justification that the scale deposits in well H-02 are asphaltene deposits. While in well H-03 sampling and analysis were conducted in February 2022, and from the analysis it is known that 93.10% of the composition of scale deposits is organic material. Hence, it is concluded that the scale deposits in wells H-01, H-02 and H-03 are asphaltene deposits.

Table 1. Results of the laboratory analysis of scale samples from wells H-01, H-02 and H-03

Well	Date	Chemical Analysis (% Weight)	
		Organic Matter	Inorganic Matter
H-01	February 8, 2022	92.58	7.41
H-02	November 24, 2021	94.6	5.4
H-03	February 17, 2022	93.1	6.9

4.3 Asphaltene Inhibitor Program

4.3.1 Design of Asphaltene Inhibitor Squeeze Program

The asphaltene inhibitor program design includes the chemical selection and the required injection volume. The selection of chemical asphaltene inhibitors is based on laboratory tests of chemical compatibility with crude oil in the HPS field. The determination of injection volume is based on the squeeze target and wellbore capacity (volume). Table 2 shows the design of the H-01 well asphaltene inhibitor squeeze program. The chemical used in the pre-flush activity to clean the well and the area around the well from asphaltene deposits was a mixture of 80% Naptha (69 bbl) and 20% Dispersant PAO27072 (17 bbl). The total main treatment volume was 226 bbl consisting of 50% Naptha (113 bbl) and 50% Inhibitor PAO82427 (113 bbl). The total tubing capacity of well H-01 is 128 bbl. Based on the service company's safety factor (minimum treatment volume is 1.5 times the well capacity), the main treatment volume in the H-01 well squeeze asphaltene inhibitor activity is 1.76 times the tubing capacity. A total of 65 bbl of crude oil was then injected as a post-flush to keep the asphaltene inhibitor around the well but not too deep into the reservoir so that it can be produced again.

Table 2. Asphaltene Inhibitor Squeeze Program Design of H-01

Stage	Naphtha	Dispersant (PAO27072)	Inhibitor (PAO82427)	Crude Oil	Total Treatment Volume	Chemical
	bbl	bbl	bbl	bbl	bbl	
Pre-flush	69	17			86	80% Naphtha + 20% PAO72
Main Treatment	113		113		226	50% Naphtha + 50% PAO82427
Post flush				65	65	Dead Crude Oil
Total	**182**	**17**	**113**	**65**	**377**	

The chemical used in the pre-flush activity to clean the well and the area around the H-02 well from asphaltene deposits was a mixture of 80% Naptha (249 bbl) and 20% Dispersant PAO27072 (62 bbl). At well H-02, three main treatment stages were conducted. In the first stage, the total main treatment volume was 378 bbl consisting of 70% Naptha (265 bbl) and 30% Inhibitor PAO82427 (113 bbl). In the second stage, the total main treatment volume is 189 bbl consisting of 70% Naptha (132 bbl) and 30% Inhibitor PAO82427 (57 bbl). In the third stage, the total main treatment volume is 189 bbl consisting of 70% Naptha (132 bbl) and 30% Inhibitor PAO82427 (57 bbl). The total tubing capacity of well H-01 is 82 bbl and the open hole section capacity is 211 bbl (total capacity 293 bbl). Based on the service company's safety factor (the minimum treatment volume is 1.5 times the well capacity), the main treatment volume for the H-02 well squeeze asphaltene inhibitor activity (first stage) is 2.58 times the tubing and open hole section capacity. A total of 1,131 bbl of crude oil was then injected post-flush to keep the asphaltene inhibitor around the well but not too deep into the reservoir so that it can be produced again. The design of the H-02 well asphaltene inhibitor squeeze program can be seen in Table 3.

Table 3. Asphaltene Inhibitor Squeeze Program Design of H-02

Stage	Naphtha	Dispersant (PAO27072)	Inhibitor (PAO82427)	Crude Oil	Total Treatment Volume	Chemical
	bbl	bbl	bbl	bbl	bbl	
Pre-flush	249	62			311	80% Naphtha + 20% PAO72
Main Treatment Stage 1	265		113		378	70% Naphtha + 30% PAO82427

Main Treatment Stage 2	132		57		189	70% Naphtha + 30% PAO82427
Main Treatment Stage 3	132		57		189	70% Naphtha + 30% PAO82427
Post flush				1,131	1,131	Dead Crude Oil
Total	**778**	**62**	**227**	**1,131**	**2,198**	

Table 4 shows the design of the H-03 well asphaltene inhibitor squeeze program. The chemical used in the pre-flush activity to clean the well and the area around the well from asphaltene deposits was a mixture of 80% Naptha (114 bbl) and 20% Dispersant PAO27072 (36 bbl). The total main treatment volume was 540 bbl consisting of 70% Naptha (378 bbl) and 30% Inhibitor PAO82427 (162 bbl). The total tubing capacity of well H-03 is 83 bbl and the open hole section capacity is 104 bbl (total capacity 187 bbl). Based on the service company's safety factor (the minimum treatment volume is 1.5 times the well capacity), the main treatment volume in the squeeze asphaltene inhibitor activity of well H-01 is 2.89 times the tubing and open hole section capacity. A total of 1,607 bbl of crude oil was then injected post-flush to keep the asphaltene inhibitor around the well but not too deep into the reservoir so that it can be produced again.

Table 4. Asphaltene Inhibitor Squeeze Program Design of H-03

Stage	Naphtha	Dispersant (PAO27072)	Inhibitor (PAO82427)	Crude Oil	Total Treatment Volume	Chemical
	bbl	bbl	bbl	bbl	bbl	
Pre-flush	144	36			180	80% Naphtha + 20% PAO72
Main Treatment	378		162		540	70% Naphtha + 30% PAO82427
Post flush				1,607	1,607	Dead Crude Oil
Total	**522**	**36**	**162**	**1,607**	**2,327**	

4.3.2 Wellsite Execution of Asphaltene Inhibitor Squeeze Program

The implementation of the asphaltene inhibitor program consists of five main stages, namely the well preparation stage, pre-flush preparation, pre-flush, main treatment and post-flush preparation, and main treatment and post-flush. Well preparation stage begins with taking pressure measurements both in the tubing and in the annulus. Mobilization of coiled tubing units and stimulation facilities was then carried out to the production optimization target wells. The injection fluids required for the asphaltene inhibitor program, namely formation water, fresh water, crude oil (post-flush), and chemical asphaltene inhibitors (Naptha, Dispersant, and Inhibitor PAO82427) were also prepared. Rig up of the kill line was then carried out and a pressure test was carried out on the entire circulation circuit up to a pressure of 5,000 psig before proceeding to the pre- flush preparation stage. Wellsite execution of asphaltene inhibitor squeeze program summary is shows in Figure 6.

Pre-flush and post-flush preparation have relatively the same stages. The preparation begins with a tool box talk (TBT) meeting related to safety in the area of the asphaltene inhibitor squeeze program implementation in accordance with the company's operational safety standards. Rig up the stimulation facility and then connect it to the X-mast tree. Rig up choke manifold for return line and sampling. Rig-up coiled tubing and pressure tests were conducted up to 5,000 psig. Injection fluid was prepared for pre-flush and post-flush activities. Bottom hole assembly (BHA) was installed at the end of the coiled tubing after the coiled tubing connector. A flow rate test was conducted and circulation pressure was recorded to ensure the proper

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functioning of the equipment.

Pre-flush begins by running in hole-coiled tubing with a size of 1.5" to the depth of the production zone while pumping Naptha and Dispersant. When the pre-flush chemical is detected at the surface, the remaining chemical (Naptha and Dispersant) in the wellbore is pushed into the reservoir. The coiled tubing was then removed from the wellbore and the stimulation facility was rigged down. The well is then shut in for 24 hours and then produced for 4 hours to purge the tubing until the oil from the reservoir flows to the surface.

The main treatment began with a run-in hole coiled tubing of 1.5" size to the depth of the production zone. Naptha and PAO82427 inhibitors were pushed into the formation by keeping the squeeze pressure below the formation fracturing pressure. The coiled tubing was then removed from the wellbore and the stimulation facility was rigged down. Crude oil was then injected as post-flush fluid to push the Naptha and PAO82427 Inhibitor deeper into the reservoir. The chemical asphaltene inhibitor was pushed into the reservoir assuming that the post-flush fluid flow was radial. The post-flush volume is considered to ensure that the invasion radius of the chemical asphaltene inhibitor (radially) is not more than 6 ft. This is done so that the chemical asphaltene inhibitor can still be produced to the surface and does not cause formation damage.

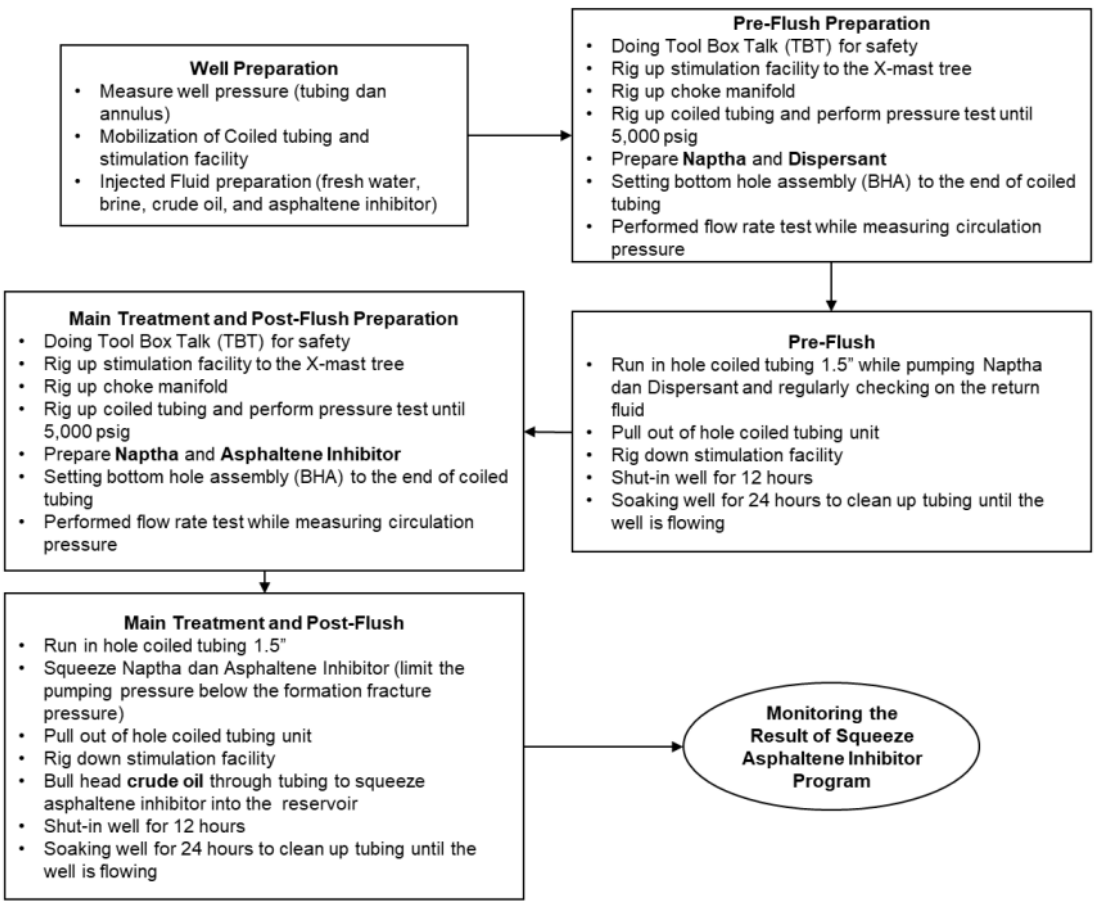

Figure 6. Wellsite Execution of Asphaltene Inhibitor Squeeze Program Summary

4.3.3 Monitoring Program Asphaltene Inhibitor (AI)

Monitoring of the squeeze asphaltene inhibitor program is limited to monitoring of production flow rate, slickline cutter gauge, and sampling of production fluid at the wellhead. Monitoring of the production rate is carried out 14 to 2 times a week. The running of the cutter slickline gauge is carried out once a month. A sampling of production fluid at the wellhead was carried out every 6 hours for the first 3 days after the asphaltene inhibitor program; every 12 hours for the next 4 days; once a day for the next 2 weeks, and once a week. The summary of the asphaltene inhibitor squeeze program monitoring can be seen in Table 5, while the summary of the asphaltene inhibitor squeeze implementation in the HPS field is shows in Figure 7.

Table 5. Asphaltene Inhibitor Squeeze Program Monitoring of HPS Field

Parameter	Frequency
Oil production rate (Well test)	Bi-weekly
Gauge cutters runs	Monthly
Wellhead samples (inhibitor close checks)	Every 6 hours for the first 3 days. Every 12 hours for the following 4 days. Once per day for the next two weeks. Once per week for the remainder of the trial.

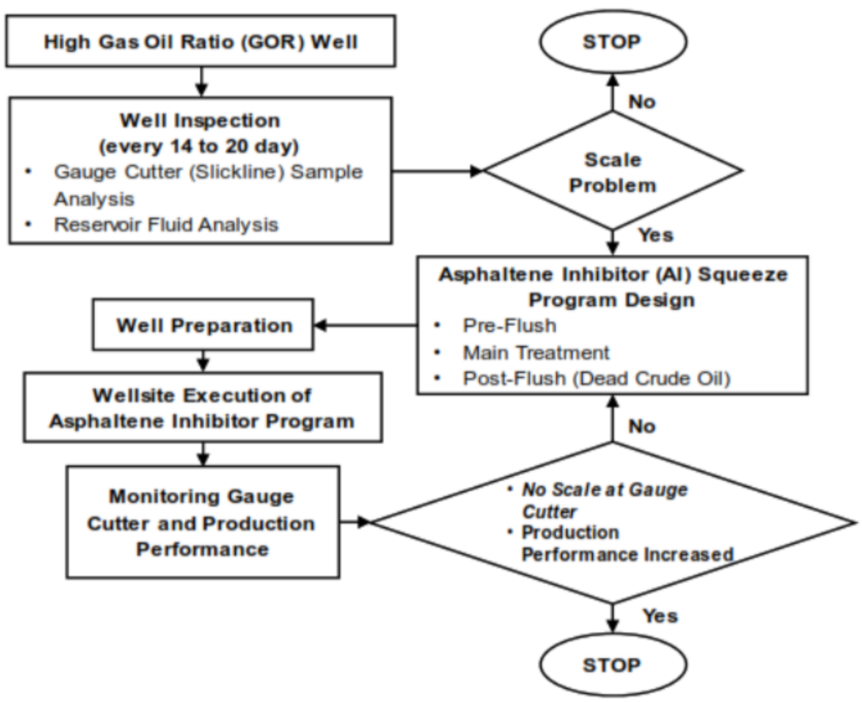

Figure 7. Monitoring Squeeze Asphaltene Inhibitor Summary of HPS Field

4.4 Asphaltene Inhibitor (AI) Evaluation

The successful evaluation of the asphaltene inhibitor squeeze program is divided into two parts: the successful evaluation of the asphaltene inhibitor squeeze program based on operational aspects and the successful evaluation of the asphaltene inhibitor squeeze program based on production aspects. The successful evaluation of the asphaltene inhibitor squeeze program, based on operational aspects focusing on asphaltene content, is in good production after the asphaltene inhibitor squeeze program has been carried

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out. The successful evaluation of the asphaltene inhibitor squeeze program based on the production aspects focuses on increasing the level of oil production after the asphaltene inhibitor program has been carried out.

4.4.1 Evaluation based on Operational Aspects

The successful evaluation of the asphaltene inhibitor squeeze program based on operational aspects relies on monitoring the results of the asphaltene inhibitor squeeze program in production wells. An indicator of the success of the asphaltene inhibitor squeeze program is the reduction in the asphaltene content in the production wells [8], [10]. Figure 8 showed a reduction in the asphaltene content in the HPS Field crude oil sample after treatment with Naptha.

Figure 8 displays the crude oil samples tested on a 10 nm filter membrane after treatment with Naptha. The third membrane shows the same crude oil content. After treatment with Naptha, there were differences in colour degradation between the initial conditions of the crude oil, and after 48 hours and 96 hours, the samples were taken. The colour difference indicates that the treatment with Naptha has succeeded in dispersing the asphaltene and preventing the formation of asphaltene deposits in the production wells.

Figure 8. Evaluation of Asphaltene Content in HPS Field Oil Samples after the Squeeze Asphaltene Inhibitor Program

4.4.2 Evaluation based on Production Aspects

a. Decline Rate Analysis

Decline rate (Di) can be one of the variables in evaluating the success of the production optimization program for wells, layers, and fields. A decrease in the decline rate after the wells' treatment indicates that there has been a repair in the production wells, while an increase in the decline rate after treatment indicates that there has been damage to the production wells. Summary of decline rate before and after squeeze asphaltene inhibitor program is shows in Table 6, and Figure 9 through Figure 11, respectively.

Table 6. Summary of Decline Rate Before and After Squeeze Asphaltene Inhibitor Program

Well	Decline Rate, % / year		Difference, %
	Before Treatment	After Treatment	
H-01	22.22	14.89	32.99
H-02	199.43	17.88	91.03
H-03	210	16.72	92.04
Average	**143.88**	**16.50**	**72.02**

Decline rate analysis is performed by comparing the exponential decline rate before the scale removal program is implemented with the exponential decline rate after the scale removal program is implemented as shows in Figure 9 through Figure 11 above. The decline rate of well H-01 before treatment is 22.22% per year. After treatment, the decline rate of well H-01 decreased to 14.89% per year (Figure 9), the decline rate of well H-02 decreased from 199.43% per year to 17.88% per year after treatment (Figure 10), while the decline rate of well H-03 decreased from 210% per year to 16.72% per year after treatment (Figure 11). The decrease in decline rate after treatment shows that production optimization through the asphaltene inhibitor program was successful in wells H-01, H-02, and H-03.

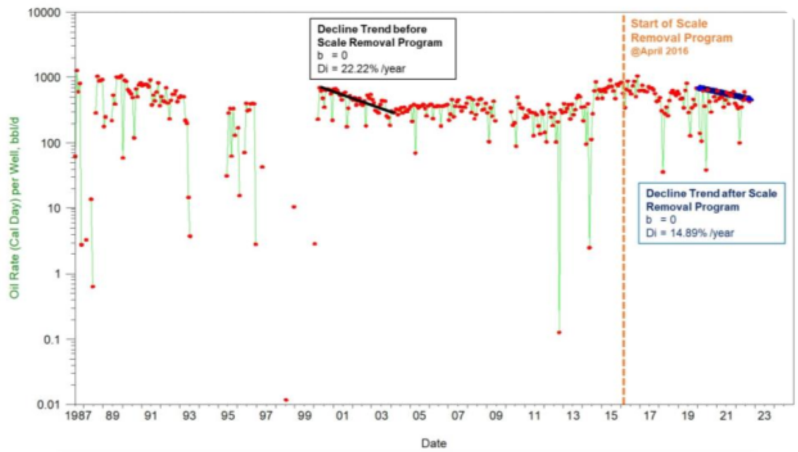

Figure 9. Decline Rate Comparison Before and After Squeeze Asphaltene Inhibitor Program at Well H-01

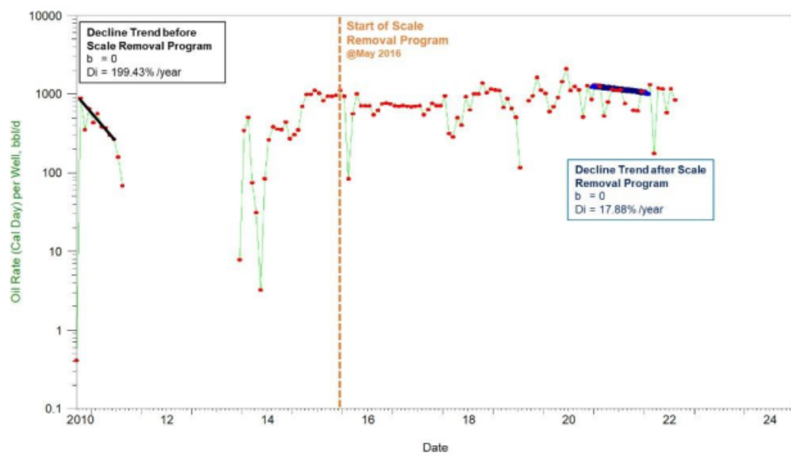

Figure 10. Decline Rate Comparison Before and After Squeeze Asphaltene Inhibitor Program at Well H-02

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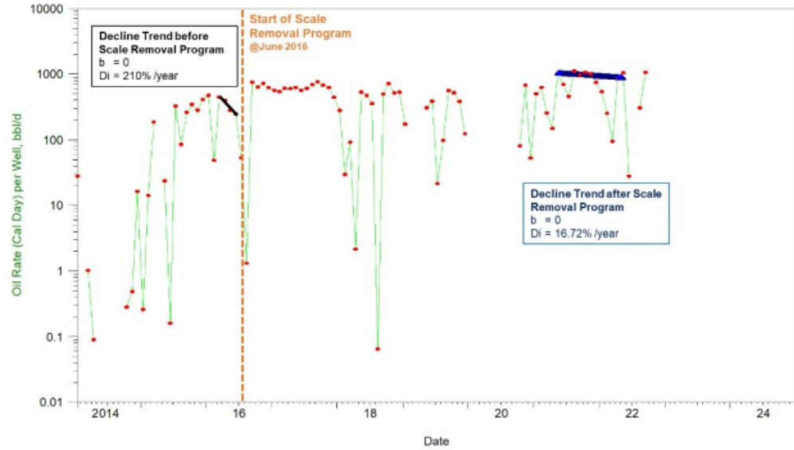

Figure 11. Decline Rate Comparison Before and After Squeeze Asphaltene Inhibitor Program at Well H-03

b. Fold of Increase Analysis of Oil Flow Rate

The fold of increase (FOI) of the oil flow rate is the ratio between the oil flow rate after treatment and the oil flow rate before treatment [23], [24]. The FOI value above one indicates an increase in the oil production rate after treatment, while the FOI value below one indicates a decrease in the oil production rate after treatment. The FOI value is used as a variable to evaluate the success of the asphaltene inhibitor squeeze program in wells H-01, H-02, and H-03 of the HPS Field.

FOI analysis was carried out on wells H-01, H-02, and H-03 after the asphaltene inhibitor program was carried out. The minimum allowable FOI value limit in the HPS Field is 1.2. Table 7 shows a summary of the FOI values from handling the asphaltene deposit problem in wells H-01, H-02, and H-03 with the squeeze asphaltene inhibitor. The range of FOI values for each treatment is 1.67 to 14.17. The FOI value for each treatment is above the minimum allowable FOI value limit in the HPS Field. The average value of FOI is 5.09. This shows that the asphaltene inhibitor squeeze program in wells H-01, H-02, and H-03 was able to increase the average production rate of the wells up to 5 times. The high FOI value indicates that based on the production aspect, the asphaltene inhibitor squeeze program in wells H-01, H-02, and H-03 in the HPS Field was successfully implemented optimally.

Table 7. Fold of Increase (FOI) Oil Flow Rate After Squeeze Asphaltene Inhibitor Program Summary

Well	Date of Treatment	Oil Rate, BOPD		FOI of Oil Rate
		Before Treatment	After Treatment	
H-01	Apr-16	690	1313	1.90
	Mar-20	213	1235	5.80
	May-21	702	1175	1.67
	Feb-22	200	702	3.51
H-02	May-16	559	1001	1.79
	Sep-19	116	824	7.10
	Mar-21	530	1142	2.15
	Nov-21	609	1080	1.77
	Aug-16	53	751	14.17
	Apr-18	91	529	5.81
	Sep-18	357	714	2.00

H-03	Aug-19	174	387	2.22
	Sep-20	81	676	8.35
	Dec-20	52	501	9.63
	Apr-21	148	1034	6.99
	Aug-21	456	1113	2.44
	Mar-22	95	867	9.13
	Average FOI			**5.09**

5. CONCLUDING REMARKS

The asphaltene inhibitor (AI) squeeze program has been successful remove asphaltene deposition and increase the oil production in wells H-01, H-02, and H-03 of HPS field. The main results show that increased the oil production with an average 72.02% improvement on decline rate and the average 5.09 on oil rate fold of increase (FOI). The asphaltene inhibitor squeeze program in wells H-01, H-02, and H-03 was able to increase the average production rate of the wells up to 5 times. The high FOI value indicates that based on the production aspect, the asphaltene inhibitor squeeze program in wells H-01, H-02, and H-03 in the HPS Field was successfully implemented optimally. Since the AI program only delays the asphaltene precipitation in the wellbore, the key stage in the whole program is the monitoring stage. The monitoring of the production well after the AI program will help in assessing when the next AI program will be performed.

6. ACKNOWLEDGMENTS

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