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A Successful Post Completion Sand Control Method Used in Thermal Enhanced Oil Recovery Operations at the Kern River Field in Bakersfield, CA

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Abstract

The Kern River Field is one of the oldest continuous producing oil fields in North America. The field was originally discovered in 1899 and today comprises more than 10,000 active producing wells. The API gravity of oil in this field ranges between 11-13 degrees, and the operator employs thermal enhanced oil recovery methods in the form of continuous and cyclic steam (CS) injection. Rod pumping systems are the most common method of artificial lift utilized in this field. The most prevalent subsurface failure event realized by the operator is a sanded/seized (S/S) pump. More than fifty percent of all subsurface failures are associated with sand production. This paper will outline the use of resin injected during a cyclic steaming event (CS), down the casing annulus or tubing, in order to consolidate sand grains in the formation and reduce the potential for the influx of sand while a well is on production. In 2013 a project team was formed to pilot this sand control method at the Kern River Field. Candidates for this treatment were selected based on the frequency of sanded/seized events and reported wellbore integrity. Through this pilot, the project team was able to extend meantime between failure (MTBF) and achieve incremental oil production. The use of resin injected during a cyclic steaming event (CS) can improve well reliability and enhance well economics of marginal oil producers by providing an alternative to more expensive remedial options.

Introduction

The Kern River Field consists of a series of stacked, shallow, highly permeable, and unconsolidated sands. The oil is contained within the sands and binds the sand grains together. Steam is used to reduce the viscosity and mobilize oil which carries sand into the wellbore. Sanded/seized (S/S) failures account for more than 50% of all subsurface failure events that occur in the Kern River Field. A S/S failure can be defined as a failure that occurs when a significant volume of sand accumulates in the pump and prevents the pump from displacing fluid. Energy added to a reservoir through means of cyclic and continuous steam injection can accelerate the transport of formation fines and disrupt bridging structures at the completion/ reservoir interface which allows for sand grains to be transported more easily into a producing well. This paper will explore the successful field trials of a post completion method of sand control used in the Kern River Field in Bakersfield, CA.

In 2013 a project team was formed to pilot the use of resin injected during a CS event. The project team selected a subset of 16 wells. Candidate selection criteria were established to help improve candidate quality and eliminate wells where wellbore integrity was a concern. The project team focused on wells that experienced higher than average S/S failure rates and wells that had a strong correlation between CS and S/S failures. Wells selected for this treatment are typically uneconomic to continue producing and would require remedial activity or other intervention. A standard operating procedure was developed and execution of this treatment was always carried out by the same crews to ensure consistency in the process.

Candidate Selection

Candidate selection was a critical component in determining the success of this treatment. Key aspects to consider when evaluating candidates are the sanding mechanism and economic viability. A well must have sufficient casing integrity to allow for effective means of sand control. Wells with casing damage in the form of significant casing holes, splits, or ruptures are not candidates for this treatment. Additionally, the presence of economic volumes of hydrocarbon and sufficient reservoir deliverability are required to provide justification for well work.

For purposes of this treatment, two primary sanding mechanisms have been identified:

1. Sand/seize after a cyclic steaming event (C/S)
2. Sand entry contributed from the inflow of reservoir fluids

Sand/seize after C/S is a result of sand bridge disruption. Wells with an established pattern of S/S after steam are candidates for this treatment. Wells treated had historical patterns of one for one and two for one C/S to S/S, with a minimum frequency of three repeated events. Wells without a predictable pattern were not considered candidates for this treatment. Wells of this nature may be considered in the future depending on the amount of down oil represented by the failure.

Wells that experienced sanding events unrelated to stimulation activity contributed significant volumes of sand through the inflow of reservoir fluids. Typically S/S events related to this sanding mechanism were associated with recent recompletions (casing perforation) or existing completions that were ineffective at controlling sand migration. Candidates selected based on this sanding mechanism had three or more sanding events per year and a known/suspected sand entry point. The sand entry point can be deduced through an evaluation of historical fill depths, location of tubing failures, and changes in S/S frequency after a producing interval is added or recompleted. In general, wells that experienced S/S failures based on this sanding mechanism can be treated without specialized isolation tools and by placing the treatment down the casing/tubing annulus. However, specific intervals that have been identified as contributing large amounts of sand may require placement down tubing and the use of packers and bridge plugs to isolate the interval. Wells with less than three failures per year may be considered in the future depending on the amount of down oil represented by the failure.

Description of Solution

An aerosol resin system applied during a cyclic steaming event is used to consolidate sand grains in the formation and reduce the potential for the influx of sand while a well is on production. Through application of the resin treatment, bridging structures of near wellbore sand grains are strengthened. The resin is created by the acid catalyzed polymerization of furfural alcohol. As a binary fluid system this lends itself well to small batch mixing for injection to manage reaction set up time without causing surface equipment issues. Once set, this resin is thermally stable, solvent resistant and acid resistant which allows the well to be thermally or chemically stimulated. The theory and chemistry of this resin based system are further outlined in SPE Paper 24051 (P.D. Fader).

Steam is used as the carrier for the resin and provides two primary functions: 1) aerosols the resin to allow for coating of the sand grains without over application and 2) through occupying pore volume retains permeability in the treated region.

It is important to follow treatment procedure and establish strong communication amongst the engineering department, operations group and vendor. Once a candidate well is selected, a job plan is written to clean out the well, run the tubing/rods and prepare the well for steam. The well is setup to receive steam per the designed casing or tubing flow path at the wellhead. A chemical injection manifold is installed as close to the wellhead as feasible. The manifold is connected to the wellhead casing valve to treat down the casing tubing annulus or connected to the tubing for down tubing treatments. Placement of the manifold allows the steam and chemical to mix in a linear flow path prior to injection into the wellbore. Steam injection is started and continues for a minimum period of twenty four hours. The resin is injected at the end of the steam cycle. Steam injection is ceased once the designed volume of resin is injected. This prevents over washing near wellbore sand grains, yet still allows for sufficient energy to retain permeability. It is of utmost importance to confirm the integrity of all components in the flow path prior to commencing the treatment. Any questionable components are to be replaced prior to treatment.

Field Trial Results

Sixteen treatments were executed during the pilot project. The project achieved a success rate of 88%, as the S/S failure rate was reduced for 14 of the 16 wells. Ten of the wells did not experience a S/S failure following the treatment within a 6 month look back period. The treatments resulted in reducing the average failure rate from 4.70 to 1.49 (failures/well/year). This improved failure rate equates to an average increase in runtime of 5.5 months/year/well and a decrease in well servicing costs of an estimated $60,000 per well. Investigation of the two unsuccessful treatments revealed that casing damage was the root cause of failure. Figure 1 indicates the improvement in failure rate following treatment.

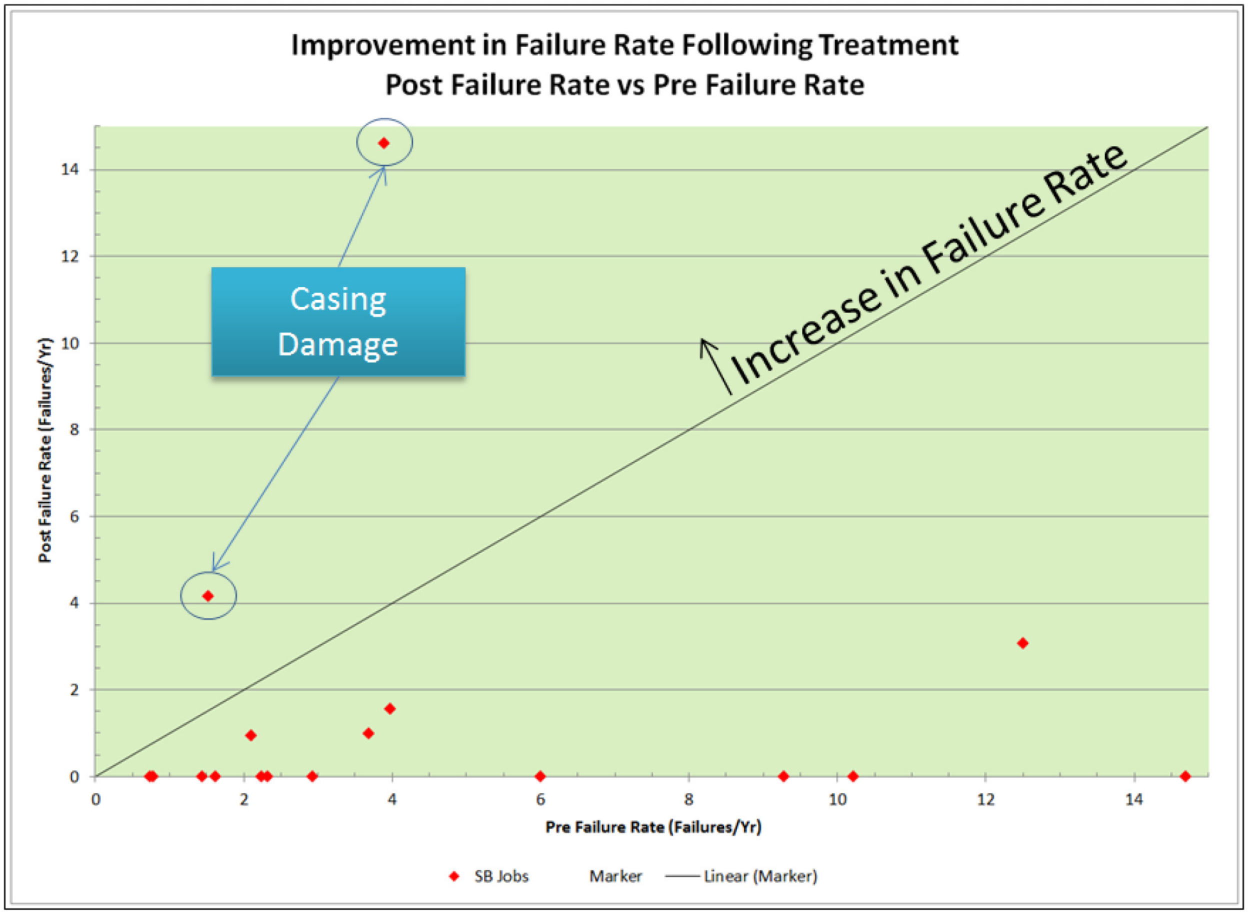

Figure 1—Improvement in failure rate following treatment

Project wells also experienced incremental oil production as a result of these treatments. The average incremental response over a 180 day period was 3.9 bopd/well. The normalized production response is illustrated in Figure 2. In addition to the incremental oil response, the project's efforts also contributed to the reduction of down oil and improved well runtime. The average downtime experienced following a well failure in this field is 5 days. The results of this treatment indicate that on average wells experienced 3.21 less failures per year. This equates to an average improvement in production reliability of more than 16 days per well per year.

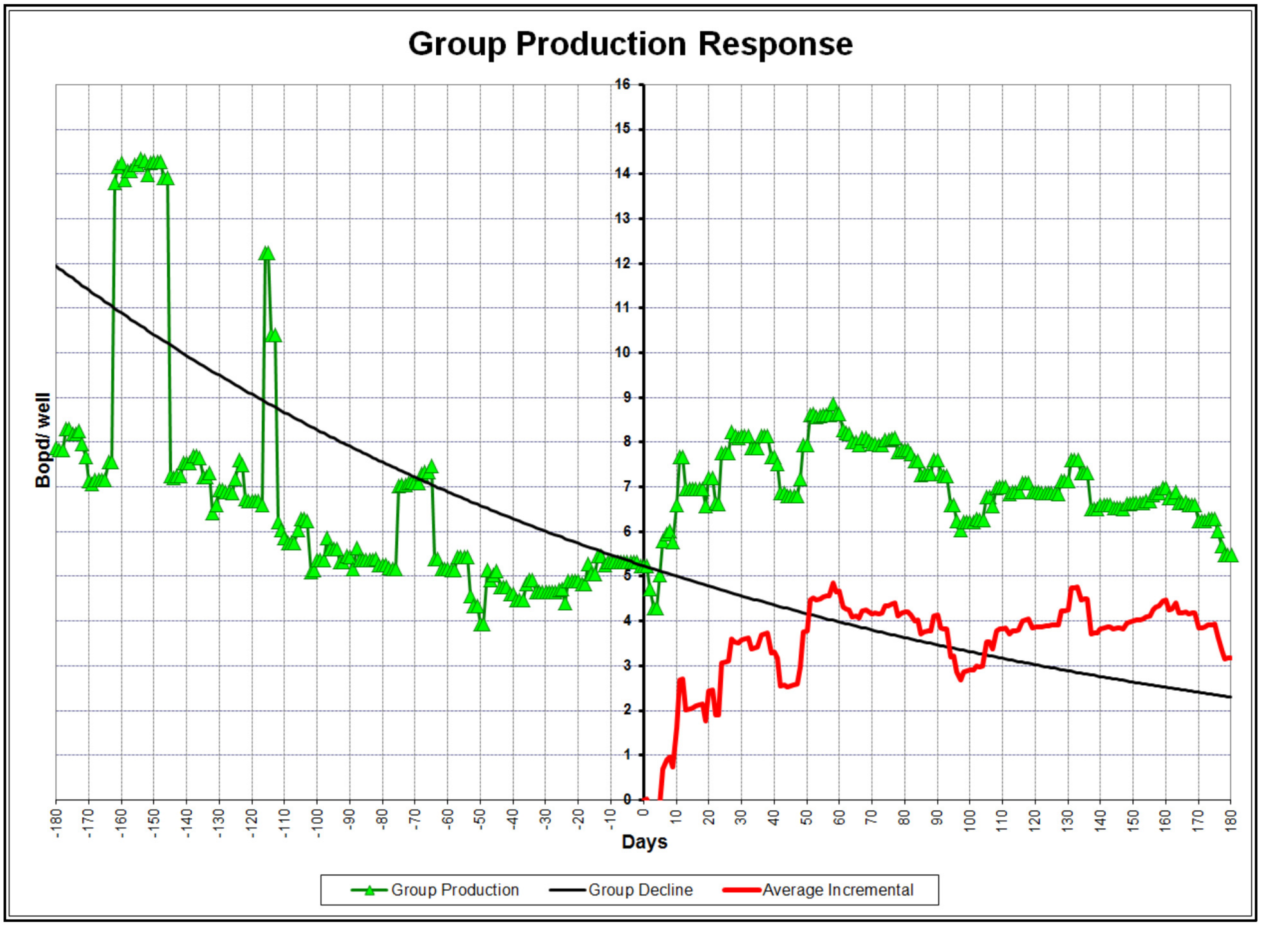

Figure 2—Normalized Curve, 16 wells for 180 days

No decrease in gross fluid production was observed following these treatments. This indicates that the resin was successfully placed without affecting reservoir permeability. Figures 3–6 illustrate the production and failure histories of four wells included in the pilot. Below are observations captured from each treatment:

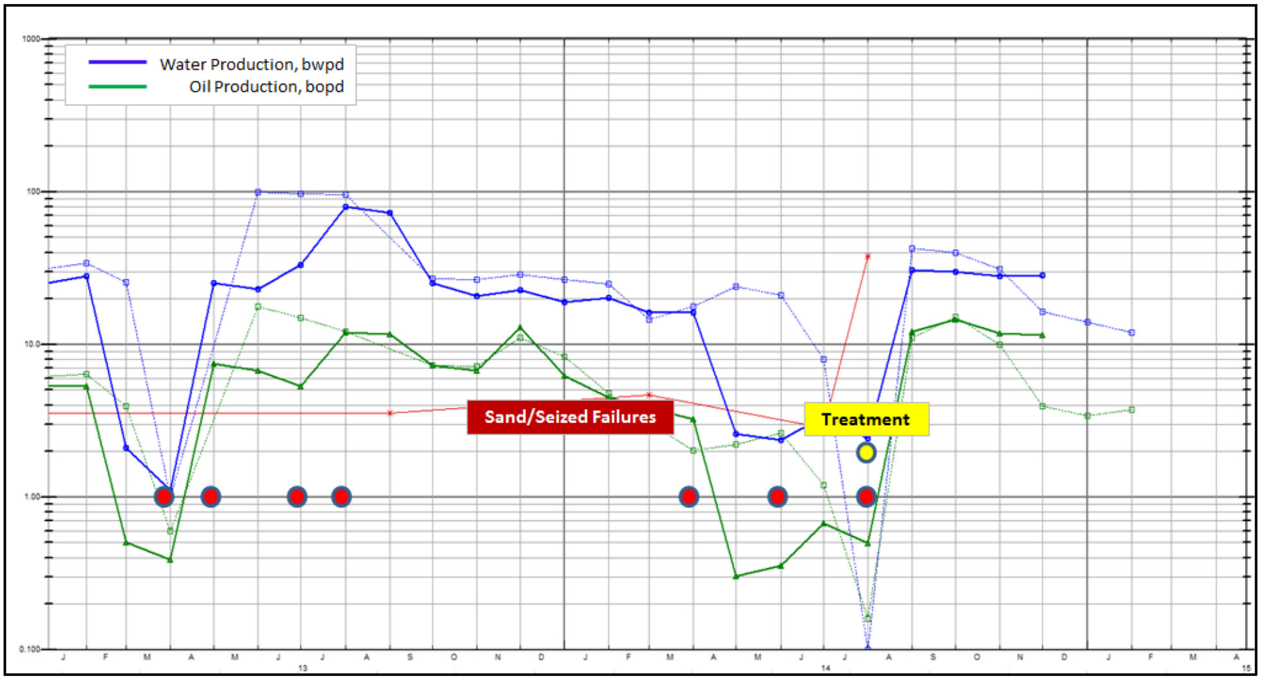

Figure 3—Well A, Production Plot

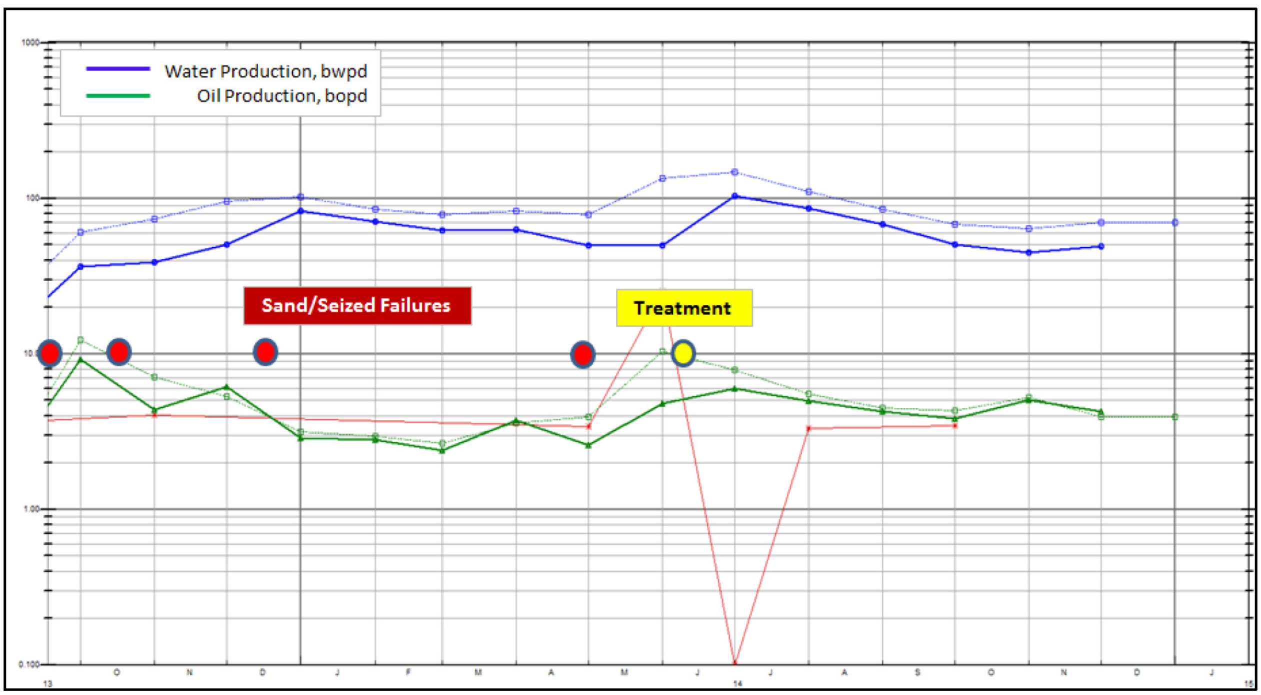

Figure 4—Well B, Production Plot

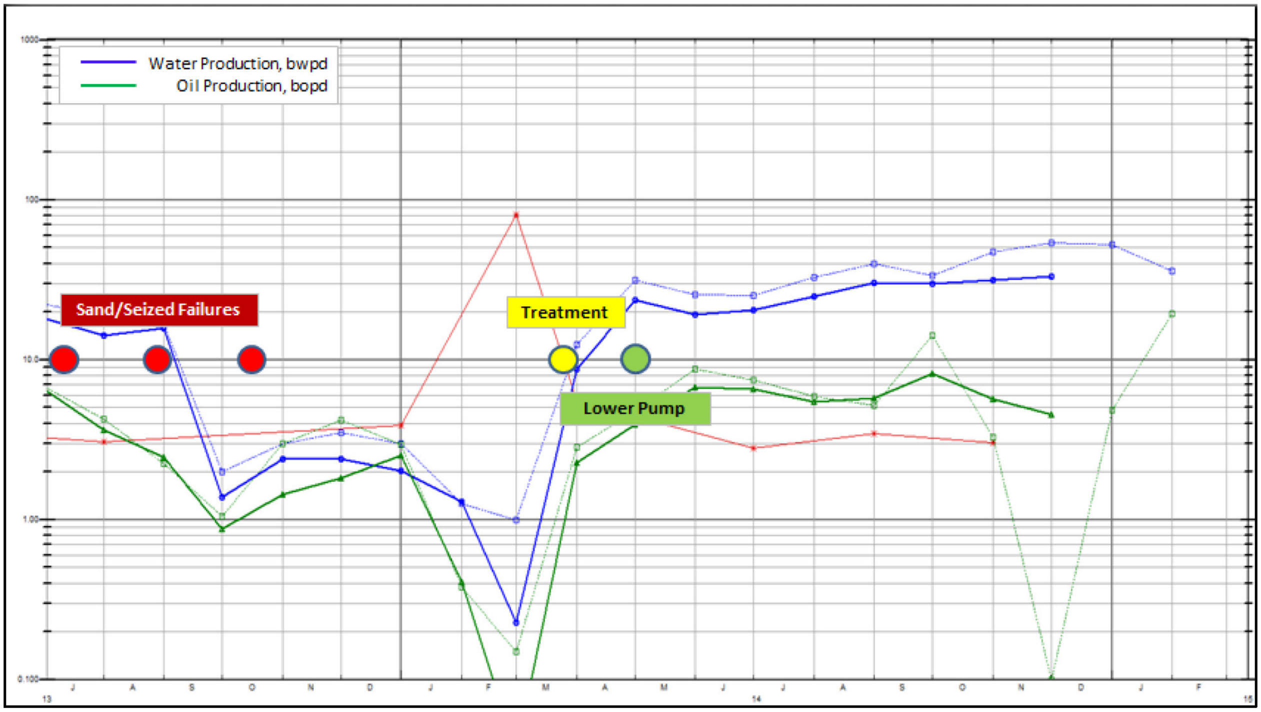

Figure 5—Well C, Production Plot

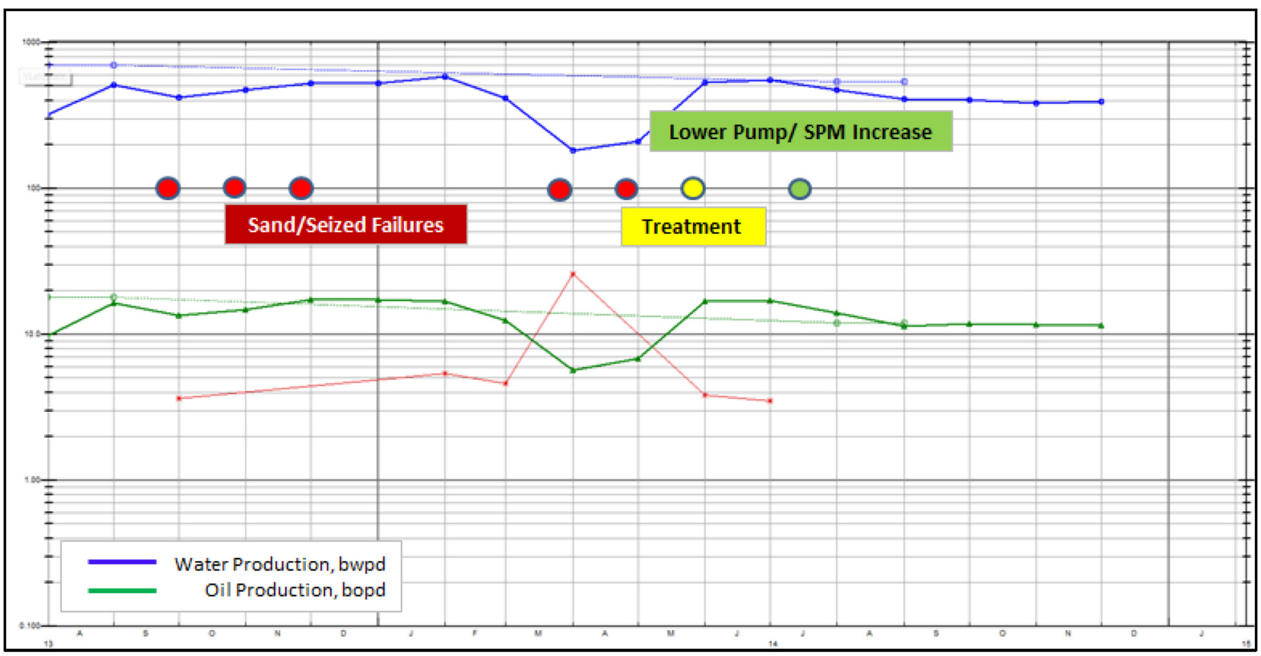

Figure 6—Well D, Production Plot

- Figure 3 – Well A, prior to being treated, this well experienced a failure rate of 5.6 (failures/year). There was also a strong correlation between CS jobs and S/S failures. The operator had raised the pump intake to improve runtime. Following the treatment, the pump was lowered, an increase in oil production was observed and the well has not experienced a subsequent failure.
- Figure 4 – Well B, prior to being treated, this well experienced a failure rate of 4.1 (failures/year). The operator had raised the pump intake to improve runtime. Following the treatment, the pump

was lowered, an increase in oil production was observed and the well has not experienced a subsequent failure.

- Figure 5 – Well C, prior to being treated, this well experienced a failure rate of 3.8 (failures/year). The operator had raised the pump intake to improve runtime. Following the treatment, the pump was lowered, an increase in oil production was observed and the well has not experienced a subsequent failure.
- Figure 6 – Well D, prior to being treated, this well experienced a failure rate of 6.5 (failures/year). The operator had raised the pump intake to improve runtime. Following the treatment, the pump was lowered, an increase in oil production was observed and the well has not experienced a subsequent failure.

This treatment has been proved as a viable alternative to other well activities targeted at reducing failure rate such as drilling sidetracks, running inner slotted liners, raising the pump intake and blocking wells from CS activity. In the Kern River Field, sidetracks are commonly used to enhance well performance, avoid damage or problem areas in the wellbore. However, sidetracks require significant investment and longer lead times to execute relative to the treatment used in this pilot project. The treatment used in this pilot project is 10% of the cost of drilling a sidetrack. Installing inner liners are expensive and typically decrease S/S failures but can also reduce well productivity by up to 50%. The treatment used in this pilot project is 27% of the cost of installing an inner liner and typically yields incremental oil production. Raising the pump intake is effective at increasing runtime, but typically results in reduced production. Wells that have a strong correlation between CS jobs and S/S failures are typically blocked from steam. This results in poor production performance. The treatment used in this pilot program has proven to be a cost effective alternative to other methods of mitigating S/S related failures. Additionally, this treatment does not negatively impact production performance and allows for the continuation of stimulation programs.

Conclusions

1. This treatment is economically viable method for reducing S/S related failures as demonstrated by the 88% success rate of the pilot program. The financial impact includes reduced well servicing costs, avoidance of associated down oil and incremental oil response through thermal stimulation.
2. This treatment can be applied to wells where the pump intake has been raised to mitigate S/S failures. Following this treatment the pump can be lowered in the wellbore to maximize production.
3. This treatment can be applied to wells that have been excluded from cyclic steam stimulation programs due to associated failures. Following this treatment wells can continue to be cyclic steamed in order to maximize production.
4. The selection criteria have been validated by the results of the pilot program.
5. The resin treatment is an economic alternative to other well remediation activities such as installing inner liners or drilling sidetracks.
6. There is an opportunity to expand candidate selection and treat wells that are outside the selection criteria of the pilot project.

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