Three-Stage SAGD Liner Intervention to Remediate a Liner System Using Concentric Coiled Tubing Jet Pump Technology

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Abstract

Excessive solids production and liner issues are familiar complications in maturing SAGD operations, potentially causing well integrity concerns. There are several factors that can occur, in isolation or in combination, to cause excessive solids production and/or liner failures in SAGD wells. Reservoir characteristics, well construction and known downhole conditions contribute to production results and potential liner degradation over time. The production strategy typically considers fluid mechanics, metallurgy, and thermal cycling to limit steam breakthrough, channeling, and/or low sub-cool events. Even with the best construction and production practices, the gradual accumulation of solids in a production well can limit optimal productivity. SAGD Operators may choose a downhole intervention to mitigate the potential of a future failure or require an intervention to prepare for liner remediation.

The paper begins by outlining common cleanout methods used in SAGD wells. Then, it discusses a SAGD downhole intervention in three stages: (1) a jetting venturi cleanout, (2) a gauge mill run, and (3) installation of a remedial liner system. The jetting venturi cleanout is comprised of concentric coiled tubing coupled with an engineered jet pump. It is designed to artificially lift wellbore materials, cleaning the SAGD wellbore while recording the volume of solids returned from a specific location. The gauge mill run confirms an acceptable diameter for smooth liner installation. These first two stages ensure seamless installation of the remedial liner system to mitigate detrimental mechanisms that limit production or impact well integrity.

Two case studies, in two heavy oil formations from two Operators, support the effectiveness of the SAGD liner intervention. The case summaries and results demonstrate the success of the SAGD liner intervention, corroborate its consistent and repeatable use and show its compatibility with remedial techniques in SAGD operations. The paper establishes the importance of effectively cleaning and clearing a SAGD wellbore in preparation for liner remediation and to provide insight into future well integrity operations.

Introduction

The unconsolidated nature of heavy oil reservoirs in the Western Canadian Sedimentary Basin (WCSB) is such that sand and fines are suspended in produced flow, and excessive solids production can cause accumulation in a wellbore. SAGD wells are known to produce for decades. As the well matures, the factors
that cause excessive solids production compound and can be further complicated by production shut-downs and restarts. The accumulation of residual solids is a concerning effect of a maturing SAGD well that can indicate a liner or well integrity issue potentially reducing productivity. Sand control or liner systems in heavy oil production are designed to optimize oil production and drawdown pressure while limiting sand production.

As a SAGD well matures, there is potential for degradation of its liner system. If productivity decreases due to accumulation of solids in the wellbore, then a cleanout may be required. There are trade-offs associated when deciding whether to preventatively clean out, or remediate, when there is a problem. In the event of a suspected liner failure, a well cleanout and liner remediation is an option that may avoid the necessity of a re-drill.

**SAGD Remediation**

During production operations, the production engineer regularly monitors production rates and data retrieved from downhole instrumentation strings for sub-cool events and the potential for steam breakthrough. Steam breakthrough risks the creation of channels leading to liner degradation, excessive solids production, and/or reduced pump efficiency and well life expectancy. To mitigate risk and long-term production loss, the production strategy may be modified by adjusting steam rates, reducing the production rate or implementing an elective remedial workover or recompletion depending on the situation or severity of the event.

**Well Cleanout Methods**

Cleanout methods for sub-hydrostatic and underpressured wells with large diameter tubulars, like a SAGD producer, can limit cleanout options. Solids removal can be unsuccessful, risking high fluid usage, loss of circulation, and causes solids to be pushed into the formation. Most conventional cleanout methods such as jointed-tubing circulation, bailing, or conventional coiled tubing systems are known to be ineffective or inefficient. These operations require high pump rates or high specific gravity fluids to move solids. High rates and large fluid volumes risk incomplete solids removal and loss of fluid into the formation potentially causing formation damage. In sub-hydrostatic wells, foam or energized fluid assisted circulation has been used as an alternative to reduce hydrostatic pressure; however, these methods are insufficient for hard bridging and the cost of liquid nitrogen can be excessive. For all methods, inadequate removal of wellbore materials often requires repeating cleanouts. Each cleanout means lost production time and an increasing cost to well maintenance. (Chen, S., Yang, D., Zhang, Q., & Wang, J., 2009; Falk & Fraser, 1998; Heinrichs & Dedora, 1995; Pineda, Lindsey, Taggart, Smith, & Ababou, 2013; Rolovic, R., Weng, X., Hill, S., Robinson, G., Zemlak, K., & Najafov, J., 2004)

In the mid-1990s concentric coiled tubing (CCT) technologies emerged in the well servicing landscape and were leveraged as an alternative method for well cleanout particularly for heavy oil, sub-hydrostatic or deviated wells. CCT is simply a coiled tubing string inside another coiled tubing string that creates an additional flow path in the work string (see Figure 1). The diameter of the tubing can be modified by varying internal and external tubing sizes to best fit the receiving wellbore, optimize circulation and fluid velocity (Falk & Fraser, 1998; Pineda et al., 2013; Portman, 2003).
One cleanout technique incorporates CCT with a jet pump to fluidize solids and create a flow path that artificially lifts wellbore materials to surface through the annulus between the two coiled tubing strings. A jet pump is an ideal choice. Since it has no moving parts, it is solids and gas tolerant. The downhole jet pump is activated by hydraulic horsepower created by a surface fluid pumping unit that does not require electrical power (unlike an electric submersible pump). The jetting head rotates in isolation, simplifying the CT operation as the working string does not need to be reciprocated or rotated. As an advantage, the use of a jet pump lowers the bottomhole pressure to minimize the loss of working fluid into the formation. (Chen et al., 2009; Falk & Fraser, 1998; Pineda et al., 2013; Portman, 2003)

A jet pump is comprised of a high-pressure nozzle, suction port and diffuser (see Figure 2). When a downhole jet pump is run on a CCT it acts as a venturi. A single-phase fluid is pumped through the inner string to power the jet pump venturi. This accelerated power fluid lowers pressure to create a localized drawdown that vacuums fluidized wellbore materials into the diffuser where fluid velocity decreases and pressure increases. The increased return pressure is usually enough to circulate commingled fluids and lift the return fluid back to the surface via the CCT annulus (space between the inner and outer coil). (Li J., Crabtree A., Kutchel M., Diaz J., Reyes W., Dugarte R. and Peña L., 2008; Pineda, et al., 2013; Portman, 2003).

Cleanout power fluids are unique to each operation. The composition of the power fluid is best designed with the existing wellbore fluid in mind and intended to establish a consistent flow rate through the jet pump for the duration of the operation. Typically, the power fluid is a combination of mainly water with a small amount of friction reducers based on the composition of the wellbore fluids. (Hibbeler, J., Duque, L., Luis, C., Gonzalez, A., & Romero, J., 2002; Portman, 2003; Rolovic, et al., 2004; Snyder & Noland, 2016)
**SAGD Liner Intervention**

In the SAGD environment, a well cleanout may be required to address a known build-up of produced solids as an intervention to clear and prepare the liner to seamlessly receive a remedial liner system. Thermal signatures, captured via instrumentation strings common in most SAGD wells, reveal areas of low sub-cool, potential channeling or steam breakthrough. A low sub-cool event could cause high-rate fluid entry into the production liner which can lead to liner failure.

The liner interventions analyzed in this paper occurred in three stages: a jetting venturi cleanout, a gauge mill run and installation of an inflow control device (ICD) in Well 1 and slotted liner in Well 2. In stage one, a jetting venturi cleanout is a CCT assembly comprised of an engineered jet pump and jetting head that removed wellbore materials to clean out the liner. Following the cleanout, stage two incorporated a milling BHA running below lock-up torque to act as a gauge ring. In the final the stage, a remedial liner system was installed.

The jetting venturi cleanout CCT assembly is a patented wellbore cleanout and testing system that simultaneously vacuums away fluidized wellbore materials, with guaranteed positive circulation to surface, while gathering continuous inflow data. The rotating jetting head is speed governed to maximize energy into the jetting force. The venturi jet pump artificially lifts the wellbore materials to surface. Prior to the operation, a technical program is completed and includes hydraulic artificial lift modeling. During the operation, a technician at surface gathers oil, water and solids cuts for final reporting.

In a SAGD cleanout intended to prepare the liner, the operation needs to accommodate for the viscosity of bitumen (see Figure 3). The CCT is especially affected by friction across three tubular walls (ID of inner and outer CT, OD of inner CT). The mobility of the bitumen in the liner is increased by the jetting force, temperature of the power fluid, and its chemical composition. A chemical injection program is carefully designed to suit SAGD facility limitations and the downhole environment in order to emulsify and reduce flowing friction of the bitumen. Samples of returns are taken every 15 minutes and chemical adjusted to assure uniform emulsification.

![Figure 3—Fluid returns at tank during jetting venturi cleanout.](image)

Throughout one of the case study wells, a three-stage chemical program was tested in three separate cleanouts (see Table 1). As stated in Table 1, the increase in lifting rate across the three operations occurred by managing bitumen viscosity and mobility. Each cleanout provided excellent learning in the importance of a tailored chemical program—the lifting rate increased with each adjustment to the chemical program.
Table 1—Example chemical adjustments versus lifting rate.

<table>
<thead>
<tr>
<th>Chemical Program</th>
<th>Cleanout #1</th>
<th>Cleanout #2</th>
<th>Cleanout #3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0 L/m³ dispersant</td>
<td>2.0 L/m³ dispersant</td>
<td>0.5 L/m³ dispersant</td>
</tr>
<tr>
<td></td>
<td>20.0 L/m³ diesel</td>
<td></td>
<td>0.5 L/m³ solvent</td>
</tr>
<tr>
<td>Lifting Rate</td>
<td>60.0 L/min</td>
<td>93.0 L/min</td>
<td>101.0 L/min</td>
</tr>
</tbody>
</table>

The technical program specifies that the jetting system's lifting rate be higher than the fluid jetting rate to optimize the scope of work and inflow to the BHA. The jetting configuration (jet angle, jet sizes, number of jets, rotational head speed, flow rate) is based on the characteristics of the well and CCT string design to ensure effective fluidizing of wellbore materials. Fluid may be pumped down the casing to maintain positive pressure on the failure region to mitigate the potential for solids inflow.

The full length of the lateral portion of the wellbore is cleaned, with attention paid to the solids returned to surface. The solids are tracked via visual samples (Figure 4) and an acoustic monitor (Figure 5). With this information available during the operation, the CCT speed and sweeps are adjusted to ensure all areas are clean before proceeding in hole, and double checked while pulling to surface.

Figure 4—Visual sample – 20% solids.
Once the cleanout is completed, the operation switches to a gauge mill run. The jetting assembly is removed from the CCT and the milling BHA attached. The gauge mill run is intended to confirm the minimum ID throughout the liner. Consistent coil speeds are used, and weights monitored. The mill acts as a gauge ring while the additional BHA components (motor, agitator, jars, etc.) provide a secondary means freeing the BHA.

When the milling BHA reaches TD of the production liner, the surface fluid pump is switched over to a metal-to-metal friction reducer (MFR) at a calculated concentration (see Equation 1). This MFR is pumped at the appropriate flow rates to displace the liner to an operator-specified percentage of liner volume. This provides a low-friction environment for installation of the remedial liner or ICD system in the final stage.

\[
Q_{MFR} = A_L \times v_{CCT}
\]

Where \( Q_{MFR} \) = Flow rate of friction reducer (m³/s)
\( A_L \) = Cross sectional area of liner (m²)
\( v_{CCT} \) = Velocity of CCT during spotting (m/s)

Equation 1. Metal-to-metal friction reducer calculation.

The remedial liner system is installed as the final stage of the intervention. The case studies describe the installation of two different types of liner systems for two different objectives. These differences indicate that stage 1 and stage 2 preparations are compatible with a variety of liner installations.

**Case Studies: Preparation for liner remediation**

To effectively install remedial liners, it is crucial to the success of the operation to remove all obstructions that may prevent the installation and prepare a clear, clean, and low-friction environment for the new liner to move through during installation. Obstructions in SAGD wells may include, but not be limited to, precipitates (e.g., paraffins, asphaltenes), blockages (i.e. bitumen plugs), reservoir solids inflow (e.g., quartzitic sand, fines), scale deposition and/or wellbore construction issues.

Stage 1 of the SAGD liner intervention described in the cases is intended to clear the wellbore of obstructions. The jetting venturi cleanout is a closed-loop hydraulic system that ensures returns to surface. This closed system (from BHA to surface) accesses the venturi and the CCT conduits to generate ample
lifting pressure and velocity. To effectively remove solids from the intermediate casing, a guide string is not preferred during the jetting venturi cleanout. Neither case described below had a guide string installed.

In the two case studies, both cases were Canadian SAGD wells with different issues. Well 1 was running smoothly but underperforming; therefore, the objective was to ensure thermal conformance and optimize production. In Well 2, high solids production caused decreased pump efficiency and increased pump wear that resulted in lower than expected productivity. The wells were of a similar age, approximately three years on production. Both operations occurred in the summer of 2018 and completed the same activities:

1. removed production tubulars
2. cleaned the wellbore to the toe
3. confirmed acceptable ID with a gauge mill run
4. spotted MFR
5. installed remedial liner
6. installed production tubulars

**Well 1: Lloydminster Formation**

This SAGD well, situated in the Lloydminster formation near Lindbergh, Alberta, has a measured depth of 1533 m, a vertical depth of 513 m, BHP of 3000 kPa and a BHT of 206°C completed with electric submersible pump. This well was underperforming due to poor temperature conformance across the liner and completion design limitations making it an ideal candidate for an ICD system to further optimize production.

The jetting venturi cleanout and a gauge mill run were performed to clean and drift the liner for the installation of an ICDs isolated by swell packers. The jetting venturi cleanout encountered a small volume of solids, no solids bridges and thoroughly cleaned the liner to allow the gauge mill to reach maximum depth without issue.

The technical program accounted for the BHA to be fluid underbalanced, with a higher lifting rate than the fluid jetting rate. This was achieved and the BHA ran underbalanced for the duration of the run. The jetting rate was regulated, and the rate averaged 35.3 L/min. Given the objective of the operation, most of the jetting power was directed outwards to thoroughly wash the liner walls. The aggressive jetting ensured that solids and oil were fluidized, allowing the venturi to vacuum the slurry into the BHA. Gross lifting rates averaged 60.3 L/min, resulting in an underbalanced rate of 25 L/min (36.0 m³/day). The total rates pumped through the CCT and returned to surface are charted in Figure 6 below.
Throughout the cleanout operation, returned fluid, oil, and solids were captured and recorded (see Figure 7). Over 15.5 hours the total volume of solids lifted was confirmed at 0.75 m$^3$. Contrary to the chart, oil was recovered between 5:30 and 7:15; however, operational challenges prevented the collection of samples. The well fluid lifting rate is the emulsion of wellbore water, oil, sand, as well as a portion of the jetting fluid and chemicals pumped from surface.
The second stage of the workover incorporated a milling BHA used as a gauge ring, with milling components typically used in case of adverse wellbore conditions. The sub-assemblies installed in the BHA included a disconnect, jar, mud motor, centralizer, bit box, twister bit mill. Figure 8 shows the weights on surface.

The gauge mill run went smoothly, with minimal weight loss throughout the lateral. The operation experienced no tags, no need for bit rotation, and used a small amount of MFR. Once TD was tagged, the BHA was retrieved to surface. The total gauge mill trip time was 6.0 hours.

The Operator successfully ran 25 swell packers with 10 mm overall clearance to a planned depth across the entire 734 m of the lateral. The success of the installation was attributed to preparations from stage 1 and stage 2 of the SAGD liner intervention.

Three months following the recompletion, the net oil production increased 143%, from 70 m³/day to 170 m³/day and the SOR is down from 4.0 to 1.5. This increase in productivity is attributed to both the cleaning of the primary sand control liner (performed by the aggressive jetting) and the recompletion design. A ratio between these two conformance improvement factors cannot be conclusively quantified.

**Well 2: McMurray Formation**

Well 2 is situated in the McMurray formation near Mariana Lake, Alberta and has a measured depth of 1337 mKB, a vertical depth of 473 m, BHP of 3000 kPa and a BHT of 200°C. The well is equipped with an oversized tubing pump (OSTP). The pump run-life was below the field average since it was commissioned. Run-life did not improve with adjustments to pump landing depths. The pump efficiency declined faster than normal and pump teardowns indicated that an excessive volume of solids was present.

In August of 2017, persistent downhole pump issues prompted the request for a jetting venturi cleanout. It successfully removed 10 m³ of solids from the well confirming there was a major issue with the liner system as discussed below.

The Operator purchased a remedial liner system with a smaller OD for installation inside the original liner. In March 2018 another cleanout was attempted to prepare for installation of the remedial liner. The cleanout circulated fluid with jointed pipe, a drill bit BHA and power swivel at surface. During the operation, the
BHA became stuck in the hole after a partial cleanout of the liner (12.6 m$^3$ of solids were removed). Coiled tubing was used to free the stuck BHA and it was removed from the well. The same coiled tubing with N$_2$ was then utilized to continue the cleanout but was unsuccessful in reaching the well TD. The Operator concluded that a sufficient length of the liner had been cleaned out, so an attempt was made to install the remedial liner. During the operation, the end of the remedial liner was unable to progress to a satisfactory depth, so the liner was pulled out of the well and stored for future use. An OSTP was re-installed and the well was returned to production.

In July 2018, a three-stage SAGD liner intervention was performed. In the first stage, a jetting venturi cleanout was performed to prepare for the second attempt at the installation of the remedial liner. For this cleanout, like Well 1, the jetting venturi cleanout technical program was designed to be underbalanced, with the jetting lifting rate higher than the fluid jetting rate. This was achieved and the BHA ran underbalanced for the duration of the run. The jetting rate was regulated and averaged 67.4 L/min. Gross lifting rates averaged 100.9 L/min, resulting in a 33.5 L/min (48 m$^3$/d) underbalanced rate. Positive pressure on the formation was maintained by pumping 50 -> 70 -> 50 L/min down the casing during the cleanout operation.

Volumes of returned fluid and solids were captured and recorded using acoustic solids metering (Figure 9). Over 15 hours, 2.8 m$^3$ of solids were lifted. With knowledge gained from previous cleanout operations, the heel (including liner top) was swept on the run in hole as shown on the depth series, as well as the solids series.

![Figure 9—Solids, fluid, oil lifted and depth versus time.](image)

This well received two jetting venturi cleanouts within a year allowing comparison of the collected data. The two cleanouts (August 2017 and July 2018) solids returned versus depth are plotted in Figures 10 and 11. The first cleanout returns markedly more returns at 10 m$^3$. The second cleanout returns were significantly less at 2.8 m$^3$. During the August 2017 cleanout, solids were first encountered at 486 mKB, the same depth as the bottom of the OSTP. Solids were not encountered until 650 mKB in the second cleanout. During both jobs, a high concentration of solids was found in the depth range of 650-1000 mKB.
In the next stage of the operation, a gauge mill run was performed using the CCT to confirm diameter. The sub-assemblies installed in the BHA included: disconnect, agitator, centralizer, bit box and tapered mill used to gauge ID. The BHA was run to TD without issue. The total gauge mill trip time was 9.0 hours. While pulling out of the hole MFR was spotted in the liner as an aid for running the remedial liner. The operation was slowed due to overpull at ~1170 mKB and ~775 mKB as shown in Figure 12. The confirmation run was successful.
After a successful cleanout and confirmation gauge mill run, the Operator proceeded with remedial liner system installation. A scraper was run on drillpipe to ensure intermediate casing integrity and drift diameter down to the new liner hanger set depth. The remedial liner system was run into the well on a work string consisting of drillpipe and heavy weight drillpipe. A pipe jacking unit was at site on standby, but it was not required. The bottom of the liner was landed at the planned depth of 1325 mKB with the hanger set at 620 mKB. The hanger (debris seal packer) was set and a pull test was performed to confirm the seal.

The successful installation of the remedial liner was attributed to the exceptional preparatory conditions from the jetting venturi cleanout, the confirmation gauge mill run, MFR spotting, and drillpipe work string. Well 2 was returned to production after installing the OSTP and instrumentation string. With the remedial liner system in place, the Operator achieved their goal of a successful recompletion.

Analysis

The case studies presented in this investigation provide a detailed analysis of two operations. The paper is not intended to provide the statistical accuracy of a longitudinal study encompassing hundreds of operations. However, the case studies do provide an analogous study of successful well integrity interventions in similar reservoirs.

To select a SAGD liner intervention, operators first assess the known well issues. Well economics dictates a range of options, from modifying production practices to re-drilling the well. In the event an ICD or remedial liner system is the selected intervention, these case studies support the three-stage process demonstrated in this paper.

To run this SAGD liner intervention, production tubing and other tubulars are removed. This provides an open wellbore for optimal cleanout coverage and is critical to ensure the OD of the gauge mill does not interfere with instrumentation string or other obstructions. MFR spotted via the gauge mill on the pull-to-surface provides a low-friction environment for the liner remediation. The case studies show two different liner installations were successfully achieved.

Both operations were performed via mast-deployed coiled tubing units using 60.3 mm or 73 mm CCT (Table 2), completed in the summer of 2018 in the WCSB. The same jetting venturi BHA was used in both case study wells.
Table 2—Key data points from Well 1 and Well 2.

<table>
<thead>
<tr>
<th></th>
<th>Well 1</th>
<th>Well 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum depth</strong></td>
<td>1515 mKB</td>
<td>1337 mKB</td>
</tr>
<tr>
<td><strong>Formation</strong></td>
<td>Lloydminster</td>
<td>McMurray</td>
</tr>
<tr>
<td><strong>BHT</strong></td>
<td>+/- 200°C</td>
<td>+/- 200°C</td>
</tr>
<tr>
<td><strong>BHP</strong></td>
<td>3000 kPa</td>
<td>3000 kPa</td>
</tr>
<tr>
<td><strong>Average jetting rates</strong></td>
<td>35.3 L/min</td>
<td>67.4 L/min</td>
</tr>
<tr>
<td><strong>Average gross lifting rates</strong></td>
<td>60.3 L/min</td>
<td>100.9 L/min</td>
</tr>
<tr>
<td><strong>Average underbalanced lifting rates</strong></td>
<td>25 L/min</td>
<td>33.5 L/min</td>
</tr>
<tr>
<td><strong>CCT size</strong></td>
<td>60.3 mm</td>
<td>73.0 mm</td>
</tr>
<tr>
<td><strong>Average bottoms-up time</strong></td>
<td>12.8 min</td>
<td>22.7 min</td>
</tr>
<tr>
<td><strong>Volume of solids</strong></td>
<td>0.75 m³</td>
<td>2.8 m³</td>
</tr>
<tr>
<td><strong>Maximum gross solids cut</strong></td>
<td>0.2%</td>
<td>11%</td>
</tr>
<tr>
<td><strong>Maximum gross oil cut</strong></td>
<td>18%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Cleanout time</strong></td>
<td>15.5 hours</td>
<td>15.0 hours</td>
</tr>
<tr>
<td><strong>Gauge mill operation time</strong></td>
<td>6.0 hours</td>
<td>9.0 hours</td>
</tr>
</tbody>
</table>

The scope of work was the major difference between the operations. Well 1 had minimal solids issues but desired reservoir conformance to maximize production flow rates. Well 2 had well integrity issues, which caused pump and production challenges when compared to offsets on the same pad. The objective on Well 2 involved the entire liner to extend the lifetime of the well and minimize future interventions. While it is too early to accurately determine if these results were met for both wells, early indication is positive.

Table 2 below summarizes key data points from both wells.

**Conclusions**

Installation of a remedial liner is predictably successful with a clean and clear wellbore that has a confirmed internal diameter. The case studies and the analysis support the three-stage liner intervention described in this paper to ensure successful remedial liner installation.

The following conclusions can be drawn from this work.

1. This SAGD liner intervention demonstrated the ability to land a variety of remedial liner systems accurately on the first attempt.
2. The jetting venturi cleanout is a reliable solution that consistently and exceptionally cleans and clears the wellbore in preparation for a recompletion.
3. The jetting venturi cleanout accurately locates and quantifies solids in the liner.
4. The jetting venturi cleanout is a diverse and adaptable operation. It can predictably remove excessive solids to clean a liner and is compatible with related remedial tasks (e.g., gauge mill run, logging, plugging, patching) to provide flexibility within one operation.
5. The gauge mill run following the jetting venturi cleanout is an important step to assure the liner ID before remedial liner installation.
6. This SAGD liner intervention is a viable solution that yields a reliable operation supporting both workover and post-intervention production economics.

7. The SAGD liner intervention is a viable option to avoid re-drill.

This SAGD intervention can offer Operators an opportunity for improved pump life, increased production, and reduced steam oil ratio.

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Nomenclature

- **BHA** bottom hole assembly
- **BHP** bottom hole pressure
- **BHT** bottom hole temperature
- **CT** coiled tubing
- **CCT** concentric coiled tubing
- **ESP** electric submersible pump
- **ICD** inflow control device
- **IT** instrumentation string
- **MFR** metal-to-metal friction reducer
- **OSTP** oversized tubing pump
- **SOR** steam oil ratio
- **TD** total depth
- **WCSB** Western Canadian Sedimentary Basin

References


