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Techniques for Installing Effective Solvent Extraction Incorporating Electromagnetic Heating (“ESEIEH”) Completions

SHIRISH R. DESPANDE[1], BRIAN N. WRIGHT[2], ALAN WATT[1]

1 – Suncor Energy Inc., Drilling & Completions; 2 – Harris Corporation, Energy Solutions

ABSTRACT

A successful test of a Radio Frequency (RF) antenna heating system in oil sands was completed in 2011. This test was the precursor to the ESEIEH pilot currently underway at Suncor Energy Inc.’s MacKay River Dover field. A consortium of Harris Corporation (Melbourne, Florida, USA), Nexen Energy ULC, Suncor Energy Inc., Devon Canada Corporation, and Alberta’s Climate Change and Emissions Management Corporation (CCEMC) are developing the ESEIEH oil recovery process that can potentially reduce the environmental impact of bitumen recovery in the heavy oil fields of Canada.

The ESEIEH process (U.S. patent 8,776,877) requires the installation of a downhole RF antenna heating system. This changes the completions method relative to traditional SAGD practices. Completions at the Dover site involved running a uniquely designed electromagnetic toolhead and electromagnetic choke assembly on three concentric tubulars with integrated solvent injection and instrumentation lines. The RF tool completion required innovation in the wellhead design, RF compliant instrumentation lines and centralizers, custom clamps and tool handling equipment for concentric pipes. The methods were also scrutinized for safety and quality control. This paper summarizes the unique aspects of RF completions and the lessons learned from the ESEIEH well installation at the Dover pilot site.

KEY WORDS

ESEIEH, Easy, EZ, RF heating, heavy oil, bitumen, solvent, GHG reduction, CO_2 reduction, water use elimination.

INTRODUCTION

According to published data, Alberta possesses one of the largest oil reserves in the world, ranking just below Saudi Arabia and Venezuela. Of Alberta’s more than 1.8 trillion barrels of deposits in ground, only 174 billion barrels mostly in the form of bitumen are recoverable by current recovery techniques. Much of this resource is recovered by surface mining, however, only 20% of reserves are recoverable by mining. The remaining 80% of reserves are buried too deep to mine. Consequently, deeply buried reserves are currently recovered by in situ techniques such as steam assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS) which involves injecting steam into the reservoir to heat the bitumen and reduce its viscosity. These techniques are more expensive than those for conventional oil and they have higher capital and operational expenditures for production, transportation, and steam generation. Furthermore, the water produced from the reservoir must be recycled and carefully disposed in order to minimize the environmental impact. The efficiency of these in situ techniques is measured in terms of a Steam Oil Ratio (SOR). The current industry average SOR range is approximately 2.5 to 3 which means about three barrels of steam are required to produce a barrel of bitumen.

The ESEIEH process is a replacement technology to SAGD that has the potential to dramatically reduce the cost of oil recovery and its impact on the environment. This paper summarizes the unique completion techniques developed during the installation of the ESEIEH wells at the Dover pilot site.

COMPONENTS OF THE INJECTOR COMPLETION

Traditional SAGD well completion involves a horizontal well pair with an injector well that delivers steam into the reservoir and producer well that produces bitumen, water and gas from the reservoir. A SAGD injector well uses a few tubulars to inject the steam and these tubulars are run separately. Their installation primarily uses standard oilfield handling equipment. Although the configuration of the ESEIEH well pair is similar to SAGD, the ESEIEH injector well completion requires additional hardware to deliver RF power to the antenna liner. This completion is comprised of three concentric tubulars, an electric choke and an electromagnetic tool head. Seven lines are clamped to the tool string and these provide data, solvent injection, and activation functions. Some specialized pick-up and handling equipment, clamps, and a customized wellhead were constructed to accommodate this completion.

Antenna Liner: The liner in the lateral of the injector well functions as an antenna to transmit RF waves into the reservoir. It contains two non-conductive composite sections called isolators where one isolator is at the center of the liner and the other is located at the heel of the liner. The center isolator separates the liner into two sections that function as the two arms of a dipole antenna. The heel isolator separates the liner from the well casing that runs to the surface and thereby electrically isolates the casing from the lateral liner section.

The liner hanger is constructed using a fixed debris seal packer (DSP) with an expansion joint to adjust for any changes in liner length caused by thermal expansion. The expansion joint and DSP components were modified to remove any sharp edges or abrupt changes in diameter to avoid potential damage to tools and lines passing across those components during installation.

Figure-1: Antenna Liner

Transmission Line: The main component of the Electromagnetic Heating (EMH) Tool is the transmission line. It is comprised of three concentric tubular with an outer steel tubular and two interior copper tubulars. The copper tubulars form a coaxial transmission line and transmit the electromagnetic energy from surface to the antenna liner. The steel tubular provides isolation from reservoir fluids and the interior annulus acts as a coolant flow path. This tubular is internally coated to keep the inside surface free of corrosion. The EMH tool is built from ten meter long jointed sections and runs from the wellhead to the center of the antenna liner.

Coolant mineral oil flows down the annulus formed by the middle copper tubular and the outer steel tubular and the flow returns up the inner copper tubular. O-rings are used on the copper tubing connections to maintain the pressure seals. There is a high electric field between the annulus formed by the inner and middle copper tubular, so this annulus is filled with pressurized nitrogen which has low electrical loss and low relative permittivity.

Figure-2: Transmission Line Components

Pick-up Nubbin (Pick-up Sub): A custom pick-up sub was built to handle the simultaneous lifting and handling of three concentric tubulars. This pick-up sub threads onto the outer steel tubular and is equipped with a spring and safety sling that attaches to the inside transmission line. The spring allows for the transmission line to be safely exposed to make the connection with the subsequent joint. The safety sling ensures that the inner lines do not slip if the spring fails. A two-piece hinged and pinned lifting cap is installed over the copper tubular male end to carry the weight of the transmission line while lifting the joint into the derrick.

Figure-3: Pick-up Nubbin

Electromagnetic Heating (EMH) Toolhead: The EMH toolhead, built by Harris Coproration, electrically connects the transmission line with the antenna liner at the center isolator. It is one of the main components of the completion. The toolhead was designed with attachment features so that it could be carefully picked up and laid down in the derrick without damaging critical components. Teflon® centralizers and gauge rings were placed on each side of the toolhead so that the electrical contacts were protected during the run down the casing.

The toolhead underwent extensive load, bend and pressure testing that simulated installation and operating conditions before it was delivered to the field. For example, a series of bend tests were executed at Harris' Palm Bay laboratory to ensure the toolhead would pass through high dog leg areas in the build section without damage. Furthermore, extensive thermal cycles and pressure tests were completed on the toolhead assembly to verify that the seals would function properly during the installation and operational phases of the pilot.

Figure-4: EMH toolhead and Anchor Sub assembly

Anchor Sub – Breakaway Coupling Assembly: The anchor sub and breakaway coupler assembly was placed directly up well from the EMH toolhead and was designed with the help of Import Tools in Edmonton Alberta, Canada. It has a set of bi-directional slips which were designed to bite into and grip the antenna liner. This secured the position of the toolhead relative to the liner so that the electrical contacts on the EMH toolhead remain connected during thermal expansion or contraction of the antenna liner. The anchor sub slips are designed to hydraulically activate and mechanically deactivate. For redundancy, a break-away coupling is placed next to the anchor sub. If the slips do not mechanically deactivate or retract, then the inner copper tubulars can be removed along with the outer steel pipe up to the anchor sub. Any remaining tools could then be fished without having to back off and washover pipe all the way to the anchor sub.

Teflon® Centralizers: Custom centralizers were utilized to avoid damage to the composite sections of the antenna liner and the electrical contacts on EMH toolhead. The fins of the centralizers were made of Teflon® that allowed the string to run smoothly across the composite section without damage. These centralizers were only implemented in the lateral section of the well up to the heel isolator and as there was no need for the special centralizers beyond this region of the well.

The centralizers were laboratory tested to determine the wear rate of the Teflon® fins when exposed to expected installation conditions. After several runs across the sharp edges of a standard DSP, it was discovered that the centralizers were worn by approximately one-eighth of an inch. The DSP was modified with a radius on all the edges to eliminate damage to the centralizer fins.

Figure-5: Teflon® Centralizers on Steel Tubular

Choke Assembly: The function of the choke was to absorb electromagnetic energy that could propagate on the EMH string back to the surface. It was designed and built at Harris' Palm Bay, Florida facilities. The choke was run in the EMH string and was located near the heel isolator in the lateral section of the well. This component underwent extensive bend and load testing to ensure that the choke could be run through the high dog leg areas of the build section without damage.

The required length of the choke was too long and heavy to run on the slant completion rig as a single joint. Therefore it was separated into two sections to accommodate the rig handling constraints. This was problematic because the outer tubular of the choke was fabricated from a composite material and the connection could not be made with tongs because there was concern this would damage the composite. Therefore, a flanged connection was created at the middle of the choke assembly. The steel neck on the flanged section was designed to allow the string to be hung in the well with the help of a C-plate and dog collar assembly while the flanged connection was made. After making the connection, the second section of choke was run in the well and installation continued for the remainder of the EMH string.

Figure-6: Choke Assembly

Instrumentation Lines: Approximately seven different instrumentation lines were run in this completion. Some lines were used for pressure and temperature sensors. One line served as a solvent delivery tube while another was used to hydraulically activate the EMH toolhead and set the Anchor Sub. Because of the number of instrumentation lines, careful arrangement of the spools and sheaves was required given the limited rig space available. It was also important to manage the sequence in which the lines were attached and to keep proper tension on the lines to avoid tangles or bending. Custom pressing blocks with magnets were used to keep the lines straight and tight while mounting the clamps. The lines were color coded to allow rig workers to easily identify each line and thus avoid line crossing and damage.

In some regions along the EMH tool the lines had to be transparent to RF radiation so that they would not self heat or cause an electrical short between sections and allow electromagnetic energy to propagate to the surface. The jacket of the fiber instrumentation lines was made from a very low loss RF-transparent material. Sections of the hydraulic and solvent lines that ran across the choke were also built with a non-conductive, low RF loss material. The cross-over between the steel line and the RF-transparent material was designed to maintain a pressure seal over the range of pressure and temperature expected during operations. Extensive laboratory tests were conducted to validate RF compatibility and mechanical integrity of the cross-overs and instrumentation lines prior to delivery to the field.

Solvent Line: The solvent line carries solvent from the surface to a feed point at the center of the liner. The solvent is vaporized and diffuses into the reservoir and dilutes the RF heated bitumen with an accompanying decrease in the oil phase viscosity. To ensure vaporization, the solvent line serpentines three times between the choke and the center isolator to increase the available surface area for heat transfer to the solvent.

Clamps: A variety of clamps were used during the completion to accommodate a varying diameter profile along the EMH string as well as the different sizes of the instrumentation lines. In total, thirteen different types of clamps were designed to secure lines and centralizers to the EMH string. A special hole cover was built to prevent objects from falling into the wellbore while mounting the clamps. Extreme care was taken to prevent the instrumentation lines from being pinched or damaged during the clamping process. Before deployment to the field, the clamps were tested in Houston, Texas to ensure proper fit and function. Some clamps had to be modified on location in order to better secure the lines to the EMH string and avoid additional sagging from the smaller instrumentation lines.

Wellhead: The wellhead used for this project was custom designed. It was originally designed to allow for thermal growth of the EMH string tubular at surface. However, thermal analysis of the string revealed that the hanger could be fixed due to the low operating temperature of the ESEIEH process. This fixity provided a method to set the tension in the tubing after locking the anchor sub. The hanger was fixed with slips on the hanger and in the bonnet. It was designed to provide the pressure seal to the casing as well as to function as a traditional tube hanger. The wellhead design will also protect the surface electrical connections from thermal expansion in the downhole string span.

Technical and Risk Reviews: Many technical sessions and risk reviews were held in collaboration with all major vendors, field supervisors, technical engineers and the rig crew. Many ideas evolved from these reviews, thus making operations safer and more efficient.

HANDLING TESTS AND LABORATORY TESTS

Transmission Line Handling Tests: The team preformed two separate handling tests to ensure that the EMH string and transmission line could be safely and properly installed. Both tests generated valuable information long before the actual completion event and therefore provided timely information that was used to make corrections prior to field installation. The handling test resulted in better handling methods that eliminated contamination of the transmission line. It also revealed that a better seal material was required to sufficiently perform over the wide range of installation temperatures. Ball bearing centralizers were added to the transmission line tubulars to reduce drag when running the lines inside the outer steel tubular, and a coating was applied to the inner surface of the outer steel pipe to reduce risk of contamination in the transmission line. Several changes in the rig handling equipment were made such as as building a tong cart to handle the 168.3mm pipe and developing new methods to ensure correct rig alignment and sheave position for final installation of the instrumentation lines.

CONCLUSION

The ESEIEH EMH tool string was successfully installed using some unique completions methods and components. Prior to the actual completions event, various laboratory, qualification and rig handling tests were conducted on individual components to verify performance before delivery to the field. Harris Corporation (Melbourne, Florida, USA) and its consortium partners learned many lessons from these tests which resulted in improvements that directly lead to successful installation at the pilot site. Although the final installation was completed within the required specifications, streamlining some aspects of the completions, for example using pre fabricated flat packed instrumentation, would benefit future commercial trials.

Finally, it is worth mentioning the extreme persistence, teamwork, care, and attention to details exhibited by the field personnel to complete this installation. More information will be gathered during the commissioning and operating stages that will be used towards the commercial product. Success of this project has great potential to bring a step change to the Canadian oil sands technology.

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APPENDIX

1. ESEIEH Completions Schematic

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