Cyclic Steam Injection (CSI) Pilot Design

Execution towards Full Field Deployment

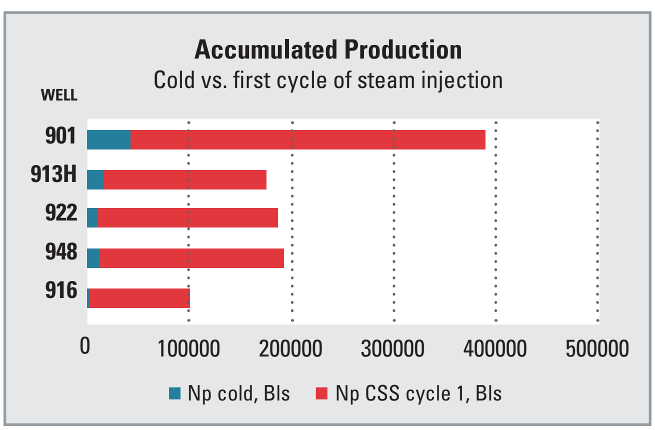
Most E&P operators are challenged with finding cost-effective solutions for improving reservoir recovery factors. Well planned CSI can provide significant benefits such as increased production, and increased recovery factor. Additionally, the earlier an operator applies the method, the more likely they are to gain positive economic results.

Field pilot can provide valuable knowledge on the feasibility and potential of CSI, reduce the full field deployment risks, and increase the operator's knowledge about the process. However, many field pilots take much longer than needed and are unsuccessful due to cost overruns, lack of clear results, inappropriate monitoring, disregard of important operations aspects, and lack of expertise.

The Halliburton method is a disciplined approach to CSI optimization that can determine the best scenario before beginning a pilot, reduce cost overruns due to trial and error, and reduce the amount of time to positive net present value. The CSI method can offer high final oil recoveries, with records indicating up to 65% of the OOIP when proper reservoirs are chosen, sound pilot designed, and execution par excellence. Halliburton can achieve this by acting as an integrated service provider with complete oversight of the entire process from visualization to evaluation of the pilot. Halliburton's approach offers the possibility of successfully executing a pilot prior to extending the technique in a cost-effective fashion.

Case Study

A multidisciplinary NOC-Halliburton team developed a pilot design based on results from the integrated reservoir study. The diagnosis study shows a steam-to-oil ratio (SOR) of 0.33 that increased cost efficiency about 9 times compared to the average as shown in the figure below.



Hot oil (first cycle of steam injection) was 11 times higher than cold which is 3 times higher than the worldwide average.

Applications

CSI is ideal for viscous oil reservoirs with good horizontal permeability and medium thickness net pay. Non fractured sandstones are preferred, but deployment in carbonate is also possible.

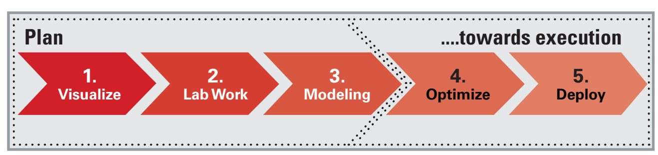
Typically, CSI is implemented right after the primary exploitation phase and in some cases as previous step for steam flooding.

Cyclic Steam Injection (CSI) Pilot Specifications*	
Reservoir Net Pay*	> 30 ft
Reservoir Temperature	> 200°F (93°C)
Horizontal Permeability*	> 250 mD
Viscosity of the Oil*	> 150 cP and < 15,000 cP
Formation Lithology	- Sandstone preferable - Limited application in carbonate or fractured formations
Reservoir Depth*	< 4,600 ft
Remaining Oil Saturation*	> 0.5

* Values ranges from successful application in the field, may vary under certain circumstances. Even if a parameter does not fall under the range mentioned, please contact Halliburton representative for confirmation.

Cyclic Steam Injection Pilot: The Five Phases Approach

Halliburton offers a tailored solution at any stage of your field's life by using a five-phase approach. The main advantage of the approach is that the operator can start the process at their convenience.



The above phases can provide clients:

1. Project kickoff and data assessment ensures a comprehensive reservoir review to evaluate performance and establish the risks for CSI.
2. Rock-Fluids analysis and detailed core laboratory tests and simulation input data increase the pilot's probability of success.
3. Base case and optimized case forecasts for the pilot, taking into account reservoir modeling and simulation, nodal analysis, and surface requirements.
4. Analysis of the impact of operational and technical uncertainties on the success of the pilot program.

5. First-cut economic analysis and forecast of the full-field implementation of the pilot design recommendations using stochastic techniques and smart optimization algorithms.

An operator's main concerns such as length of injection cycle, amount of steam to be injected, water source, conditions for water treatment plant or building and operating restrictions can be addressed to optimize conditions for the pilot.

Deliverables include a representative pilot area, well integrity analysis, rock and fluids characterization, suitable laboratory work program to evaluate changes in oil saturation during steam injection, numerical simulation, facility design, construction and operation among others.

Features of the Halliburton Approach

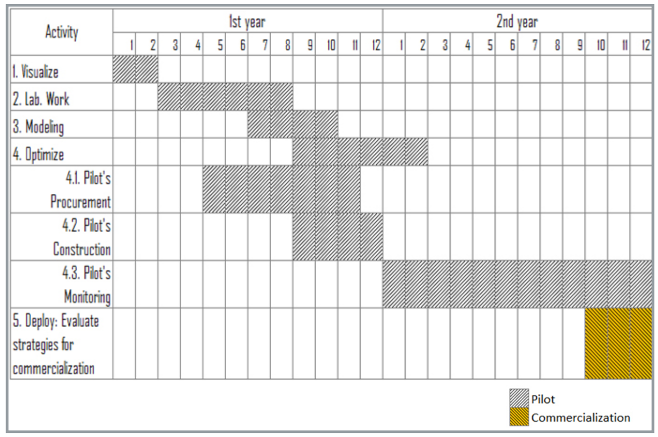
- Detailed laboratory analysis for improved simulation and estimation of production potential
- Designed for quicker production response from producer wells, improving pilot program and full program economic performance
- Stochastic analysis of risk uncertainty and optimized design using smart algorithms

The Halliburton Approach Can Provide the Following Benefits

- Offers early determination of potential effectiveness of development scenarios through the semi-quantitative Chance of Success (COS) methodology
- Maximizes available surface and subsurface infrastructure
- Reduces the level of risk at commercial application by addressing surface/subsurface operational parameters that can be unknown
- Quickly integrates the process at any stage during the life of the reservoir and supports the best operator workflow to plan and execute the pilot
- Provides accountability through all phases in the process
- Can provide the proper number of cycles, field operating conditions, steam quality, or specification for designing surface facilities
- Offers the possibility of acquiring an integrated view of the process when implementing the approach

Typical Project Schedule

Estimated project duration including execution and monitoring of a pilot is in the order of 24 months. Start of commercialization phase relies on the pilot's response.



Example of duration reported

Technologies

- Smart algorithms to optimize crude oil recovery strategies by looking at different uncertainty variables (k, porosity, thickness, oil price, operation costs) and decision variables (injection rate, time, soak time, steam quality). Our stochastic machine (DMS™) couples with analytical and numerical simulation models from different tools.
- DecisionSpace® well planning and WellCat™ software can assist in modeling multiple steam-injection scenarios, handling super-heated steam or saturated steam with a given quality.
- FiberWatch® service is a distributed temperature sensing technology to monitor steam profile.
- Chemical Management Services offer solutions to handle flow assurance issues by monitoring the response from pilot.

In summary, the Halliburton's Five Phases approach can provide a structured outlook including uncertainty, economics and risks for the pilot and first-cut economic forecasts for full field implementation.

For more information, contact your local Halliburton representative or visit us on the web at www.halliburton.com.

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