eSteam™

Disruptive Downhole Steam Generator for Heavy Oil Recovery

Introduction

Steam injection processes are used worldwide to recover heavy oil and oil sands. Since the first known application of steam in a Venezuelan oil field in the late 1950's, worldwide heavy oil production has undergone phenomenal growth, and is currently estimated at 2 million B/D. This growth, especially since the oil price collapse of the mid-1980s, is attributed primarily to three factors:

1. Higher and more stable oil prices
2. Lower capital and operating costs
3. Technological advances

The first two factors provided greater operating margins, which in turn allowed more projects to be installed on properties previously thought to be marginal, thus increasing production attributable to steam application. Technological advances that include geological, geophysical, reservoir, facilities, and production engineering disciplines helped reduce costs and improved recovery, thereby stimulating investment in heavy oil and oil sands. Important horizontal well advances made during the past decade have helped increase heavy oil and oil sands production.

Steam generated at the surface is currently the most common technology for in-situ thermal stimulation of heavy oil, however it has significant limitations due to heat loss that make it uneconomic for some 2 trillion barrels of deeper heavy oil resources. eSteam's™ downhole steam generator has the ability to unlock these deeper deposits and allow steam to be used where it was previously not economical.

Steam injection methods account for most of the heavy oil recovered worldwide as an Enhanced Oil Recovery (EOR) method. Currently heavy oil production is less than 7% of the world's oil production; this percentage is not expected to increase dramatically without significant changes in reservoir management. Surface Steam injection of viscous heavy oils has been used successfully since early 1960's.

eSteam's™ disruptive game-changing downhole steam generator substantially reduces wellbore heat losses and achieves the highest feasible quality steam, pressure and temperature in the reservoir. eSteam's™ unique, innovative methodology attains enhanced heat efficiency for less energy resulting in more oil production at a faster rate for a lower cost of steam.

eSteam's™ benefits compared to conventional OTSG surface steam injection are:

- Better economics based on lower:
  - Steam-to-oil ratio
  - Produced-water treatment costs
  - Capital cost of surface facilities
  - Operating and lifting costs
- Significantly improves mobility-ratios
- Decreases the amount of steam injected into the reservoir
- Superior steam distribution at the reservoir interval improves sweep efficiency
- Delivers high-quality steam to reservoirs below 2,500 ft. with no depth limitation
- Mobile, scalable zero emissions heater
- No moving equipment in the wellbore

Downhole steam generator development activities began with the Department of Energy program carried out at Sandia National Laboratories, Albuquerque, New Mexico. This was followed by an objective of commercializing the development work from Sandia for future extractive methods for heavy oil.

In 1982, the Department of Energy (DOE) and Sandia National Laboratories (Sandia) began a downhole steam generator project known as "Project Deep Steam". This project was based on the premise that significant reserves of heavy oil, worldwide, were beyond the reach of surface generated steam, i.e. heat losses to deep formations were too great to provide any effective stimulation at a depth set at around 2500 feet. In order to achieve the goal of steam delivery to deep formations, an initiative was taken to improve or develop new injection string to minimize heat loss and the other to design and demonstrate the operation of a device, which would generate steam in the wellbore at the depth of the formation. In 1976, the DOE funded Sandia $26 million budget over six (6) years. In carrying out this mission, Sandia initiated an in-house effort for the downhole steam generator development. In 1982, the DOE and Sandia began a field development test in the City of Long Beach to place two direct contacts, high-pressure combustors in the Wilmington Oil Field. The field test was burdened with limited success.

Sandia's downhole steam generator had several customary objectives such as reliability, feasibility, and minimum environmental impact. A criterion was established that all assemblies could not exceed 4.5 inches in diameter. This figure was consistent with the inner diameter plus fishing margin for a 7-inch casing. In order to achieve firing rates of significant magnitude, it was necessary to carry out the combustion process at high pressure. Sufficient surface for efficient heat transfer was a major objective.

eSteam's™ downhole steam generator met all of Sandia's objectives and more. Therefore, eSteam™ can be particularly suitable for recovering many heavy oil deposits around the world that have experienced low recovery efficiencies through primary and secondary (waterflood) production methods. These deeper heavy oil resources typically require thermal stimulation to reduce viscosity in-situ for improved production volumes. eSteam's™ downhole steam generator has overcome the technological constraints of deep heavy oil production. eSteam™ has developed a zero emissions surface boiler that has eliminated air quality issues. eSteam's™ downhole steam generator can be operated without maintenance for long periods of time since there is no moving equipment downhole in the wellbore that is a uniqueness of the downhole environment. Furthermore, eSteam's™ downhole steam generator is not an electrical or combustion technology that eliminates special requirements imposed on a downhole combustion system. eSteam™ has mitigated the technical challenges that include tool positioning and inaccessibility, installation and operational safety, pressure and temperature management. eSteam™ has demonstrated the potential to reduce wellbore heat losses, create optimum steam, pressure and temperature in the reservoir that will provide better steam distribution resulting in improved sweep efficiency with lower residual oil saturation. eSteam™ exhibits a new generation of thermal in-situ EOR technology to improve conventional SAGD, unlock deep heavy oil resources as well as those in environmentally challenged locales such as California, Canada, and arctic environments.

A horizontal well method, called Steam-Assisted Gravity Drainage (SAGD), is currently used to tap Canada's huge hydrocarbon resource, and has become extremely popular. It involves a pair of horizontal wells with one used as a surface steam injector overlying the other used as an oil producer. eSteam's™ downhole steam generator has improved on conventional SAGD that provides for three (3) novel options: One methodology is for downhole steam to be created near the bottom of the vertical wellbore and then released into the horizontal wellbore that should allow the steam to reach the toe of the horizontal wellbore instead of mostly hot water in the latter half of the horizontal wellbore; second methodology is to create the downhole steam directly in the horizontal wellbore; third methodology is to create downhole steam in a plurality of vertical wells overlying a horizontal production well.

eSteam's™ downhole steam generator has substantially reduced wellbore heat losses, greatly improved the quality and rate of steam injected into the formation at certain specified values for the optimum operation of a steamflood in vertical wells and we expect similar or better results in SAGD wells.

The heavy oil production from high quality steam and Btu's delivered directly into the subterranean formation will vary depending on the reservoir characteristics.

Reference: Marshall, Billy W., Sandia Natl. Laboratories, Project DEEP STEAM, Preliminary Field Test, Conference Paper presented at the SPE California Regional Meeting, 24-26 March 1982, San Francisco, California, Publisher-Society of Petroleum Engineers, Document ID--10744-MS.