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Fiber-Optic Down-Hole Sensing: A Discussion on Applications and Enabling Wellhead Connection Technology

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Abstract

In the current climate of high oil & gas prices and forecast future shortfall in reserves, it is critical that new technology be implemented to maximize recovery from any suitable reservoir. One of the most promising areas of offshore oil and gas R&D has been the ongoing development of improved reservoir and production monitoring technology implemented using fiber-optic sensors. This paper will contribute new performance data for fiber-optic connection systems and sensor requirements and will document and contrast the various sensor technologies and their capabilities and applications.

This paper provides a review of the advancements in fiber-optic in-well sensing technologies and the applications to which they can be applied, set-in context with the importance of optimizing reservoir performance. This is combined with an analysis of the development and qualification of fiber-optic feed-through systems that are a fundamental technology for the installation of in-well optical fiber. This discussion will include design guidelines for feed-through systems and will be supported by case studies for the sensor and feed-through systems proposed for BP Atlantis in the GOM, and BP's West Africa project, Greater Plutonio.

The paper also offers a design guideline for the qualification of fiber-optic feed-throughs for horizontal and vertical trees and landing strings, and the fiber and system performance criteria for optical fiber sensors of various types. It will review the measurement capabilities and system requirements of various fiber sensor systems and will present the design problems, qualification methodology and test results for the development of fiber-optic feed-though systems for both vertical and horizontal X-trees.

Introduction

Historically, the oil industry has always produced reserves as efficiently as available technology and the often incompatible demands, of early payback of CAPEX investment and maximization of lifetime recovery permit. This has led to an average production of oil in place of ~35%. With the application of a variety of "Intelligent Wells" technologies, the down-hole system suppliers are forecasting that this lifetime recovery can be improved to between 50% and 60%. Recent estimates of reserves based on current recovery rates show that the industry has identified reserves for only 85% of forecast demand. This requires that the operators increase exploration, typically now into politically or technically difficult regions and also use advances in production technology to permit re-evaluation of identified reserves. These varied technologies are often grouped under the heading of "Intelligent Well or Smart Well Technology" [Ref 1].

The forecast step change in recovery is due to the combination of Intelligent Well technologies**.** Prior to the development of in-well sensors, the only viable means of gathering down-hole information was through periodic intervention based on logging techniques. Although these provide valuable data, the intervention process is both costly and has an inherent risk of damaging the well. This led to infrequent logging, compromising the ability to optimize production. Consequently, the need for better down-hole technology, providing intervention-less flow monitoring and flow control has been identified. The on-going challenge is to develop cost-effective, reliable solutions.

There are a number of technologies that together promise the ability to significantly increase recovery. These include:

- Electrical down-hole sensors, providing point source temperature and pressure monitoring.
- Flow rate and water content sensors.
- Down-hole electro-hydraulically actuated flow control systems.
- Improved reservoir modeling based on frequent or real-time reservoir performance data.
- Fiber-optic down-hole sensors with higher reliability at elevated temperature than electrical sensors.
- The development of both electrical and fiber-optic well-head wet-mateable penetration systems.