Introduction

Since Conventional oil wells have limited and diminishing returns, newer techniques are being devised to recover oil from unconventional sources. One potentially abundant unconventional source is oil shale (aka kerogen shale). A new method of “In-Situ Retorting” for converting kerogen shale to oil is under development and requires special techniques to monitor the in-ground process. A key technique is distributed temperature sensing (DTS) using optical fiber cables, but DTS at temperatures above 300° C is not possible with optical fibers using polymeric coatings. Gold coated optical fibers manufactured by Fiberguide Industries have been employed in a DTS system for a pilot project conducted by American Shale Oil, LLC.

Conventional Versus Unconventional Oil

The conventional method of obtaining oil is to drill a well into an underground location where the oil flows freely from a pool of oil called a reservoir. As the number of conventional reservoirs has diminished, the price of oil has increased. Fortunately, conventional oil sources are not our only option. Oil exists in other geological formations where the petroleum is extracted using techniques other than conventional oil well methods. These unconventional oils such as oil shale are now becoming economically and technically accessible because of higher oil prices and new technologies.
“Shale Oil” and “Oil Shale” Confusion – They are not the Same

The most common current usage of the term “Shale Oil” is oil that exists in rock formations where the rock is not sufficiently permeable for the oil to flow freely through the rock to a well hole drilled into the rock formation. Shale oil is more accurately termed “tight oil”. Hydraulic fracturing (aka “fracking”) is a modern technique for creating fissures in the rock and injecting special fluids (water, sand, and chemical mixtures) at high pressure to free up the oil and force it toward horizontal wells. Once removed from the ground, the oil is ready to be delivered to existing refineries to be separated into various fuels and chemical intermediaries.

“Oil Shale" is not the same as Shale Oil, but it can be used as a source of creating petroleum products. Oil shale (aka kerogen shale) is an organic rich fine-grained sedentary rock containing kerogen. Kerogen is an intermediate chemical state created from decayed organic matter before it is transformed into petroleum in the earth. There are man-made processes (retorting) to produce oil by heating kerogen to sufficiently high temperatures (pyrolysis).

Figure 1 below is an example of oil shale rock.

Figure 1: Oil Shale Rock

Source: [http://www.southampton.ac.uk/~imw/Kimmeridge-Oil-Shale.htm](http://www.southampton.ac.uk/~imw/Kimmeridge-Oil-Shale.htm)
Figure 2 projects tight oil contribution to past and future energy sources that are providing the current boost to US production, but tight oil will go through a peak and will decline steadily. As tight oil declines, oil shale should become a common source of oil within the next 10 years and come on stream when tight oil is declining.

![Figure 2: Past and Future Petroleum Energy Sources](http://amso.net/peak-oil/)

**DTS as Key Tool for Monitoring Extraction of Unconventional Oil**

Extracting unconventional oils has been made more efficient with sophisticated techniques including the ability to measure temperature of the entire well system. Distributed temperature sensing (DTS) allows monitoring the temperature at many points along the well where optical fiber cables are the temperature sensor element. In most in-well DTS systems special optical fibers with polymeric coatings are commonly used in the cables rated for temperatures as high as 300°C. Polymeric coated fibers have very limited life expectancy above 300°C.
High Temperature DTS for Oil Shale In-Situ Retort
Gold Coated Fiber as Key Enabling Technology

Application Note 13-0819

In-Situ Retort Temperature of 350°C or Greater Require Metal Coated Fibers

Temperatures required to convert kerogen to oil are 350°C and higher. Fiberguide Industries’ gold coated optical fiber withstands temperatures of up to 700°C which readily handles the temperatures necessary. Detecting hot spots is vital to controlling in-ground systems.

In-Situ Retorting

The trapped oil can be decomposed and released through chemical processes by mining and treating the shale called retorting. Alternatively, the shale oil can be retorted in the ground (“in-situ” retorting) by heating the shale directly, pumping the oil to the surface, and refining the recovered shale oil.

![Figure 3: Oil Shale Alternative Recover Schemes](http://commons.wikimedia.org/wiki/File:Oil_shale_extraction_overview.png)
American Shale Oil (AMSO) Pilot Program

Fiberguide Industries’ gold coated optical fiber was recently used in an RD&D test program of oil shale in-situ recovery run by AMSO which reported their initial result at the 32nd Oil Shale Symposium in Golden Colorado on October 15-17, 2012. This paper is on the AMSO website:

http://amso.net/wp-content/uploads/2013/01/603ae0ae-d2c2-4f74-ba44-a26ca9f7e67c.pdf

DTS at 400°C Enabled with Fiberguide Gold Coated Optical Fibers

One of the key objectives of AMSO’s pilot program was to measure the actual well temperatures. Monitoring the well temperatures continuously is essential for properly controlling the amount and rate of heat applied, which ultimately determines the amount of oil recovered by the in-situ retort process.

The DTS system used by AMSO was supplied by Petrospec, who is a leader in applying fiber sensing technologies to technologically challenging oil recovery applications. Petrospec’s Xtreme-Duty™ DTS system is rated to 700°C.

http://www.petrospeceng.com/gorex/extreme-duty-dts

Although the paper referenced above does not give any details about the performance of the DTS system and the gold coated fiber from Fiberguide Industries, both AMSO and Petrospec are reasonably satisfied that the initial DTS trials were successful in detecting hot spots up to the maximum well temperatures, which reached almost 400°C over several hundred meters of fiber.
Bibliography / Links:


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USGS Oil Shale Site: [http://energy.usgs.gov/OilGas/UnconventionalOilGas/OilShale.aspx](http://energy.usgs.gov/OilGas/UnconventionalOilGas/OilShale.aspx)

American Shale Oil: [www.amso.net](http://www.amso.net)

Petrospec: [http://www.petrospec.net/](http://www.petrospec.net/)