Monitor gas, oil, and water levels in the fracture system of a carbonate formation regularly and cost-effectively to optimize steam injection and liquid offtake rates during thermal recovery of heavy oil.

Deploy WellWatcher BriteBlue HT high-temperature multimode DTS fiber to record the differential thermal relaxation in gas, oil, and water following a temperature perturbation.

Accurately determined fluid contacts—with lower operating costs and lower HSE exposure—to within 1 m of wireline gradiomanometer surveys, leading to deployment of the fiber in 14 observation wells in preparation for startup of the full-field thermal recovery process.

An operator uses thermally assisted gas-oil gravity drainage (TA-GOGD) to produce heavy oil from a highly fractured carbonate reservoir in Oman. Steam is injected into the fractures, generating a gas gradient across the carbonate reservoir so that the oil drops down by gravity. The steam also heats the reservoir so that the reduced-viscosity oil drips out faster. Reservoir pressure is kept low by using aquifer pumpoff wells, which maintains high steam quality and creates a large density contrast between the light gas and heavy oil for efficient gravity drainage.

Gas, oil, and water levels in the fractures and in the matrix are different. Oil extracted from the carbonate accumulates in the fracture oil rim, from where it is produced by wells intersecting the fractures. Reservoir surveillance needs to provide regular measurement of the various fluid levels in the fracture system, so that the oil rim position and thickness can be managed by adjusting the offtake rates of oil and aquifer water. With 14 observation wells, steam injection surface facilities, and downhole temperatures of 247 degC, frequent wireline gradiomanometer interventions were costly, impractical, and presented HSE exposure.

Schlumberger proposed a novel deployment of WellWatcher BriteBlue HT high-temperature fiber to measure distributed temperature. An observation well was completed with open hole across the reservoir. A ½-in U-tube was clamped to the outside of predrilled tubing run in the hole; fluid levels inside and outside the tubing were at equilibrium with the fluid levels in the fractures. Inside the U-tube, a ¼-in control line was placed containing the double-ended optical fiber in nitrogen gas.

A DTS measurement cannot indicate fluid levels if the fluids are at thermal equilibrium; therefore, a temperature perturbation that did not change the fluid levels had to be introduced. Water 10 degC cooler than the expected reservoir temperature was circulated by a pump connected to the U-tube containing the double-ended WellWatcher BriteBlue HT high-temperature multimode DTS fiber to induce a thermal perturbation for monitoring the levels of gas, oil, and water in the formation.

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Initial temperature logs of the warming water at the depths of the fluid contacts. Real-time visualization software enabled quality control of data and provided approximate fluid contact depths. Further analysis was used to refine the results, leading to injection and pumpoff profile changes to optimize reservoir drainage.

The fluid contacts identified with this technique were within 1 m of the levels measured using gradiomanometer logs and are sufficiently accurate to manage the oil rim. The field trials were done in a “cold well.” Once the reservoir is heated, pumping cool water will create a larger temperature change in the U-tube, leading to longer relaxation times and more accurate measurements. Fourteen observation wells have been completed with this system in preparation for the startup of the full-field TA-GOGD process.

Reference

Achieve accurate results with lower surveillance opex and minimized HSE exposure
With the pump stopped, the rate at which the cooler water inside the U-tube reached thermal equilibrium with the warmer wellbore fluids was measured via rapidly repeated distributed temperature surveys. This temperature recovery is known as thermal relaxation. Gas, oil, and water have very different specific heat capacities and thermal conductivities, so each surrounding fluid took a different amount of time to heat the water inside the U-tube. The differences caused sharp discontinuities on the temperature was pumped through the annulus between the U-tube and the control line. The pumping continued until the temperature in the U-tube at reservoir depth fell to about 6 degC below that of the surrounding wellbore fluids. Immersed in nitrogen, the fiber was protected from both water (hydrogen exposure) and the mechanical strain caused by friction with a moving fluid.

When the pump was stopped, the time taken by the cooler water inside the U-tube to reach thermal equilibrium with the warmer wellbore fluids was a function of those fluids. The exponential time constant is a measure of this relaxation time—the discontinuities indicate the depths of the oil/water and gas/oil contacts. Although the time constant for gas is theoretically higher than for oil, the cooling effect of convection currents created in the gas by this completion design resulted in a sharp drop instead.

Injection of cold water for one hour produced a significant drop in temperature along the length of the fiber. The discontinuity toward the right side of the graph is caused by the transition from cased to open hole.

CASE STUDY: WellWatcher BriteBlue HT fiber enables accurate monitoring of fracture oil rim, Oman