

# Fiber-Optic DTS Flow Profiling Installed in Advanced MRC Well

Richard Kluth, SPE, Sensornet; and Garth Naldrett, SPE, FloQuest

The current decline in crude oil prices has created major interest in methods that significantly reduce overhead and improve efficiency in operations. Distributed temperature sensing (DTS), used for advanced, in-well permanent monitoring, is a technology that can deliver on both of these objectives.

DTS has demonstrated long-term reliability, high performance, and application benefit in a range of production- and injection-well types. An area of particular interest is the application of monitoring in horizontal and advanced well completions. While allowing significant improvements in production and reservoir depletion, these wells have caused data-gathering disruptions for the operators. In particular, the options for performing well logging are much reduced, and the costs of performing a production log extremely high. These factors are related to the costs of both the more advanced horizontal well-logging tools and the more expensive logging

methods—such as coiled-tubing and tracker systems—used to convey these tools into the wellbore.

DTS allows this monitoring gap to be closed. In line with advancements in this technology, Sensornet and FloQuest have developed a real-time digital flow-profiling system, which aids increased production, reduces operating costs and improves recovery. Digital flow profiling with DTS is used to determine distributed flow-allocation profiles in production and injection wells. The system combines DTS fiber-optic technology with software modeling and data interpretation (**Figs. 1a and b**).

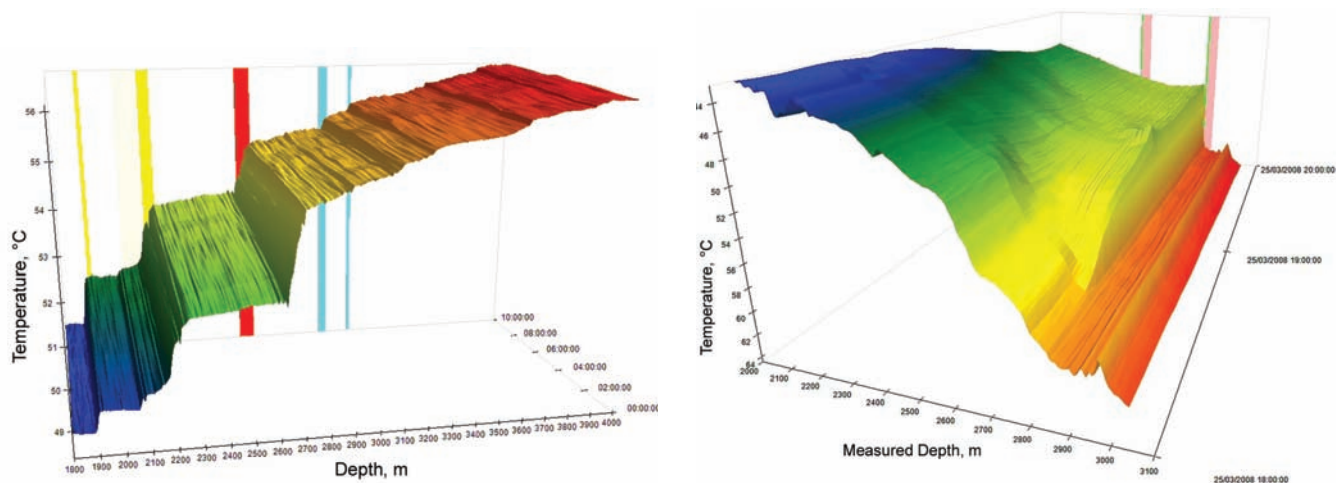
The combination of the two technologies enables accurate location of fluid entry points across an entire reservoir. The result is a permanently installed system providing continuous data similar to that obtained from a production-logging tool (PLT), even before the completion is locked down.

The key to obtaining accurate and reliable flow information across the

reservoir interval by means of DTS data relies on two principal factors. First, the DTS system must be able to detect very fine temperature changes. (The DTS system discussed here can measure temperature changes of less than  $0.01^{\circ}\text{C}$  at all points along the reservoir.) Second, to extract valuable information from the temperature data, it is essential to combine it with information on the geology, reservoir fluids, and the completion. In the system under discussion, this information is obtained by means of interpreting data from software models.

Two main areas of innovation have been combined to provide digital flow profiling:

- Improvement in DTS metrology, achieving better than  $0.01^{\circ}\text{C}$  temperature resolution. (Temperature resolutions as fine as  $0.004^{\circ}\text{C}$  have been achieved in the field.) This allows detection of very small temperature differences in commingled horizontal wells and near real-time, full-range



**Figs. 1a and b—(a) A 3D flow profile obtained by means of real-time DTS monitoring technology and data-visualization software. (b) A visualization of real-time flow variation monitored at the downhole choke.**

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- Development of software enabling the efficient management, visualization, and interpretation of DTS, production, completion, and petrophysical data.

In addition to improving production and sweep efficiency, the information obtained during, or soon after, completion installation can enable significant operational improvements. By using a permanent cable and monitoring the fiber during installation, it is possible to determine the location of any fluid losses. It also becomes possible to monitor well stimulation or fracturing immediately after installation. Using the temperature profile, the operator is able to see, in real time, the effect and efficiency of its wellbore treatment.

The system provides continuous PLT-type data in highly deviated and complex wells, without the costs, risks, and deferred production associated with conventional logging techniques. In addition to monitoring the flow distribution in production and injection wells in real time, the system provides information often not accessible with traditional PLT technology. Traditional techniques often only provide a snapshot of what is really happening in the well, whereas digital flow profiling provides real-time data, allowing the operator to view changes in the well as they occur and to make timely decisions to help optimize production.

Another advantage of the digital flow-profiling system is reduced operating costs because of fewer PLT interventions required. A PLT intervention can cost from USD 400,000 to 800,000 on an offshore installation, and an offshore platform generally has 18 or more wells. A typical logging regimen includes seven to 12 PLTs run annually at approximately USD 570,000 per well. The use of digital flow profiling could mean potential annual operating savings of approximately USD 5 million. Any compartmentalized, complex reservoir will benefit through better characterization, enabling more informed well planning. Improved well planning because of digital flow profiling can result in operators needing to drill fewer wells. Simply eliminating one well from an offshore drilling program can save USD 30 to 40 million.

Further benefits include:

- Reduced personnel exposure to wellsite risk because of the reduction/elimination of PLTs
- Reduced risk to well integrity and no risk of equipment lost in hole
- No deferred production from logging campaigns
- Better understanding of the placement of acids and inhibitors, which can reduce the volume of fluids injected and result in operational and environmental improvements
- Transferring undesirable operating spending into capital investment
- Potential reductions in the number and depth of wells drilled

### Case Study: DTS Flow Profiling of Complex MRC Well

The digital flow-profiling system was recently deployed for a major operator in the Middle East and involved the successful installation of the world's first distributed fiber-optic monitoring system in a maximum-reservoir-contact (MRC) well.

Over the past 6 years, the operator has pioneered the use of intelligent-well systems in its MRC wells to reduce development costs and minimize water production and early gas breakthrough. Its original MRC wells included open-hole laterals, drilled from a 7-in. completion liner, to provide the required contact/reservoir footprint to optimize rate and recovery.

More recent designs have used smart-well-completion technology in the 7-in. cased motherbore to control inflow from each lateral, extending well life and increasing recovery. In the event of water/gas breakthrough in any lateral, the downhole valves are remotely operated from the surface through hydraulic and instrument lines run outside the production tubing.

These types of wells are considered the most complex yet monitored by fiber-optic DTS technology. The digital flow-profiling system was deployed as part of a trial to monitor continuously the flow contributions from two laterals and the motherbore of a multilateral well. Deployment in the 14,500-ft well was achieved in less than 2 days, despite the need to pass the DTS cable through three production packers and three inflow control valves (ICVs) en route to the top of the liner.

The type of DTS system used in the field trial afforded a significant benefit because a fixed fiber was already in place, which enabled continuous monitoring of the system during the installation. This resulted in a high degree of confidence in the system's operation during deployment and enabled completion equipment to be monitored during operational tests, before the production packer was set. Thus, each ICV could be tested individually during run-in-hole operations. This enabled the confirmation of correct operational sequences, as well as fluid-circulation and zonal-isolation events.

In the trial, digital flow profiles were able to provide a constant stream of high-resolution, real-time data, along with interpretation. Complete temperature profiles were captured, validated, and delivered. Operation of the flow-control valves was confirmed, and flow rates were allocated from each producing zone. The PLT-type flow information was available continuously, making PLT intervention unnecessary, saving the cost of logging, and eliminating logging-related production risks.

Initial data from the installation have proven the required resolution of 0.01°C has been achieved, despite the fiber length and three in-well cable splices.

The result is a permanently installed, continuous well-logging system. It provides a temperature profile across the length of the well and enables flow profiles to be obtained that can be used in numerous applications, including:

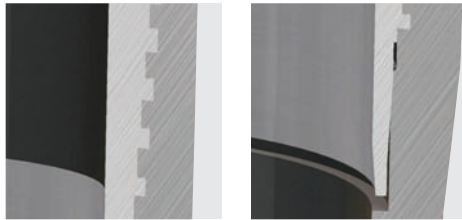
- Measurement of flow contribution from different zones
- Continuous allocation of production in real time
- Confirmation of intelligent well-control-valve position
- Configuration of intelligent well-control valves to optimize production
- Observation of well stimulation
- Monitoring of well unloading during cleanup
- Observation of fluid movement behind casing and crossflow during shut-in

The client plans to install additional DTS monitoring systems to perform real-time monitoring of lateral contributions in future MRC wells. **JPT**

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