AN INTELLIGENT APPROACH

Savio Saldanha, Halliburton, USA, discusses zonal control in multizone mature fields.

With significant advancements in drilling and completion technologies, many operators are revisiting their strategies for their mature fields as an incremental source of oil production. Various enhanced oil recovery (EOR) techniques have been explored to exploit these incremental reserves. Wells are being strategically re-drilled to accommodate a desired injection flood pattern, laterals are sidetracked from the existing wellbores to maximise the drainage area, and long extension horizontal wells are being drilled to maximise the payzone for production or injection. The economic benefits of multilateral (MLT) or extended reach technologies are well known. Operators are continually looking to increase the number of laterals in a single wellbore or extend the reach of a horizontal wellbore. The challenge, however, lies in determining how to efficiently control the number of laterals or the numerous compartments in a horizontal well. Intelligent completions provide operators with the ability to optimise their reservoir management processes by enabling remote monitoring and

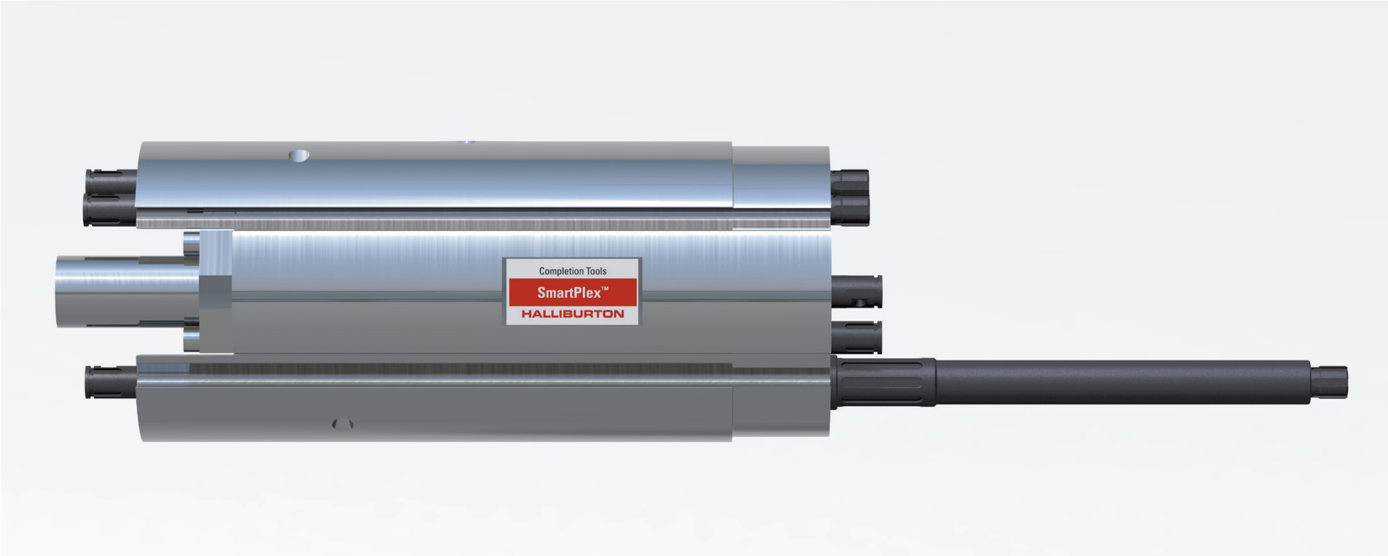

Figure 1. *Electro-hydraulic control manifold.*

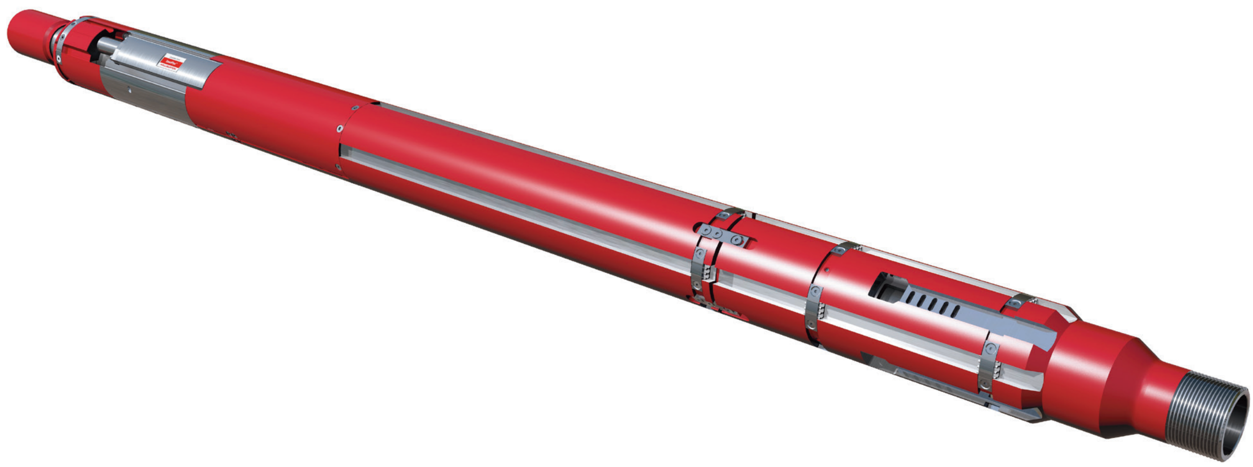

Figure 2. *ICV electro-hydraulic manifold.*

control of their reservoir intervals. The reliability and benefits of current intelligent completion technology is known and widely accepted. Intelligent completions have been deployed in many MLT wells or extended reach horizontal wells worldwide. However, the maximum number of zones that can be controlled economically and efficiently using the traditional direct hydraulic (N+1) control architecture is six zones.

The limitation for using direct hydraulics to control more than six interval control valves (ICV) in a single wellbore include the following:

- Limited penetration for additional hydraulic lines with existing wellheads.
- Add-on cost/ft for each additional line required for every additional ICV.
- Longer valve actuation times for extended reach wells.
- Special flatpack, clamps, and handling accessories (for more than six lines).

New ICV control system

To address these limitations, Halliburton has recently developed and trial tested a new electro-hydraulic downhole ICV control architecture called the SmartPlex® downhole control system with a major operator in the Middle East. The new control system provides selective control of ICVs in an intelligent completion, which is operated remotely from the surface. With three control lines (two hydraulic lines and one electrical line), up to 12 ICVs can be selectively controlled. The system uses passive electrical components to enable multiple ICVs to be connected to the same three control lines. Each ICV is coupled to a manifold (Figure 1) that houses an electromechanical gate. A surface controller enables remote selection of any gate in the system. After the desired gate is selected, electrical current from the surface is activated to open the selected gate. This action enables hydraulic fluid from the surface to communicate with the desired ICV. Depending on the direction in which the ICVs need to move (i.e., open or close), pressure is applied to the corresponding control line, and remains under pressure until all ICV moves have been completed in the desired direction (i.e., open moves for all desired ICVs before proceeding to close moves).

Reliability of an electrical or electro-hydraulic downhole ICV control system is essential for a multizone intelligent completion system. To address reliability concerns, the electrical control line and the electrical chamber of the control system manifold are filled with dielectric hydraulic fluid and maintained under pressure to keep the internal biased to the external environment, preventing failure of the termination as a result of fluid ingress (flooding) into the electrical chamber. A special electrical wellhead outlet at the surface enables the hydraulic fluid in the electrical line to be monitored and filled, if required.

The most basic version of the new control system in a multizone completion will operate simple open/close ICVs. However, for advanced reservoir management applications, an upgraded version of the control system enables the ICVs to be manipulated to the desired choke position. The choke positioning of the ICV is achieved by controlling the time required for the fluid to vent from the closed chamber of the ICV for a desired choke position. A surface callibration followed by an in-situ calibration is conducted to validate the time required for the choke to travel from a full-close to open position. This total time is then divided by the number of choke settings on the ICV flow trim to derive the time required to vent (fluid from the close chamber) for each choke setting. The two callibration events assures accuracy of the choke positioning. The results of the calibration for each choke setting is entered from the surface automated panel. The surface automated controller handles all ICV operations intelligently. First, the desired ICV is selected, and then the desired choke setting is selected. The surface controller handles the ICV manipulation automatically by controlling the time that the directional control valve (DCV) at the surface panel remains open (for the close line) for the desired ICV choke setting. After all ICV open moves in the system are conducted, the controller automatically bleeds down all system pressures.

Benefits

The new control system provides many advantages for ICV control, as compared to all-hydraulic or all-electrical control systems.

- As the system uses three control lines to control up to 12 ICVs, the number of control lines required for each valve is reduced. On a 12-zone completion, the new control system provides more than 75% savings in control line cost, as compared to a 13 line flatpack using direct hydraulics.
- Significant Opex savings are derived when comparing the time required to actuate ICVs with the new control system, as compared to those that use a direct hydraulics control system. With the new system, the hydraulic control lines are pressurised once and remain pressurised until all valve actuations are complete. This functionality effectively reduces the operational time required to pressure up and bleed down control lines multiple times to move multiple ICVs with direct hydraulics control architecture.
- The new system uses a simple method to discretely position the ICV choke by controlling the time required for the fluid to exhaust from the hydraulic chamber of the valve. This simple method eliminates the need for high end J-slot or hydraulic metering modules that can significantly increase equipment costs, which are impractical for the cost-sensitive mature field.
- The reliability of electrical systems has improved over the years; however, a single failure mode (such as a termination failure) can bring down the entire system. The new control system addresses this failure mode by fluid-filling the electrical system with a pressurised dielectric hydraulic fluid and keeping it biased to the outside environment. This approach is not only proven and reliable, but also eliminates the need for expensive electrical bulkhead termination, keeping the price point for this system in line with the mature field market segment.

Field trial

A major operator in the Middle East has been trial testing various technologies to improve and optimise its reservoir drainage area. Zonal control is an essential requirement for this strategy. The pilot well was an extended reach horizontal well that was compartmentalised into six intervals, with a requirement to monitor and control each interval. A six-zone SmartPlex system using ICVs (Figure 2) for zonal control was proposed. On the monitoring side, permanent downhole electronic gauges, multi-dropped on a single tubing-encapsulated conductor (TEC) wire, were planned. A fibre optic line was also planned as part of the completion solution for distributed temperature profiling. Finally, for zonal isolation inside casing, packers with the ability to feed through the required control lines were recommended.

A team of dedicated individuals both from the operator and service companies had numerous meetings to discuss and formulate a plan to perform the completion in accordance with the design. Several system integration tests (SITs) were performed to enable the operational crew to become familiar with the technology, especially with splicing and terminating electrical and hydraulic lines. Bottomhole assemblies (BHAs) were prepared in the shop to minimise the number of electrical or hydraulic lines that would be terminated on the rig floor, reducing rig time. Job safety analyses were conducted to ensure that all rig site activities could be optimised, yet be performed safely.

The job was successfully completed with no health, safety, or environment issues or downtime. Because this was the first installation of this technology, extra precautions taken resulted in a slower make-up and run-in-hole time, as compared to conventional intelligent completions. Once on bottom, all ICVs were functioned open and closed. The control lines were then fed through the tubing hanger, the tubing spaced out, and the hanger landed. The tubing was then pressurised to set all of the zonal isolation packers. The special wellhead outlet was connected to the wellhead, and the control system electrical line was fed through the outlet. After the wellhead was installed, the ICVs were tested again with the portable control unit. At the time of writing, the automated control panel was being installed at the wellsite.

Conclusion

Lessons learned from the first successful field trial will be used to refine field procedures for subsequent installations. The technology has given the client confidence to implement the new control system on additional wells. A second generation of the control system is currently being developed that will enable electronic gauges to be deployed on the same electrical line that controls the ICVs; this enhancement will provide additional cost savings by eliminating the electrical line currently required to deploy several electronic gauges on a single line. The field trial has proven the reliability of the new technology; the cost savings and benefits described in this article make the new downhole ICV control technology a suitable solution for zonal control in multizone completions for mature fields.