Intelligent well systems advance toward maturity

Dr Guy Vachon, Baker Oil Tools

INTELLIGENT WELL TECHNOLOGY made significant progress during 2003. The number of installed **Baker Oil Tools** systems in 2003 was almost equal to the total accumulated number of installations in the previous four years. Several new milestones were reached including installation of an all-electric intelligent well system in a subsea deepwater application and installation of hydraulic choking valves.

There has been an increased interest in and use of three and four zone intelligent completions and applications on injectors as well as broader consideration of ESP applications. The industry is witnessing significant changes in attitude towards use of this technology. In the past operators had studied the potential benefits. A few have been tentatively testing the technology in order to gain first hand experience regarding the risks and issues in the context of intelligent wells. The acceleration in activity last year resulted in two important trends. Emboldened by recent successes and rising reliability rates, more operators are trying their own "experiments".

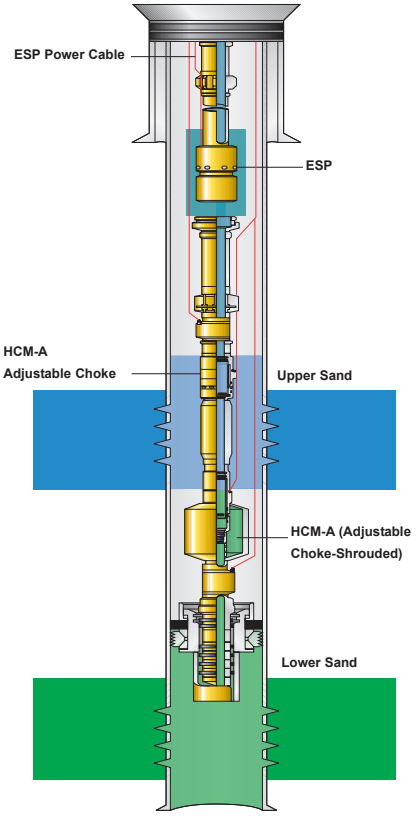
More importantly, those with experience in the technology are finding template applications with proven economic advantage. These applications are finding their way to standard completion practice.

Another interesting fact is that two-thirds of the producers are artificially lifted wells operating on borderline economics. The economic successes of intelligent well technology applied to these wells immediately crushed the myth that intelligent well technology can only be economically justified in high-end applications.

Another hint to this is the observed distribution between land wells, platform wells and subsea wells; two land wells and two platform wells have been installed for every subsea well.

IMPROVED RELIABILITY

Intelligent well technology reliability remains a concern with most operators but the facts prove that the technology is a relatively safe investment. As of this writing, Baker Oil Tools installed a total of 38 hydraulic sleeves and electric valves in 27 intelligent well systems of varying complexities. The total accumulated days of operation have been in excess of 35 years and none of the hydraulicly operated sleeves or electric ly operated valves have failed to date.



An example of a "typical" intelligent completion with commingled production from two zones with adjustable chokes and artificial lift provided by en electric submersible pump.

However, intelligent well systems include the zonal isolation methods, hydraulic and electric control lines, connectors, expansion joints, downhole wet-connectors and other accessories that contribute to the overall system reliability.

The overall performance of these components is again much higher than most operators expect. For example, the company has recorded zero failed electric or hydraulic connectors out of more than 250 installed connectors. No failures have been recorded either on any of the above mentioned accessory components other than control lines.

The company recorded five failed hydraulic control lines out of almost 80 hydraulic and electric lines deployed. These failures occurred during the early stages of the technology and directed changes in running procedures as well as adoption of various safeguards. The longest recorded operation of a single hydraulic operated valve is 3 ½ years and counting.

The rapid maturing of new intelligent well systems results from their having been built on proven technology that has been used for many years in safety valves and conventional sliding sleeves. To date, the company has run more than 15,000 tubing retrievable safety valves and almost 10,000 sliding sleeves with almost negligible failure rates. A successful track record in intelligent well technology needs to be maintained as this technology particularly is only perceived to be as good as its last installation. Equipment design and deployment practices are being improved constantly in order to stay ahead of operators' expectations.

ADJUSTABLE CHOKES AND ESPS

Baker Oil Tools installed multiple hydraulic adjustable chokes under an ESP in Ecuador in December 2003. It incorporated pressure, temperature, and flow measurement devices to commingle and optimize production from two zones. The intelligent well system provides full zonal control and real-time data monitoring, thus allowing the operator to monitor and optimize the production from each zone.

This intelligent well technology provides the zonal control and real-time data required to adhere to governmental regulations for commingling multiple zones while dealing simultaneously with the different characteristics of each zone to optimize production. This system also eliminates the need for intrusive well interventions that would have been necessary in a conventional completion.

In order to identify a proper candidate a reservoir simulation and nodal analysis was performed to simulate the effects of commingling the two zones and quantify

the economic benefit. In order to maximize the economic impact the overall cost to the operator had to be minimized. This could be accomplished by installing the system during the workover of an existing completion and by utilizing as much as possible the current product offering from the completion company. New product development risks delays and increases costs.

In short, current products must mesh with an existing well profile. The completion design and operation should be as simple as possible. For example, since the intelligent well system will be installed in conjunction with an ESP, retrieving it easily was a factor in the decision making process.

The chosen well was previously produced utilizing a Y-tool with the ESP hanging on the end of the tubing string. The two zones were separated by two production packers with mechanical sliding sleeves in each zone. Production was alternated between zones by running wireline through the Y-tool to shift the sleeves. The main drawback to this method is the constant requirement for intervention to shift the sleeves and the inability to assign production to each interval. Intervention requires shut down of the ESP and thus a temporary shut down of production. So, the operator assumes the costs associated with the intervention and lost production. The installation of an intelligent well system can eliminate the costs associated with intervention. Permanent monitoring equipment was installed below the chokes to provide valuable real-time pressure, temperature, and flow data. Pressure and temperature were provided for each zone, while flow is only provided for the lower zone. During the commingled production, the flow rate from the lower zone can be viewed on surface thus providing the production allocation required.

ELECTRIC COMPLETION

On 3 August 2003, Baker Oil Tools completed the word's first subsea, deepwater all-electric intelligent completion system for **Petrobras**. The InCharge™ System was installed in the 8-MLS-67HA-RJS well in 3,540 ft of water in the Marlim field in the Campos Basin. It was permanently tied back to the Petrobras-40, the world's largest capacity floating production unit, via a 3.7 miles umbilical. This installation represented the culmination of a five-year joint development project by Petrobras and Baker Oil Tools in association with other companies. The project was launched in late 1999 in pursuit of state-of-art technologies designed to help Petrobras address the challenges of operating in water depths exceeding 9,000 ft.

The completion design requirements did not anticipate more than two zone isolations and associated flow control. Thus, it was determined that the simplest and most reliable way to minimize operational risks would be to make the InCharge system completely independent from the lower, horizontal gravel pack sand control completion, and to deploy the InCharge system completely separately from the sand face completion. The resulting intelligent completion solution consists of an Intelligent Production Regulator (IPR) to allocate flow into the upper zone(tubing to annulus), with a shrouded variation of the IPR to control injection flow (tubing to tubing) to the lower zone.

The intelligent completion system was subjected to extensive, rigorous testing at all phases of development. The completion design concept was reviewed and pre-qualified during factory acceptance testing in January 2001 with an eye toward system deployability.

Months later, the same system was shipped to Brazil and installed into the Petrobras 8-VRG-D-RN land well in Mossoro (Rio Grande do Norte State). The system was fully functional during the entire trial period from May 2001 thru April 2002 and was remotely monitored and controlled from Natal via a satellite link.

In parallel all subsea interface requirements were being checked and qualified as well. Petrobras had requested minimum additional investment in order to enable power and communication throughout the existing subsea infrastructure already in use (i.e., tubing hanger, tree andtree cap, running tools, service umbilical, communication umbilical, etc).

A set of subsea connectors (service and permanent) was designed, tested and manufactured to meet those requirements. An umbilical characterization test was performed in the Petrobras storage facilities in Vitoria City (Espirito Santo State), proving the InCharge surface control system's ability to communicate via direct umbilical control without any impedance matching modifications (no POD requirements) over distances in excess of 40,000 ft (12 km).

The InCharge system was deployed in July 2003 and commissioned in August. It is monitoring real-time measurements of downhole pressure, temperature and flow in both the tubing and annulus. As a result, Petrobras can selectively manage injection flow contribution to the reservoir intervals in real time, thereby allowing continuous field optimization in response to changing depletion conditions downhole.

The InCharge intelligent well technology allows injection flow contribution to be properly allocated; water and gas breakthrough to be controlled; and multiple target zones to be pre-completed and selectively brought on stream (or shut off at will) from the PC-based control system. A remote terminal installed in Petrobras headquarters in Rio de Janeiro and linked to the platform over their existing IT infrastructures permits remote monitoring and control of the completion.

An analysis of time devoted to the InCharge completion operation reveals that rig time for this operation, over and above that which would have been required for conventional completion procedures, was negligible. However, had Petrobras chosen to use their conventional service test string technique, rather than the intelligent completion system, an additional two trips would have been required to perform the selective injectivty testing. Thus, ultimately, using an intelligent completion system for this well proved to be a time saver.

SUMMARY

Emboldened by technical success and economic advantage, users of intelligent wells are pushing the technology envelope while increasingly adopting these new tool and techniques. We are observing a change in attitude as intelligent wells go from the realm of science fiction to an accepted part of the tool box for the completion engineer. This change is being brought about by solid reliability track records as well as the identification of practical and economically advantageous common applications. ■