

Intelligent wells can improve reservoir performance

Michael Konopczynski, WellDynamics International Limited

WHILE THE UPSTREAM petroleum industry struggles with maturing assets, dwindling reserves, and more difficult exploration environments, it seeks lower development costs and speedy and maximum hydrocarbon reserve recovery. Intelligent well technology can improve project performance for complex, challenging field developments.

APPLICATIONS

An intelligent well allows control of flow into or out of the reservoir without physical intervention, with or without downhole sensors and monitoring. Since the first SCRAMS® system was installed seven years ago, over 185 intelligent well systems have been installed worldwide by a number of suppliers and service companies.

The principal application of intelligent well technology is the ability to actively manage the reservoir recovery process. Intelligent wells can control the distribution of water or gas injection in a well between layers, compartments or reservoirs. They can restrict or exclude production of unwanted effluents from different zones in a production well. The operator can manage where he injects water or extracts oil to mobilize unswept reserves. This is particularly important for wells with complex architecture, extended reach, long horizontal or multilateral wells, and for reservoirs characterized by high degrees of anisotropy, heterogeneity or compartmentalization.

Many reserve accumulations have been discovered that are too small to be economically developed on their own, and many of these small reserves are stacked or in close proximity. Sequential exploitation does not produce the oil fast enough or in great enough volumes to be economic under conventional development methods. The solution is to commingle the uneconomic reserves. Intelligent well technology addresses the reservoir management and regulato-

ry concerns with commingling by providing individual reservoir control, the ability to prevent cross flow, and the ability to allocate flow to each reservoir.

BUSINESS DRIVERS

Increased hydrocarbon reserve recovery and accelerated production have long been recognized as the key value drivers for adoption of intelligent well technology. However, the majority of intelligent well applications to date have been in offshore platform and subsea installations, driven largely by the economics of avoiding future well intervention costs.

Intelligent well business drivers will differ for each application, and justifying the additional expense of intelligent wells based on increased reserve recovery can be difficult. In today's financial environment, reduction in capital

disadvantages of these complex well architectures, intelligent well technology provides monitoring and control of the movement of fluids downhole.

Finally, downhole sensing allows the operator to better understand the reservoir and recovery process and to make faster and more informed operational decisions. The dividends are improved utilization of asset infrastructure, reduced effluent production, accelerated production, improved hydrocarbon recovery, and better selection of infill well locations and numbers of wells to efficiently develop an asset.

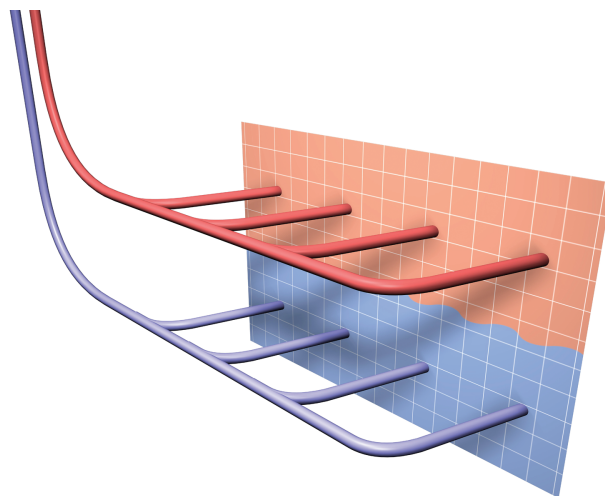
INTELLIGENT COMPLETIONS

The main functionalities of intelligent wells are downhole flow control and sensing. There are three key components used in most intelligent well completions: downhole flow control valves or interval control valves (ICVs); downhole sensors; and isolation packers. Ancillary components and systems, including power and communication lines, clamps, splice subs, surface and sub-surface control systems, and data acquisition and control systems, support these components.

Several flow control capabilities, actuation methods and choke trim designs are available. Downhole flow control valves may be binary (on-off), limited discrete positioning, or infinitely variable. Actuation methods may be hydraulic (balanced or mechanical/gas spring return), electric, or hybrid electro-hydraulic. The selection of the right flow control option is critical, as it may have an

impact on the number of zones/intervals that can be realistically controlled in one well, and may affect the overall reliability of the integrated system.

There are many sensor technology options. The most widespread downhole sensor technology in use is the electronic pressure/temperature gauge. Combining pressure/temperature gauges with a differential pressure flow measurement element, such as a venturi, allows suppliers to offer downhole flow meters.



In the Saih Rawl Multi-Lateral Waterflood in Oman, lateral wells of four to seven legs are typically drilled for both producers and injectors with producers overlaying injectors.

expenditure of a development project is critical. In terms of intelligent wells, this means that the same or better asset performance must be realized by fewer intelligent wells than the base case development plan with conventional wells. Using extended reach horizontals, multilaterals or commingled completions leveraged with intelligent well technology can reduce the number of wells required to develop a structure. To overcome the reservoir management

Optical fiber distributed temperature sensors, pressure sensors, and passive acoustic flow meters are now mature technologies.

To independently control separate intervals, zones or laterals of the wellbore, isolation packers are required, and these must provide for feeding power and communication lines through the isolating elements. Surface data acquisition and control systems are necessary to complete the interface between the operator and the downhole SmartWell tools.

DIGITAL HYDRAULICS

The Digital Hydraulics system is a closed loop, all hydraulic actuator control system. It uses digital (binary) code impressed on the hydraulic lines to command a suite of downhole flow control valves or ICVs. The patented Digital Hydraulics concept uses the logical presence of pressure or absence of pressure to communicate between the surface controller and the downhole tools. The precise pressure level or time for

which it is applied is unimportant. This system is simple to operate yet gives reliable command and communication to a large number of tools while minimizing the number of control lines.

The key component of the Digital Hydraulics system is the Digital Hydraulics "decoder" unit, a device that detects and responds to the sequenced application of control line pressure to enable communication with the ICV actuator piston. All decoder units in the well are connected to all the hydraulic control lines so that they will respond to only one sequence of applied pressures. Once activated, the decoder unit allows U-tube communication between two of the downhole control lines across the ICV piston. With this technology, three control lines can control up to six downhole tools, and four control lines can control up to twelve downhole tools.

Seven Digital Hydraulics systems have been installed. The greatest number of zones controlled in one well with the Digital Hydraulics system is five zones,

which is also the record for the greatest number of zones controlled in an intelligent well.

DIGITAL HYDRAULICS IN OMAN

The Saih Rawl Shuaiba reservoir in central Oman is a low permeability limestone reservoir producing light oil with pressure maintenance by means of a water flood. Extensive development started in the early 1990's when multilateral horizontal well technology enabled economic production rates from wells and sustainable water injection for the water flood. Multilateral wells of four to seven legs are typically drilled for both producers and injectors with producers overlaying injectors.

To improve water flood efficiency and reduce water cut of produced fluids, Petroleum Development Oman installed a Digital Hydraulics SmartWell in a Saih Rawl well that allows each of the four laterals legs to be independently opened and closed at will from surface using three hydraulic lines. The intelligent well system has been integrated with the electric submersible pump installation by providing a hydraulic disconnect, allowing replacement of the electric submersible pump in the upper completion section without affecting the lower intelligent well section.

The intelligent completion was installed in the Saih Rawl well in July 2002 and produced shortly thereafter. Several production tests were conducted by opening and closing each of the four laterals individually and in combination, to establish the maximum oil production potential and optimum completion configuration for maximum oil and minimum water production. The SmartWell completion immediately raised production. Initial results indicated a reduction in water production by 28% while net oil production increased by 1,437 b/d. The well performed beyond expectations with an incremental 1,200 b/d six months after the installation. All Digital Hydraulics systems operated flawlessly.

REFERENCE

The case history in this article is based upon OTC paper 15134, *The Use of Surface Controlled Hydraulic Interval Control Valves for the Management of Water Production in the Saih Rawl field, Sultanate of Oman*, by M Boyle, J Earl, and S Al-Khadori. ■