Critical Issues
in drilling and completions

Recession may have put damper on drilling, but industry forging ahead on technology, frontier E&P

SAND CONTROL
In GOM deepwater, there are no straight answers for this big-hitter challenge

CHAIRMAN PROFILE
IADC's 2010 leader is Pride's Louis Raspino
Ecuador completions use ICDs to control early water breakthrough, allow uniform drainage

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PETROAMAZONAS is making the most of its horizontal wells in Ecuador’s Amazon jungle by completing these wells using inflow control devices (ICDs). Awareness of the shortcomings of horizontal wells prompted the company, with the assistance of Schlumberger, to address the issues of early water breakthrough and heterogeneity and permeability contrasts up-front.

The result has been higher performance compared with a conventional completion, delay of potential early water breakthrough, no sand production and the efficient restriction of high mobile phases.

PLUS AND MINUS

Horizontal wells are superior in production and recovery to conventional wells; however, they are subjected to early water coning toward the heel. And water can break through anywhere in the well (not just at the heel) due to permeability variation and proximity of water traps.

Furthermore, conventional completions do not effectively handle heterogeneity or permeability contrasts exposed along the sand face. Early water breakthrough reduces potential hydrocarbon recovery; when water breaks through, hydrocarbons are lost and subsequently cannot be drained.

The key advantage of using an ICD is that it balances the flow across the entire horizontal section, delays early water breakthrough and enables uniform areal drainage. The use of ICDs has two main flow-control objectives. One is to obtain a uniform inflow profile along the well by applying adapted flow restriction on high flow-rate zones and simultaneously stimulate low-to-moderate producing zones, thereby delaying water breakthrough. The second is to balance flow rate of highly mobile phases while favoring the less-mobile oil (achieved by introducing a controlled pressure drop).

Benefits include:

• Improved well cleanup.
• Minimization of the heel-toe effect.
• Reduction of gas- or water-coning.

• Balanced flux from high productive zones.
• Stimulation of lower-to-moderate permeability intervals.

FUNCTION, OPERATION

ICDs operate as shown in Figure 1. Fluid enters the screen, then flows between screen jacket and base pipe into the housing and through the ceramic nozzles. When fluid enters the nozzles, the potential energy is transformed into kinetic energy, which is absorbed in the main trough in the base pipe. This results in a pressure drop between the annulus and the tubing. Different nozzle sizes are available, making it possible to design the ICD completion to the required well geometry and flow rate.

The ICD nozzle setting can be preset or, alternatively, may be performed on the pipe deck. The wire-wrapped screen optimizes particle size distribution of bridging material and is used for sand control.

Several ICD configurations and scenarios should be investigated to provide the optimal completion solution for a specific reservoir. Nodal analysis modeling is the most time-efficient and cost-effective way to obtain completion scenarios, and it enables rigorous screening of various completion design options, minimizing uncertainty. Nodal analysis predicts

Figure 1: In an ICD completion, fluids enter the screen and flow between the axial wires and the unperforated base pipe into the ICD housing before passing through the nozzles and entering into the base pipe.

Figure 2: Reservoir and ICD interaction can be simulated with nodal analysis modeling in order to evaluate various completion design options. Pressure loss is illustrated as a network of resistors, pressure loss in the formation, pressure loss in annulus, pressure loss in the completion, and pressure loss in the tubing.
what will happen in a forecast/validation scenario, and the best case is input to a dynamic simulator (Figure 2).

**BLOCK 15, ECUADOR**

Block 15 in Ecuador’s Oriente Basin is composed of two main fields – Paka Sur and Eden Yuturi (Figure 3). Both are clastic reservoirs with variable fluid and rock properties. This prolific basin is part of the upper Amazon River drainage systems and covers approximately 80,000 sq km. Reservoir challenges have included friction introduced by the heel-toe effect and permeability contrast. Also, parts of the wells are positioned close to the WOC and are subject to early water breakthrough.

In the heterogeneous reservoir having variable rock properties, high-permeability layers, compartmentalization and uncertain reservoir description, conventional completions are prone to preferential drainage along thief zones of high-permeability streaks. This results in a non-uniform reservoir drainage and subsequent areal sweep, bypassing reserves (Figure 4).

Horizontal wells were chosen for ICD completion in Block 15 instead of the conventional deviated well because of reservoir thickness, oil column and strong water drive. Initially, a series of feasibility simulation scenarios were directed toward sensing the ICD performance versus a conventional completion.

Table 1 shows the initial production and reservoir information input to the Nodal analysis pre-design. The responses are sensed for two wells named Well I, placed in a consolidated formation, and Well II, drilled in a non-consolidated reservoir and having higher viscosity (about 18.7 cP) than Well I. Simulations were performed with a hydraulic Nodal analysis simulator to compare the performance of a conventional screens completion versus one with ICDs.

A very conservative approach was selected, the criteria being a comparative interplay between pressure, flux contribution from the reservoir into the well and water cut reduction. The result showed an efficient water-breakthrough delay (occurring anywhere) and enhanced production. Water cut is reduced from about 74% (conventional completion) to about 30% using ICDs in the final completion. A removable housing was chosen to allow calibration with real-time data and final fine-tuning prior to placing the completion in the ground.
The key logging-while-drilling tool used to geosteer Well I in the consolidated formation is a bed boundary mapper that provides reservoir navigation capability using a 360° deep, directional measurement. It is capable of showing the orientation of boundaries as far as 21 ft from the borehole using a combination of state-of-the-art tilted coil technology and multiple frequencies and spacings.

Well II in the non-consolidated formation has a different well geometry from the one in the consolidated formation—8 ½-in. and ICDs with 6 5/8-in. outside diameter (OD). Well II is navigated 800 ft measured depth (MD) inside the principal zone without caolin, with an average resistivity of 26 ohm-m. It is estimated to have located the well 5 ft true vertical depth (TVD) below the caolinitic sandstone.

**COMPLETING WELLS I, II**

Well I is the first horizontal well completed with ICDs in a consolidated formation in Block 15. Accurate placement of the well, navigation and real-time geocell data allowed engineers to review and calibrate the ICD base-case modeling and to verify the final ICD completion. ICD nozzle size and configuration were refined and reset at the well site before running in holes with the use of a fully adjustable ICD.

Figure 5 shows the final completion layout. The open-hole packers minimize the risks related to the annular flow: erosion and/or plugging of the screens. The water-breakthrough simulation with ICDs decreased water rate significantly compared with the conventional completion.

Well II, completed in a non-consolidated formation, performed initially as expected. Initial simulations for a conventional completion were predicted to be about 60%, while ICDs showed only about 20%. Well II required post-completion treatment because of the secondary plugging effects of the drilling fluid (shale stabilizer). Today the well has recovered in terms of pressure, increased flux and lower water cut.

**WELL PERFORMANCE**

The ICD installation on Well I has shown higher performance than a conventional completion, reducing water cut, balancing flux, monitoring pressure and delaying potential early water breakthrough. Well II in a higher viscosity reservoir (18.7 cP) transversed more heterogeneity and required well cleanup; after-well reconditioning showed recovered pressure and production profile. Early ICD feasibility and base case simulation of scenarios allowed for an efficient field operation. Removable housing options were used in both wells and real-time data facilitated nozzle size refinement to be used with fully adjustable ICDs versus fixed settings. The application of ICD technology will be considered in other fields by Petroamazonas.

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