‘Autonomously’ going with the flow – Extending well life and increasing production in heavy oil wells

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For many years, inflow control devices (ICDs) have been used for this purpose. However, being passive in nature, once water or gas breaks through, the choking effect cannot be adjusted without intervention. Furthermore, the viscosity difference between heavy oil and water creates an unfavourable mobility ratio. This allows water to flow much faster through the reservoir and into the wellbore displacing oil production from producing zones.

A new generation of flow control

Autonomous inflow control devices (AICDs) are designed to automatically react to the properties of the fluid flowing through them. By restricting the flow of less viscous fluids, such as water and gas, it allows more viscous fluids, such as heavy oil, to pass through with minimum pressure drop.

Deployed as part of the lower completion using zonal isolation packers to divide the reservoir into compartments, the AICD can be integrated with sand control screens for soft formations. By restricting the flow of water in high water cut zones, it enables greater drawdown of the reservoir in high oil saturation zones, thereby reducing water cut and improving oil recovery for the overall well.

Tendeka's wide range of FloSure AICDs are applicable to both high value subsea wells producing thousands of barrels a day, and low yielding land wells producing just tens of barrels per day. The device comprises of three components; valve body, nozzle, and disk as seen in Figure 1. It is constructed using erosion resistant material and is engineered to fit within standard ICD housings without protrusion into the completion bore.

AICD functions are based on Bernoulli’s Principle which, by neglecting elevation and compressible effect, restricts the flow rate of low viscosity fluids by increasing flow resistance. Fluids flow through the AICD and into the production conduit, moving to the surface together with the production from the rest of the well, as shown in Figure 2.

Reducing water cut – a case study

AICDs have been used in brownfield wells across Europe, Middle East, China, and North America as a retrofit solution after water cut increases, most commonly when water cut has reached up to 96%.

Designed to control water cut, one of the first AICD retrofit installations was in 2014 in a heavy oil environment, offshore China, and showed a significant increase in oil production. The length of the well was 600 metres horizontal and was completed initially with a 5.5” screen with gravel pack in an 8.5” open hole. Retrofit AICDs were installed on 4” pipe joints and deployed inside an existing 5.5” screen. The well was previously shut-in due to the water cut exceeding 96%. Following installation of the AICD completion a reduction in water cut to 93.6% was observed.

The water cut reduction enabled a resultant increase in the oil production from 43m3/d to 55m3/d, or 28%. Based on the positive results of the initial well, there have been many more wells within the field completed with AICDs as a retrofit solution or primary completion for new wells.
One of the key challenges in successfully implementing AICD in this field, as with many late field life applications, was the limited availability of well performance data, production logs and dynamic reservoir models. To demonstrate the potential value of AICD technology, a series of hypothetical scenarios were created and a statistical approach adopted.

In the case where water saturation was at 96% across the producing section, AICDs could not add value, however, in scenarios where variation in water cut increases, value can be demonstrated provided the additional pressure drop resulting from the AICD does not limit well production. In this case, progressive cavity pumps were used to drive production and therefore, the low reservoir energy was not a limiting factor. Similarly, a statistical approach was adopted to evaluate the success of AICD application with the range in increased oil production of zero to 165% but with an average of 44% immediately following installation.

**Advancing autonomous technology for IOR**

Using AICDs in heavy oil fields to control water can help reduce water cut. The viscosity difference between heavy oil and water provides a favourable mobility ratio well suited to this technology and has been shown to increase oil production. The trial well was flowing with initial water cut of 96% similar to the well in the area. After installation of AICD, the well is now producing with 93% water cut.

It is envisaged that the water is coming from wet sand in the heel of the well and the AICD is choking the high-water zone area. The water cut reduction enabled a resultant increase in the oil production from 43m³/d to 55m³/d, or 28%. As the water is restricted upon breakthrough, the overall recovery of the well is improved when compared to operations using conventional methods and passive ICDs.

The use of AICDs requires a thorough understanding of the technology, well performance and downhole fluid properties that will impact the design and determine the ultimate recovery. The reservoir model will also have at least some degree of uncertainty that needs to be addressed using sensitivity analysis to ensure the AICD will perform in the well in all scenarios.