The rapid growth of unconventional oil and gas production in the past decade is largely a result of advances in horizontal drilling techniques that allow longer laterals to reach deeper into the formation. While this well design is attractive because of the contact it affords between the wellbore and the formation, it does not come without production challenges. For example, rather than achieving consistent or near-uniform production across the entire lateral, certain sections might be favored for production over others. This undesirable outcome arises from several factors, including the influence of frictional pressure drop in the completion string, reservoir heterogeneities, changes to fluid composition and mobility, breakthrough of undesired fluids (i.e., water or steam), and variations in reservoir pressure along the wellbore. This results in an unbalanced inflow profile, diminished production, and subeconomic well performance.

Historically, operators were left with limited options to address these issues, short of the costly decisions to recomplete the well or drill a new one. Over the past 15 years, operators have increasingly installed inflow/injection control devices (ICDs) during well construction to avoid the problems. These devices are placed strategically along the lateral to balance the production/injection profiles across the entire length and to compensate for variations in permeability. Recovery and injection performance have improved as a result.

A Retrofit Device

However, until recently, ICDs could only be effective when installed as part of the initial completion. To address uneven production in existing wells without flow control systems, Baker Hughes has developed the Equalizer retrofit (RF) device, the industry’s first ICD designed to be installed post-completion. The RF ICD is able to equalize production flow across the entire lateral and restore a well to its desired performance level.

While the retrofit system is applicable to most production scenarios, it has found the most applications to date in steam-assisted gravity drainage (SAGD) wells (Fig. 1). Common problems in SAGD wells include inadequate fluid production control in the completion, which leads to uneven steam conformance, lower sweep and thermal efficiencies along some sections of the lateral, adverse heel-to-toe effects, and the risk of live steam entering the producing well.

The RF ICD system allows operators to install one or more flow control devices inside the existing completion (whether executed with a slotted liner or a screen) by means of tubing to equalize the inflow of hydrocarbons. This gives operators the flexibility to install inflow/injection control equipment after the completion is in place, or replace existing systems to reduce costs and maximize ultimate recovery from existing wells.

These systems are typically installed with high-temperature packers rated up to 300°C (572°F), which serve to compartmentalize flow in certain areas of the well. These packers help to channel production through the ICDs, block off damaged liner zones, and improve recovery along the length of the wellbore.

The RF ICD incorporates many of the design elements of the service provider’s previous generation of flow control technology, including a tortuous flow path geometry. The flow path gives selective resistance to gas, steam, and water breakthrough. Should one or more of these undesirable fluids enter the ICD, the pressure drop across the device increases, causing the unwanted fluid to be choked back to avoid breakthroughs in the lateral. For desirable fluids (i.e., oil), the pressure drop across...
the device decreases, thus allowing selective production. All of this is achieved autonomously by the device, without intervention on behalf of the operator to scale back unwanted fluids or promote hydrocarbon flow. The system can control flow under a wide range of changing reservoir conditions throughout the well’s life, thus maximizing oil recovery from the well while reducing the steam/oil ratio (SOR) for improved sweep efficiency. Before installation, the devices can be set to one of the multiple field-adjustable flow resistance ratings to further optimize performance on a reservoir basis.

The device’s antiplugging and self-cleaning design enables reliable, long-term operation without intervention. A large inflow area allows for low fluid velocities and minimizes erosional effects to further enhance reliability.

**Alberta Case Study**

An operator in the Alberta, Canada, oil sands was experiencing poor conformance in the steam chamber along the length of a producing SAGD well, which resulted in localized hot spots in the lateral, a degraded liner, and restricted production. A device to remedy the production problem would need to generate a uniform steam profile along the lateral to eliminate the hot spots and the liner degradation and would have to fit inside the well’s 8¾-in. liner.

Starting in mid-2013, the service provider and operator worked together to devise an appropriate deployment strategy for the RF ICD, which began with detailed field and reservoir analyses to optimize the completion design. Integral to this work was the detailed study of the formation geology surrounding the well. Even minor changes to geology along the lateral can have a significant effect on the performance of the ICD. Understanding these changes and accounting for them in the design and placement of each ICD system helps to optimize the productivity of the lateral.

The work resulted in the optimal sizing and placement of tubing-deployed ICDs and swell packers to compartmentalize the flow in the well’s lateral section. The completion was designed around temperature, pressure, and geological and well-proximity data. And the design was optimized to counteract the specific production-limiting issues in the producing well to improve wellbore conformance and production efficiency.

The planning resulted in a smooth installation of the ICD system and packers, with no unplanned downtime or deployment delays. Within a month of installation, the well recorded an 87% rise in oil production, from 371 B/D to an average of 695 B/D (Fig. 2). The SOR dropped from 4.1% to 2.8%, a decrease of 31%. The operator reported that the installation of the retrofit system made the injector/producer well pair the most prolific in the field.

After a month of consistent, improved production that almost doubled fluid production rates, the customer installed two additional RF ICD systems across the field and plans to install more.

In all, nine retrofit systems have been installed in the same number of wells since September 2013 for various SAGD production operators in Alberta. The operators have experienced similar benefits of improved volumetric sweep and better steam chamber control in their wells. On average, the cumulative oil recovery has increased by more than 25% based on available public data with a 3-month time lag.

**More Application Options**

The service provider is now investigating other deployment options for the RF ICD in other wells and with additional tools to shorten deployment time and improve performance. For example, in sandstone and other unconsolidated reservoirs, the well may produce sand in sufficient amounts to hinder reliable RF ICD operation. Common sand-related problems include an inability of standalone slotted liners or screens in the completion to provide an adequate flow control, and the buildup of sand deposits that may limit production.

The ICD can be combined with one of several screen systems, including wire-wrapped or metal mesh screens, to control sand production while equalizing flow across the horizontal interval. These systems have demonstrated an ability to equalize the liquid level along the length of the wellbore and autonomously prevent the effects of steam or water breakthrough. This helps to optimize sweep efficiency and maximize oil recovery.
In consolidated formations, such as carbonates, the RF ICD can be deployed with a multitasking valve, which is incorporated into the system’s body to temporarily block flow while running the ICD. This option eliminates the need for a concentric string when deploying the device and enables hydraulic activation of packers without fluid loss.

Once the device is run to the bottom and packers are set, the valve is activated hydraulically to open the completion string to the formation and allow unrestricted flow to the ICD. This deployment option has been well accepted because it enables a reduction in rig time. Deployments in new wells using the multitasking valve with the ICD have shown a 1- to 2-day reduction in rig time compared with concentric string methods.

While the results obtained with the RF ICD depend strongly on the geometry of each well and the conditions of each reservoir, the successes observed have led operators to plan deployments of the device in several additional wells this year. JPT