

# OILFIELD TECHNOLOGY

EXPLORATION | DRILLING | PRODUCTION | APRIL 2019

## Engineered Solutions for Smarter Completions

IT'S ALL ABOUT THE RESERVOIR



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100 YEARS



# A NEW PERSPECTIVE

**Kjetil Borgersen, Halliburton Completion Tools**, explains how behind-casing monitoring can offer a new perspective on the reservoir.

**H**ydrocarbon formations are complex structures. While each is unique, there is often interaction between other formations within a given field. For many years now, the industry has explored and succeeded in finding new ways of increasing its understanding of the dynamics within and between

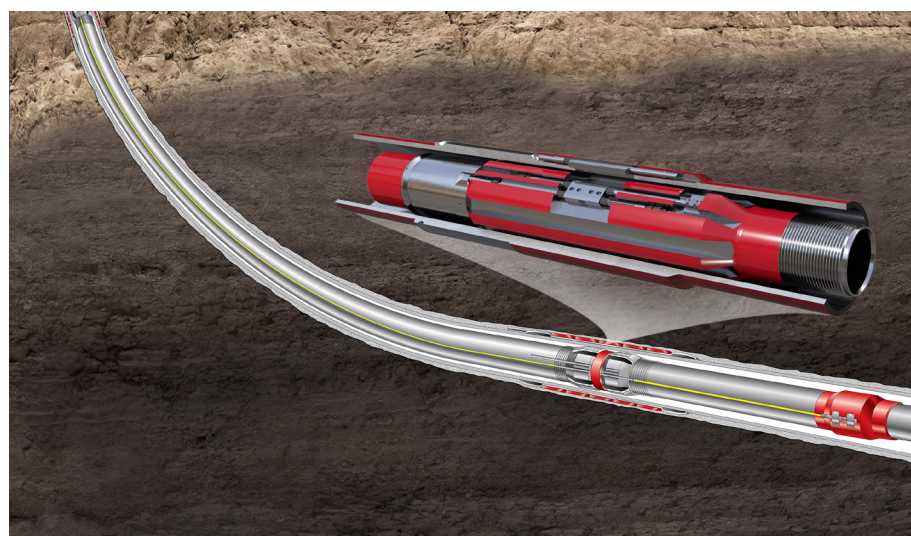
the formations being developed to recover hydrocarbons safely, efficiently, and at the highest possible recovery rate.

Equally important to understanding formation behaviour and achieving high recovery rates is the need to ensure integrity, in terms of reducing the risk of uncontrolled release

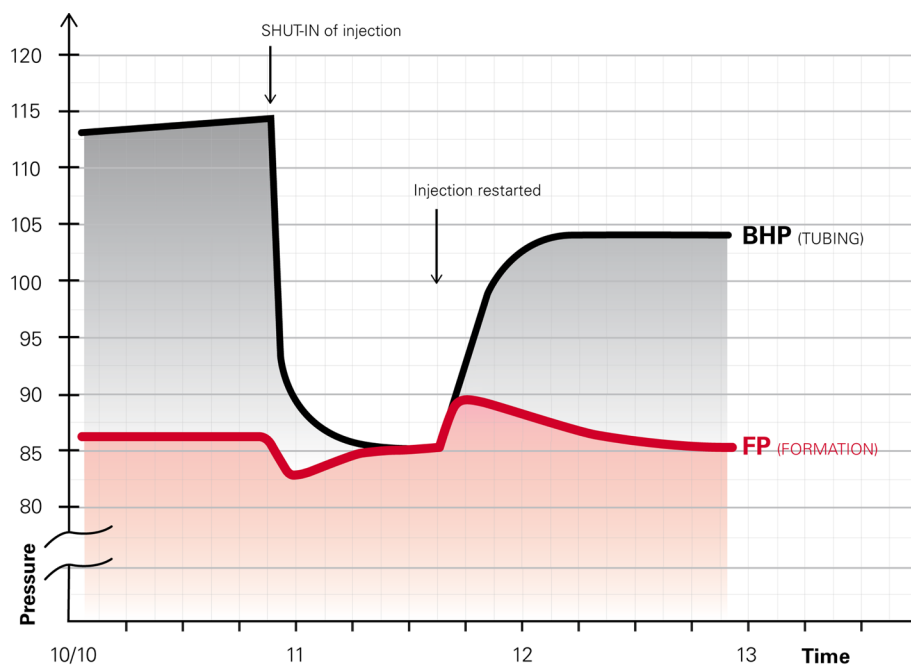
of formation fluids. Ensuring integrity is key not only from a well perspective, but also with respect to the reservoir itself. To verify and ensure integrity, access to the formation is needed from a monitoring standpoint. Well barrier philosophy often inhibits access to behind-casing monitoring. During well construction, data can be obtained from traditional logging methods, but during production this data is unavailable and may have to be acquired by using observation wells or employing lengthy periods of shut-in.

The ability to implement continuous long-term in-situ behind-casing formation monitoring from flowing wells, without compromising well barriers, is a significant challenge. To achieve behind-casing formation monitoring without making changes to the drilling programme or well design, two key challenges need to be resolved, both related to barrier elements:

- ▶ Power and communication from behind casing to surface.
- ▶ Monitoring through cement.



**Figure 1.** The DataSphere® LinX® monitoring system is a step change in reservoir monitoring enabled by wireless through-casing power and communication.



**Figure 2.** LinX® system technology provides continuous data from previously inaccessible locations, thereby eliminating the need for shut-ins.

Halliburton has developed, qualified, and installed the DataSphere® LinX® wireless through-casing monitoring system to enable long-term, continuous monitoring behind casing and inside the cement, effectively resolving both of these challenges.

Power and communication behind casing are achieved by utilising a traditional wired entry to the A annulus, the same as with traditional downhole monitoring technology, and then behind-casing power and communication is established using inductive coupling technology. Inductive coupling is a well-known concept used in modern everyday household devices. The challenge at hand was to make the inductive coupler work through steel, and have it survive the demanding run-in-hole process, which often involves thousands of feet of open hole, and finally a hostile downhole environment and cementation.

The use of nonmagnetic steel serves as a 'window' in the

casing for the electromagnetic signals to penetrate. A combination of design of service processes, rigorous testing, and improvements based on installation experience has resulted in a robust solution that has been continuously monitoring pore pressure since 2012. In a recent installation, the LinX system was successfully spaced out and landed at 6250 m MD after going through a 1750 m horizontal openhole section.

The concept of monitoring through cement may be misunderstood because the cement is used as a barrier between the casing and formation to avoid hydrocarbon communication along the wellbore. Hence, it is not expected to transmit pressure at all. Looking at the properties of any type of cement, it becomes clear that all cement has permeability and porosity. The permeability is very low, but it exists, so significant delays should be expected in the measurement. Therefore, instinctively it might also be assumed that the cement would need to be perforated to establish connectivity between the sensor and the formation.

What has been proven is quite the opposite: the transmission of pressure through cement is instant, without delay or offset. This is because the cement flexes like membrane or a bellow, transmitting pressure directly and without any flow required. The thought of pressure changes without flow may sound strange, but if thought about from a rock mechanics perspective, as is done in a reservoir but on a much smaller scale, it makes sense. The ability to do this has been demonstrated multiple times and in various applications. Over the recent years, pore pressure has been monitored during injection, and communication between injectors, fracture height on remote wells and hydrostatic



pressure shifting due to tidal action have all been detected through cement at the subsurface sensor.

## Driving increased recovery and reduced risk

Whilst the following advantages can be achieved through the instrumentation of dedicated monitoring wells, these come at great cost, especially with subsea wells being expensive and with data that is often difficult to access due to the lack of infrastructure. The significant advantage to the wireless behind-casing approach is that the same data can be accessed continuously from a flowing well, driving revenue either through injection or production, without having to spend the capital investment. The cost is lowered and thereby so is the threshold for obtaining key data on the formation.

Just as with a monitoring well, the greatest value of behind-casing sensors comes from strategic deployment throughout the field.

Logging can give similar information, but it is not a permanent real time monitoring solution, the difference being a very limited sample rate, down to the frequency of measurements done either from drilling operations or strategic shut-ins for dedicated monitoring purposes. What happens between logging operations remains unknown and that missing information could provide valuable insight into the behaviour of the formation. Permanent monitoring with the LinX system provides a continuous stream of data to enable trend analysis of events over time in the formation. For example, one can observe the behaviour of an intelligent completion when monitoring the effects of opening and closing valves to optimise production, or changing injection rates in surrounding injectors and understand the reaction of the formation to various well operations. Monitoring pore pressure in the formation at key locations supports field development planning and thereby improves on cost reduction efforts, risk reduction and improved recovery.

The accuracy of the measurement done on a logging type approach should also be taken into account. For example, the MWD measurements are highly dependent on the permeability of the tested formation, as the skin of the formation, which is upset by the drilling process, is being monitored. Studies show that in low permeability formations, like shale, the time required for the skin to return to virgin pressure is close to one year. So, in order to read the pressure accurately the sensor would need to be reading the formation pressure for a long time. This is similar in formations with higher permeability, but the time to reach virgin pressure is less.

The same goes for shut-ins of injectors to monitor formation pressure. Typically, operators want to ensure the pressure in the reservoir stays below the fracturing pressure of the caprock to avoid compromising caprock integrity. An accurate reading of the pressure can be acquired when not injecting, but the pressure imposed on the caprock during injection is quite different. In fact, top of reservoir behind-casing pore pressure monitoring shows that there is a significant difference between the pore pressure working on the caprock during shut-in versus during injection. The same data also shows that there is no correlation during injection between the tubing pressure and the top of reservoir pressure. As can be expected, the only time they correlate is after an extended shut-in. The ability to place permanent monitoring behind casing in injectors allows the operator to continuously track top of formation or even caprock

pore pressure, effectively reducing the number of shut-ins associated with pressure evaluation and optimising injection performance.

As described earlier, behind-casing monitoring of pore pressure can be applied strategically across a field to better understand the unique properties of the formation and how it reacts and interacts with the surroundings.

One example would be overburden pore pressure. Pressure regimes in the overburden drive cost and risk during the drilling stage. As the pressure in the overburden might be uncertain, drilling engineers have to plan and equip for contingencies. This can be a costly exercise, but monitoring of overburden in formations experiencing overburden pressure issues reduces the risk of drilling and the cost of contingencies. The LinX system can be used for observation and risk management in these situations.

The reservoir itself is the primary target for various enhanced oil recovery (EOR) techniques to increase recovery. EOR techniques can affect offset parts of the formation. From instrumented wells, the flowing bottomhole pressure can be read accurately using a traditional permanent monitoring approach, but it is limited to the formation the sensor has connectivity with.

Behind-casing monitoring enables operators to continuously monitor communication and pressure development on strategically selected points of the lithography along the entire length of the wellbore in producing or injecting wells. One example where there is no connectivity from a traditional permanent monitoring approach would be the case of an injector potentially having communication to a layer of the formation other than the target reservoir. By placing a sensor behind casing in the layer suspected of receiving injection, the operator can better plan for future injectors as the understanding of inter-formation connectivity is increased.

In the case of a stacked reservoir with two layers of producing sands, an operator would want to start producing from the lower sands, but they could not be certain about the connectivity between the two. By placing a sensor behind-casing in the upper sands and following the pressure development during depletion of the lower sands, it is possible to determine the communication, if any, between the layers and plan the development of the wells with less cost and uncertainty.

## Conclusion

In summary, the formations encountered as the industry strives to increase recovery with minimal risk and cost are all unique and interlinked. What is done in these formations affects not only the target reservoir, but also the surrounding lithography. Having a good understanding of formation behaviour reduces risk and cost and contributes to increased recovery.

Behind-casing monitoring uses inductive coupling technology and transmits pressure instantly, even through cement, despite the cement being an effective and working barrier in the well. This allows a look through the barriers of producing and injection wells to follow pore pressure development in strategically selected lithography along the wellbore, in real time. Just as an operator would use monitoring wells as a strategic tool across the field, it is now possible to deploy behind-casing monitoring technology in flowing wells without interrupting revenue generation. ■