# Reducing reservoir uncertainty

*Gaining acceptance of any new technology - in what has traditionally been a risk-averse industry - has never been easy. Brian Champion from Expro's Wireless Well Solutions product line, explains how the industry is embracing an emergent wireless monitoring technology to reduce reservoir development risk and enhance well safety.*

## Reducing reservoir uncertainty during appraisal and development

Uncertainties in reservoir connectivity and compartmentalisation risk are major concerns when evaluating any new field appraisal or development option. Having a better understanding of reservoir connectivity can provide significant benefits in determining the most effective drainage strategy and optimising the field development plan. One route to reducing uncertainty is to maximise the time spent on appraising the prospect. Both multi-well interference and long term pressure build-up testing provide valuable information about connected volumes but naturally, there is always a time-cost pressure to minimise testing durations.

## Data gathering in deepwater

Drill Stem Testing (DST) operations are performed on Exploration / Appraisal (E&A) wells for the sole purpose of gathering data. This includes critical information about the reservoir pressure and temperature, the reservoir fluids, the achievable flow rates and productivity index, the formation permeability and skin, the connected volumes and size of reserves.

In the high operating cost, deepwater subsea environment, there is always pressure to complete testing operations in the shortest possible timeframe. As a result, well testing operations may be terminated early, before there has been sufficient time for the pressure transient response, being monitored during a pressure build-up period, to adequately investigate any far boundaries. This can mean that critical decisions regarding future field development plans are taken based on limited and insufficient data sets.

**A wireless approach to reservoir monitoring and control**

By the application of a novel Cableless Telemetry System (CaTS™), well testing no longer has to end at well abandonment. Expro's Advanced Reservoir Testing™ service enables abandoned wells, zones or pilot holes to be monitored for extended periods beyond final well abandonment.

Based on electromagnetic (EM) data communications technology, the CaTS system wirelessly transmits high quality pressure and temperature information from the reservoir to seabed using the well's tubing, casing or liner as the transmission medium. Signals can also be transmitted from seabed to reservoir, to command and control downhole hardware such as flow control devices.

Under favourable well conditions, the CaTS wireless technology has achieved very long point-to-point transmission ranges in excess of 12,500ft, meaning the quantity of in-well equipment is minimised resulting in reduced deployment time and savings on well monitoring costs.

Of critical significance, the EM technology does not require a tubing string in the well to communicate along, and the signal is not attenuated by cement plugs, bridge plugs or cemented casing or liner. This makes CaTS ideally suited to operating in the permanently abandoned well environment, where typically only cemented casing or liner strings remain in the well.

Whilst non-ideal, where the metallic structure of the well may be non-continuous between the point of data transmission and data collection, for instance between a sidetrack and a mother bore, there are options to 'short-hop' the data over the gap.

The system uses standard completion components so there is no requirement for special plugs or packers thus minimising deployment costs. It can be retrofitted into existing wells using either wireline or coil tubing, externally or internally mounted on a tailpipe below a permanent packer during DST, or

alternatively, deployed as part of a lower completion assembly for sandface monitoring.

**Post-abandonment reservoir monitoring**

Using the CaTS wireless gauge technology, it is possible to instrument a subsea E&A well at the time of final abandonment so that it can be used as a high value, long-term, monitoring asset for years beyond abandonment.

Exploration and appraisal wells are typically permanently abandoned after logging or after short periods of production testing and without obtaining any long-term pressure data, thus losing a valuable opportunity to prove the reservoir model. By installing a CaTS wireless transmitting pressure / temperature gauge into the well at the time of well abandonment, it is now possible to acquire high quality reservoir pressure data for periods of several years beyond abandonment.

Post-abandonment reservoir pressure data is being used by operators to monitor for connectivity with adjacent assets that are either being produced, or injected into, and also to collect long term pressure build-up data to investigate far reservoir boundaries and establish connected volumes. This is proving to be highly valuable information that would not be detected during the course of a typical 48 or 72 hour pressure build-up performed during a DST. In either case, high value reservoir information is being collected over long monitoring periods and at low incremental cost.

By using the well's steel liner or casing as a signal conduit, the data is transmitted from the reservoir to the seabed wirelessly. The CaTS gauge uses a high specification quartz crystal pressure sensor featuring high accuracy, high resolution and excellent long-term stability performance, which is critical where very small pressure changes need to be detected accurately and consistently over long monitoring periods.

The pressure data is transmitted using a digital signal, providing reassurance that there will be no loss of fidelity in the data quality resulting from the wireless transmission process.

Being addressable, multiple discrete zones can be monitored in a well, with up to 20 zones having been instrumented successfully in a single well (Reference SPE paper 102745)

The pressure / temperature data being transmitted from downhole is stored at the seabed in a battery powered, remote subsea receiver which is rated for operation at water depths of up to 10,000ft. The mounting arrangement for the receiver is flexible and may be deployed on the well debris cap or where required, may be integrated into an anti-trawl frame seabed protection structure. The data is subsequently collected from the subsea receiver by periodically sailing a supply boat overhead the abandoned well location and uploading the data from the receiver's memory using wireless through-seawater communications.

Once installed in an abandoned subsea well there is no requirement to re-enter the well using a semi-sub rig; the only remaining abandonment liability is to sever and recover the wellhead at a convenient time in the future, which can typically be performed using a work vessel.

**Accelerated market adoption**

The world first successful application of this wireless technology system in a permanently abandoned subsea well took place in an appraisal well on the BP operated Clair Field, located West of Shetland in the UK North Sea (Reference SPE paper 108435).

Being a naturally fractured reservoir, connectivity and compartmentalisation were considered to be key uncertainties in the development planning process for Clair. Since the Clair Phase 1 platform had come on-stream 10 months prior to spudding the appraisal well, there was judged to be an opportunity to monitor the dynamic reservoir response in the abandoned well. The

monitoring objective was to identify any depletion due to ongoing production, and to monitor for the impact of pressure support resulting from water injection.

A total of 18 months of high quality wireless gauge data was recovered from the permanently abandoned well, which reduced uncertainties about the Clair reservoir and large-scale connectivity across the field. The CaTS gauge provided a unique insight into the pressure profile across the field, helping to give BP and its partners, a better understanding of the field's complex reservoir formations and structure.

Advanced Reservoir Testing, using CaTS in-well wireless telemetry technology, allows the reservoir engineer to cost effectively gather critical reservoir connectivity data from an abandoned well or zone for input to the future field development planning process.

Since the initial success on Clair, the market demand for the CaTS Advanced Reservoir Testing service has seen accelerated growth. The technology has now been successfully applied to monitor the reservoir pressure response in permanently abandoned or suspended subsea wells in some of the world's most challenging and hostile deepwater provinces, including the Norwegian Barents Sea and the Santos Basin of Brazil. Multiple abandoned wells have now been instrumented with CaTS and data has been successfully recovered wirelessly from wells having reservoirs located more than 10,000ft below the seabed and in water depths in excess of 7,000ft. These long transmission ranges have been achieved point–to-point without the need for any intermediate relay stations or boosters being installed in the well.

CaTS has also been successfully installed in exploration wells that are abandoned immediately after open hole logging has been completed and without a DST having been performed. Despite never having been flow tested or cleaned up, high quality data has been collected that clearly demonstrates the reservoir response due to interference effects resulting from production or injection events in the adjacent field area.

**Enhancing well safety**

There is increasing industry focus on the development and application of new technologies for well integrity monitoring. Examples include the long term monitoring of the pressure in multiple annuli in subsea production wells, and the verification of pressure barriers during well suspension or plug and abandonment (P&A).

CaTS technology can be flexibly located in the A, B, C, or in fact, any annulus, and the pressure and temperature data can be wirelessly transmitted to a seabed receiver without requiring any annular penetration. Constraints on system longevity, resulting primarily from battery pack performance and the inherent self-discharge effects, currently limit the operation of the annular monitoring system to a few years. However, Expro is currently considering options to deliver life of well wireless annulus monitoring to address this limitation.

In terms of barrier verification, the NORSOK Standard D-010 covering well integrity in drilling and well operations requires that a plug shall be verified to the maximum differential pressure at the time of barrier placement. The CaTS EM technology is unaffected by bridge plugs or cement plugs, making it ideally suited to both short and long term well integrity monitoring applications.

**Barrier verification during well suspension or P&A**

During workover or P&A operations, it is common to install both deep and shallow set bridge plugs as temporary barriers at an early stage. In some wells it can be necessary to establish these two barriers deep in the well and relatively close together. The sealing integrity of the lower plug can generally be validated by pressuring up from surface and monitoring for any leakage using the surface pressure gauge. However, when installing the upper plug, and due to the relatively small volume of fluid between the two plugs, it is unlikely that a pressure test applied from surface will detect any leakage past the upper plug.

Thus, when using surface measurements, the sealing integrity of the plug cannot be properly verified at the time of installation by differential pressure testing.

By installing a CaTS wireless transmitting pressure gauge below the upper plug, the pressure below the plug can be monitored in real time at surface whilst the pressure testing operation is being performed. This operation requires no additional equipment to be incorporated into the logging string used to deploy the plug, thus there is no compromise to system reliability. It is also compatible with any third party supplied e-line or plug setting equipment and has been successfully applied where the plug is deployed using a well tractor. Most importantly, the plug deployment and monitoring exercise can be completed during a single run in hole operation, minimising costs.

A well abandonment barrier verification campaign has successfully been completed from light well intervention vessels on 10 subsea wells in Norway, with the first application of the technology for barrier verification during P&A in the UK North Sea planned for summer 2014.

**Production optimisation in high rate big bore gas wells**

CaTS is also being applied in the large bore completion environment to deliver a sandface monitoring capability that has enabled production rates to be optimised in high rate gas wells (Reference SPE paper 145581). Six CaTS large bore mandrel systems have been installed in the Shell-operated Ormen Lange Field in Norway. These systems feature full 2-way communications between the mandrel located at the sandface and the onshore control room at Nyhamna, enabling gauge settings to be varied and pressure build-up data to be collected. Data from the CaTS systems has been used to optimise production across the entire field.

**Retrofit Flow Control**

Where a tubing retrievable safety valve has failed due to plugging or a leak in the hydraulic control line, the valve is rendered inoperable. The absence of a functioning control line means that the deployment of an insert valve is also

not possible. Where legislation allows, well production may be re-established by the deployment of a storm choke or ambient valve.

These are generally considered to be temporary flow control solutions used whilst a well workover is being scheduled or alternative remedial activities are planned. Recognising the limitations of these existing remedial solutions, which are not fail-safe or surface controllable, Expro developed the FlowCAT$^{TM}$ retrofit valve. This valve was successfully trialled in an onshore gas well for 6 months with zero leakage and no false closures observed (Reference SPE paper 130427), however it is yet to be deployed in the offshore platform environment.

FlowCAT is Expro's first wireless flow control product and whilst not yet fully commercialised, has demonstrated the capability of the CaTS EM communications to reliably and consistently control downhole hardware.

**Conclusions**

This emergent wireless communications technology is seeing accelerated industry adoption for applications throughout the well lifecycle. By adopting the Advanced Reservoir Testing approach during the E&A through development phases, CaTS is being used to reduce reservoir uncertainties at low incremental cost.

During the production phase, there are both completion conveyed and retrofit through-tubing CaTS products available that are being used to optimise production and to gain an improved reservoir understanding. There are also annular monitoring solutions available that do not require any penetration of the annulus.

During well suspension and P&A, this technology is being applied to ensure compliance with monitoring requirements stipulated in well integrity standards related to barrier verification.

Looking to the future, the CaTS technology is being developed further for both monitoring and control applications in Advanced Completions, which will lead to achieving Expro's ultimate goal of delivering the "Wireless Reservoir".

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