Delivering Diagnostics for the Duration

Keith Feather and Simon Sparke, TGT Oilfield Services, United Arab Emirates,
discuss revitalising ageing wells with new well integrity diagnostic systems.

Well integrity management is a full lifecycle process adopted from the well design and construction phase right through to abandonment.

Yet, just as well diagnostics should take place at the outset of the well life (with even new completions sometimes containing flaws such as leaking connections and poor cement isolation), there is an increased focus today on routine integrity management, as well systems age and move towards abandonment.

Revitalising ageing wells

In many regions of the world, increasing demands are being placed upon ageing well stock as operators seek to extend field life. Significant remaining reserves are the prize and technology-enabled process innovations, such as drilling multi-lateral extensions from existing wells, puts these within reach.

In the Middle East, for example, more than 70% of the ~800 platforms and associated well-stock are more than 25 years old, and in the North Sea, according to the UK Oil & Gas Authority, there remain 20 billion bbls of oil and gas resources still to be recovered on the UK Continental Shelf – a region that has been continually developed for nearly 50 years. In such cases, whilst multi-lateral well components are new, the original wellhead, conductor and production casings have remained the same.

Although previous well stock survived through regular maintenance of the more accessible elements of the well, today

more powerful well integrity diagnostics are required to monitor casing strings, tubulars and other crucial well components throughout the well system – from inside the tubing.

New diagnostic systems

Through-barrier diagnostics is a valuable resource in proactive integrity management today because it evaluates critical aspects of the entire well system from inside the tubing.

Through-barrier diagnostic systems can sense dynamic well behaviour and properties throughout the well, helping operators to evaluate the condition and performance of critical well components from inside the tubing. By harnessing heat, acoustic and electromagnetic (EM) energy, the system can determine the wall thickness of individual tubulars, and locate and quantify fluid movements behind the pipe.

Two key areas where these diagnostics are having a major impact today are in tracking corrosion and sustained annulus pressure (SAP).

Tackling corrosion and the rise of chrome

In some regions, downhole conditions are highly corrosive and well completions are constantly under attack from aggressive fluids, such as hydrogen sulfide, carbon dioxide and chloride. The degradation of wellbore tubulars and metal barriers is a major threat to well integrity.

On the Arabian Peninsula for example, formations such as Rus, Simsima, and Daman can cause severe corrosion of the outer well casing strings. Corrosive fluids from the aquifers can reach the outer casing surface because of integrity breaches in the outer well annulus. This is because either the outer cement sheath has degraded over time, or the initial cementing operation may have been compromised by the formations' inability to support the pressure, resulting in cement losses and an imperfect seal.

In such cases, comprehensive and regular inspection is required by operators to determine whether corrosion is taking place at an acceptable rate, or if intervention and remedial action is required. To this end, the well diagnostics approach must provide quantitative information about multiple casing strings efficiently and reliably.

Yet, previously few operators were able to track corrosion to this level of detail and across all pipe strings.

To address this challenge, TGT has developed EmPulse® – a multi-barrier pipe inspection system capable of providing barrier-by-barrier visualisation of the tubulars that make up the well operating envelope, reliably and proactively.

Ultra-fast EM-based sensor technology and time-domain measurements, coupled with advanced Maxwell processing, enable the system to quantify metal loss in up to four barriers independently and accurately.

In this way, it delivers sensitive and fast response measurements, bringing with it significant advantages over the frequency-based measurements offered by ordinary pipe inspection systems. Frequency-based measurements are also unable to distinguish the thickness of individual barriers and as a result provide limited information about barrier condition or the precise location of failures.

In a bid to pre-empt corrosion, many operators are opting for alternative steels and corrosion resistant materials, such as chrome, nickel and molybdenum. However, such materials pose even more challenges to ordinary pipe inspection systems with the decrease in ferrous content causing EM signals to decay too quickly for an effective measurement.

Yet, recent deployments in the Middle East have shown that EmPulse can quantitatively determine the individual tubular thickness of up to four concentric barriers, even when there are high amounts of chrome in the tubulars.

In one Middle East operator-witnessed 'yard test' consisting of a 28% chrome pipe with built-in mechanical defects, the high-speed EM sensor technology within the system correctly identified the man-made problems in a controlled environment. Additional operations took place in two live Middle East wells in a very high hydrogen sulfide gas production scenario with 28% chrome tubulars. In this case, the system again functioned as planned, and recorded the status of three concentric well barriers. A multi-finger caliper recording also confirmed the electromagnetic results for the condition of the inner pipe.

As operators endeavor to protect well integrity in challenging production environments and require versatility over tubular materials, it is good to see that through-barrier diagnostics – backed up by many of the industry's leading well log analysts – are meeting these challenges and providing a complete end-to-end well diagnostics solutions.

Cementing and SAP

Two other challenges to well integrity today – both interlinked – are that of well cementing and SAP.

As operators look to deeper and longer reach wells, cementing techniques and sealing abilities have been pushed to the limit.

According to the Society of Petroleum Engineers (SPE), at least 25 - 30% of wells are estimated to have annular pressure problems with cementing being one of the root causes. One outcome of this is SAP – pressure in any well annulus that rebuilds when bled down.

SAP is often the result of weaknesses in the cement during completion; or cement degradation due to thermal and pressure loading; leaking tubing connections or wellhead seals; and corrosion. According to a 2013 SPE webinar on wellbore integrity, out of ~1.8 million wells worldwide, a staggering 35% have SAP.

So how can well cementing and SAP be addressed?

To date, conventional means of tracking poor cementing and SAP is through surface measurements, such as fluid sampling, bleed-off/build-up data and downhole measurements such as 'cement bond logs', temperature and ordinary noise logs. This, however, only provides limited information and may be unable to locate leaks and unwanted flowpaths behind multiple barriers – especially when the leak rate is low.

To address this information gap, TGT's 'spectral diagnostics' technology tracks fluid movement behind pipes from within several casing strings. This is achieved using high-fidelity downhole sound analysis systems to capture the frequency and amplitude of acoustic energy generated by liquids or gas moving through integrity breaches and restrictions. Complementing this, spectral diagnostic systems utilise high-precision temperature measurements to help locate integrity breaches throughout the well system.

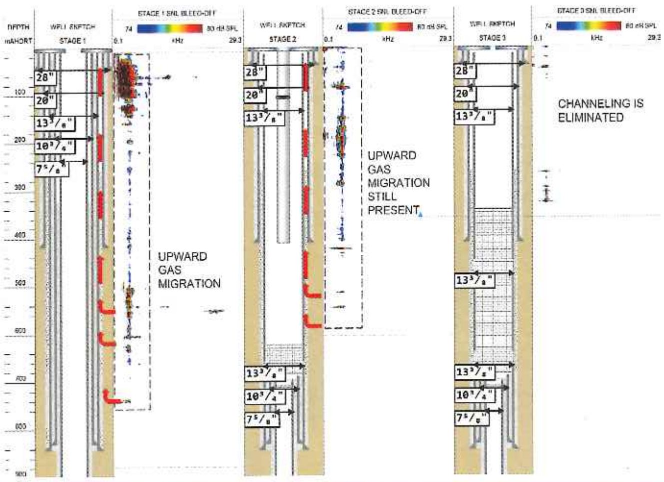

Figure 1. *Spectral diagnostics were performed during the three stages of abandonment for this well, helping the operator target special remediation measures pre-abandonment and validating integrity post-abandonment.*

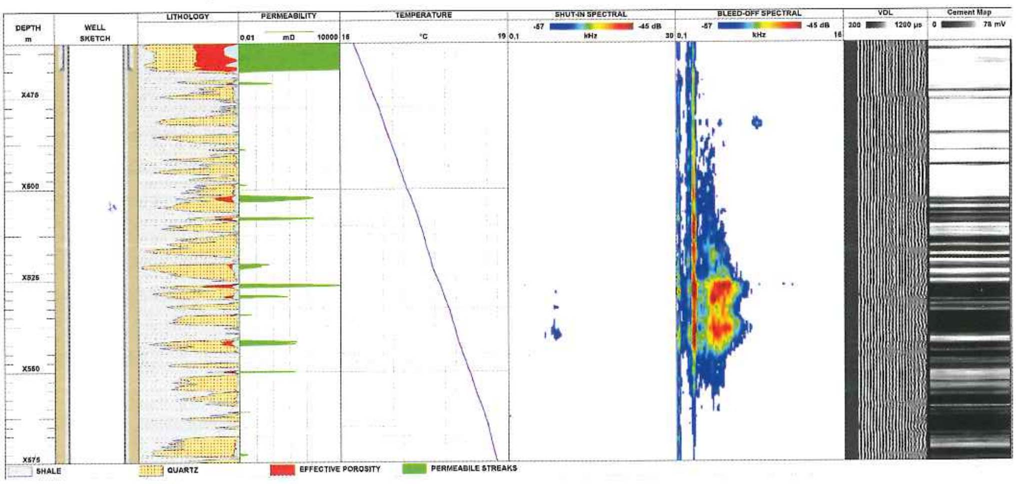

Figure 2. *Information from spectral diagnostics in a water injector well.*

Conventional production logging measurements typically assess only high-rate first-barrier failures. Meanwhile, the high-fidelity recording, sensitivity and clarity of spectral diagnostics enables the tracking of even low-rate leaks at very early stages behind multiple barriers, thereby enabling timely intervention.

In Figure 2, a water injector well experienced sustained B-annulus pressure, although the build-up rate did not exceed 1 bar/d, indicating a low-rate leak. A cement bond survey indicated good cement bonding below X500 m, and poor bonding above, making it likely to provide flowpaths for fluid movement behind casing.

A survey utilising the spectral diagnostics system was conducted and revealed fluid flow from the reservoir around X540 m and channelling up the annulus through the incorrectly assumed 'good bonding' area.

The frequency spectrum pattern correlated with reservoir permeability and fluid-type profiles, suggesting gas was being produced from these formations. The operator used the information to target a cement squeeze operation at the desired location in the well – restoring B-annulus integrity and eliminating the SAP.

Abandoning wells securely

Spectral diagnostics can also play an important role in ensuring that wells are properly sealed during abandonment, especially with respect to unwanted fluid flow along the outer boundaries of the well system to surface – clearly a situation the operator wants to eliminate.

Operators perform through-barrier spectral diagnostics prior to abandonment to indicate the integrity status of the entire well system, and reveal where special remediation measures need to take place to seal the well properly and permanently. Diagnostics are also performed post-abandonment to validate that there is no unwanted fluid flow taking place and that the well is secure.

The well shown in Figure 1 was part of an abandonment campaign where the operator observed sustained annulus pressure building at a rate of 0.1 bar/d in the C-annulus and 5 bar/d in the B-annulus. The maximum pressure in B-annulus was 35 bar while in C-annulus it was only 3.2 bar.

Multiple survey and plug/section milling stages were executed to abandon the well and each time through-barrier spectral diagnostics aided in targeting the plug intervals and verifying the integrity of the plug. After the third stage, the sustained annulus pressure was eliminated in both annuli, and spectral data confirmed that the unwanted flow in the outer annuli had abated. Figure 1 shows the acoustic frequency-amplitude spectrum seen at stages 1 and 2 reveal zones of upward gas migration behind casing. The acoustic spectrum that was seen after stage 3 confirms that the gas migration had been stopped (the small acoustic response is due to residual gas).

As a result, the operator could depart from the well, confident that it was completely secure.

Effective diagnostics

Well integrity is all about ensuring that the right fluids connect safely and productively via the wellbore to the surface and do not stray along unwanted flowpaths inside or outside the well system.

Operators select through-barrier diagnostics to deliver the crucial information they need to ensure well system integrity throughout the well lifecycle.