Through Tubing Acoustic Logging for Well Integrity and Flow Allocation

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Introduction
In the ever-growing competitive market place in today's oil and gas industry, operators are proactively exploring new and improved means of working in a smarter manner and reducing costs. Within this challenging higher priced environment the health of the well is critical for sustained production and maximizing recovery as we seek to exploit ever more difficult reserves. The ability to be able to log behind casing promptly and accurately identifying well integrity and reservoir issues is fundamental in making smarter business decisions to ensure longevity of field life and optimal sustainable production performance.

This article explores some of the challenges of Well Integrity and Reservoir Flow Allocation facing the industry and how the combination of sonic and temperature logging can provide Oil and Gas professionals with addition information to make informed well decisions.

Well Integrity
Integrity remains at the forefront of well safety throughout the well's lifecycle from drilling through to latter stages of plug-back, abandonment and decommissioning. The basis of well and completion integrity not only encapsulates safety, but also the overall productivity of reservoir and well performance.
Several well integrity studies and surveys conducted in Norway[1] over the years have revealed that the industry needs to revise its philosophy on barrier integrity. Barrier control is an important health, safety, and environment (HSE) factor, critical in avoiding major incidents caused by completion component leaks or during loss of well-control situations.
Monitoring isolation and running diagnostics when signs of failure manifest are essential for maintenance of a healthy well and production strategy. While conventional spinners and temperature logging can assess first barrier leak, there is a technology gap for measuring leaks occurring behind first barrier[2] or for identifying fluid movement between production / injection zones that should be isolated. Fluid can move between such zones via cement channels, bypassing packers or through the formation itself.

Spectral Noise Logging for Well Integrity
The latest generation of high bandwidth, high definition Spectral Noise Logging (SNL-HD) provides unprecedented investigation[3] into the isolating status of completion components, identifying previously undetectable failures in tubing, GLM, SSD, packers and casing leaks. Combining noise logging with temperature logging allows identification of various well component failures, diagnosing critical elements such as the source of sustained annuli pressure (SAP), and identifying complex or multiple annuli communications.
The Spectral Noise Log (SNL) log combined with a temperature log provides the engineer with substantial information on the acoustic pattern of flow within the well.
A typical SNL log gives the well engineer a plot of the noise spectrum and intensity with depth indicating behind casing fluid flows, leaks and annulus communications. (See case study below – figure 1).

Well integrity Case Study – B Annulus Pressure.
In the example below, it was observed by the engineer that there was gas build up in the B Annulus, which resulted in measured surface pressure of 65 psi. TGT Oilfield Services were contacted and requested by the Operator to investigate and identify the source of gas contributing to this casing pressure that was observed at the surface. An integrated well survey including High Precision Temperature (HPT) Logging and Spectral Noise Logging (SNL) was developed to investigate this. The results were as follows:

- Two sources of gas were observed from noise under shut in conditions at depths X726ft to X742ft and X762ft to X780ft (figure 1, shut-in panel)
- Bleed-off survey (figure 1, Bleed –Off SNL Panel), indicated upward movement of gas from the two gas-bearing zones.
- 'Channelling' noise was observed from the source of gas to the shoe, followed by lower –frequency noise as the gas travels between the 13 3/8 in and 9 5/8 in casing to surface.
- Temperature profile gradient change indicates the source of the gas entering the B Annulus

Reservoir Flow Allocation
Reservoir management is a complex process, with many challenges associated with uncertainties in reservoir dynamics, such as flow allocation and accurate material balance.

[1] *SPE 112535 Well – Integrity Issues Offshore Norway, 2008*
[2] *SPE 161983 Leak Detection by Temperature and Noise Logging*
[3] *SPE 161712 Innovative Noise and High Precision Temperature Logging Tool for Diagnosing Complex Well Problems*

TGT Oilfield seeks to mitigate the effects of these uncertainties by aiding our clients in optimizing reservoir performance through technology which focuses on answering how each layer in a well contribute to total production / injection.

When considering behind casing logging of a producer, it is unusual for the borehole (perforation) flow profile to represent that of the formation. The flow geometry behind the casing can be complex, where water bearing layers out-with the perforation interval can contribute significant flow via cement channels or near wellbore fractures.

Likewise, borehole measurements of injectivity profiles can be misleading as injected fluid flows through cement channels or near wellbore fractures out-with the perforation interval

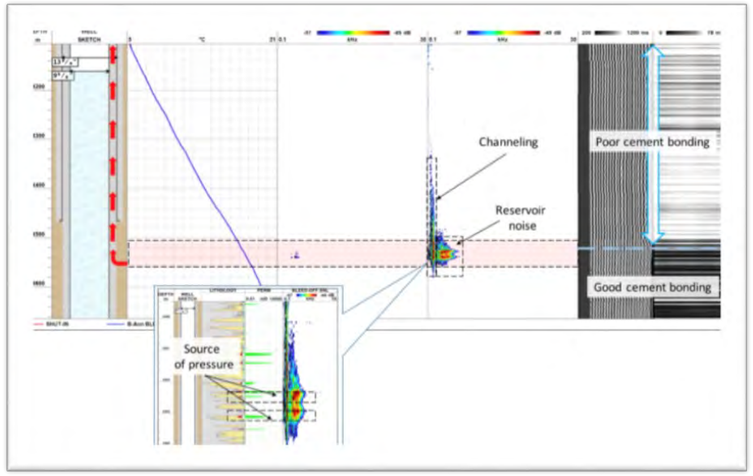

Figure 1: from left to right - depth, well schematic, temperature, SNL panel (Shut-in and Bleed-Off), CBL-VDL

Spectral Noise Logging for Reservoir Flow Allocation
High Definition Spectral Noise Logging's (SNL-HD) unrivalled sensitivity across a wide frequency range enables detection of cement channel flows and identification of all active units[5,6]. Temperature measurements compliment this acoustic profile. Combining open-hole logs, SNL-HD profile and conventional PL tool measurements allows determination of true flow geometry behind casing for complex cases.

SNL-HD, consisting of the latest generation of SNL sonde and a high precision temperature sensor, is run in conjunction with a spinner and multiphase-sensor (capacitance, resistivity, densitometers, Temp and Press) module.

- The spinner is utilised to measure borehole inflow profile and multiphase-sensors to determine relative volumes of fluid phase.
- SNL-HD sonde provides qualitative reservoir flow[7] profile, capable of distinguishing matrix from fracture flow. SNL-HD also provides direct measurement of active flow unit thickness behind pipe. Assessment of fluid movement across completion elements (SSDs, packers, etc) is also acquired.
- Temperature profiles under shut-in and flowing conditions are acquired. These provide qualitative information on fluid movement in near wellbore region. Temperature simulation can be performed, and by building advanced thermal model (and subsequent matching of geothermal) the quantitative flow profile can be solved.[8]

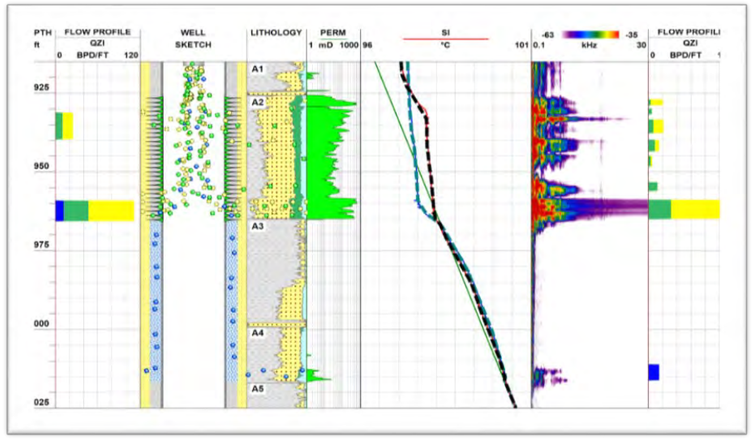

Figure 2: from left to right - spinner flow profile, well schematic, OH log lithology and saturation, OH log permeability, temperature (measured and simulated), SNL panel, temperature flow profile

Reservoir Flow Allocation (RFA) Case Study – Production Profiling
The example in figure 2, demonstrates the limitations of traditional borehole measurements and the need for behind tubing surveying. Based on the borehole (spinner) measurement profile alone, one might conclude that the formation across the lower section of perforation interval is the source of water. A Spectral Noise Log challenges this interpretation as it is clear that a contributing zone lying outwith the perforation interval is providing the source of water even though this zone should be hydraulically isolated with cement. Without this additional information, a suitable work over solution would not have been identified.

[4] *SPE 178112-MS An Integrated Downhole Production Logging Suite for Locating Water Sources in Oil Production Wells*
[5] *SPE 161712 – Innovation Noise and High Precision Temperature Logging Tool for Diagnosing Complex Well Problems*
[6] *SPE 171251 – Identification of Behind-Casing Flowing Reservoir Intervals by the Integrated High-Precision Temperature and Spectral Noise Logging Techniques (2014)*
[7] *SPE 177616-MS – Integrated Formation Micro-Imager (FMI) and Spectral Noise Logging (SNL) for the Study of Fracturing in Carbonate Reservoirs (2015)*
[8] *SPE 16607 – Evaluating Injection Performance with High Precision Temperature Logging and Numerical Temperature Modelling (2013)*

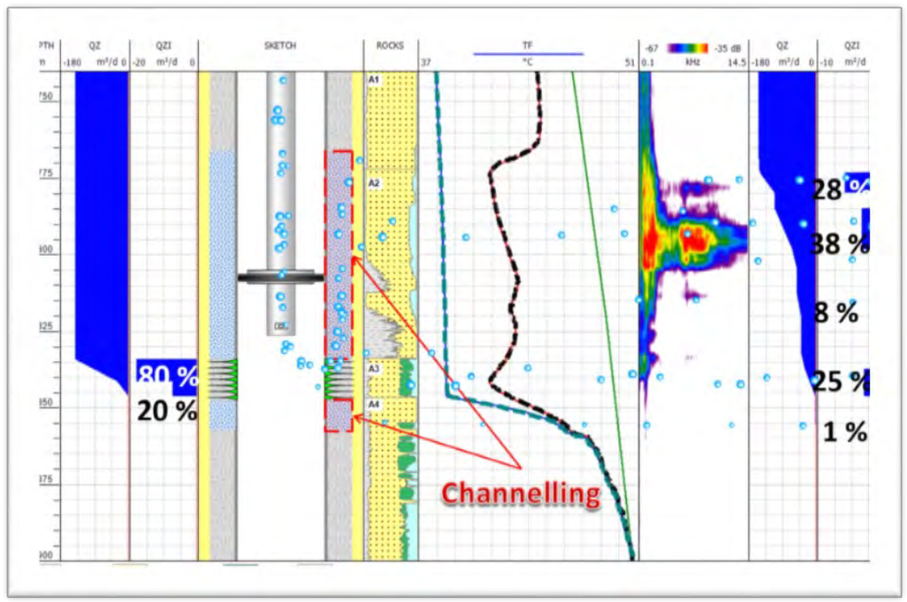

Figure 3: from left to right - spinner flow profile, well schematic, OH log lithology and saturation, temperature (measured and simulated), SNL panel, temperature simulated flow profile

Summary and Conclusion

Evidently the changing economic landscape has and will continue to force the oil and gas industry and related businesses to explore the full advantage of the technological tools available and their importance under various applications to address industry issues.

As can be clearly concluded proper well integrity monitoring is paramount in preventing failures and accidents at wellsite. TGT highly effective leak detection methodology of combining High Precision Temperature and Spectral Noise Logging (HPT-SNL) can monitor processes behind the casing, enabling and ensuring identification of leaks in the tubing, casing and cement.

This same technology of the HPT-SNL, utilised in a different application and mode can aid in reservoir flow description revealing insightful information such as: source of water breakthrough, identification of thief zones, and identification of bypassed oil and additional revenue.

The addition of Spectral Noise Logging aids in the understanding of the true inflow profiles of producer wells and injection profiles of injector wells operating in an asset, information that is critical for production technologists, well integrity engineers, reservoir engineers and petrophysicsts alike.