Leak detection - Identification of source of low rate sustained annulus pressure

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Introduction:

This article demonstrates one of the largest challenges many Operators face – low rate leaks in casing annuli. Such leaks show the barrier isolation failure and are critical to fulfill the requirements of regulatory for abandonment or to continue well operation in a healthy manner. With the current development of the logging tools, the source of the sustained annulus pressure can be identified if it builds up more than 1 bar a day. The cases below were published previously by Operators to demonstrate the capabilities of Spectral Noise Logging to investigate the source of low rate build up and leak off.

Spectral Noise Logging for leak source identification:

The passive noise logging is a well-known technique to identify different events downhole. The noise generated by the fluid or gas moving through channels, fractures, pores or wellbore is captured by the sensitive hydrophone. The logging is done via stations while pulling out of the wellbore to reduce the influence of the noise from the tool movement and hence focusing instead on the minor events, such as low rate channeling and contributing reservoir. The captured noise data is then transformed into the spectral panel which describes the frequency and the amplitude of the noise source. The fluid noise spectrum and volume is strongly dependent on the fluid type, pressure, temperature, and flowrate. Although the noise intensity increases linear with increasing flow rate, the noise frequency spectrum depends not on the flow type or velocity but on the type of media or channel through which the fluid moves.

Downhole High Precision Temperature data for tracking the flow:

Leaks in well completion components are conventionally detected by shut-in and bleed-off /leak off temperature logging with subsequent qualitative and quantitative interpretation of temperature logs. The problem in interpreting temperature logs is that they respond to various events and, in many cases, one cannot distinguish if it is vertical flow, lateral flow or some residual effects. In many cases of low rate leaks the behind-casing communications had undetectable differences between shut-in and bleed-off / leak off temperatures, temperature logging was helpless in identifying leak sources, but the temperature gradient change helped to identify the long-term events, such as crossflow or continuous annulus building up / bleed off channeling and pressure source formation.

Survey planning:

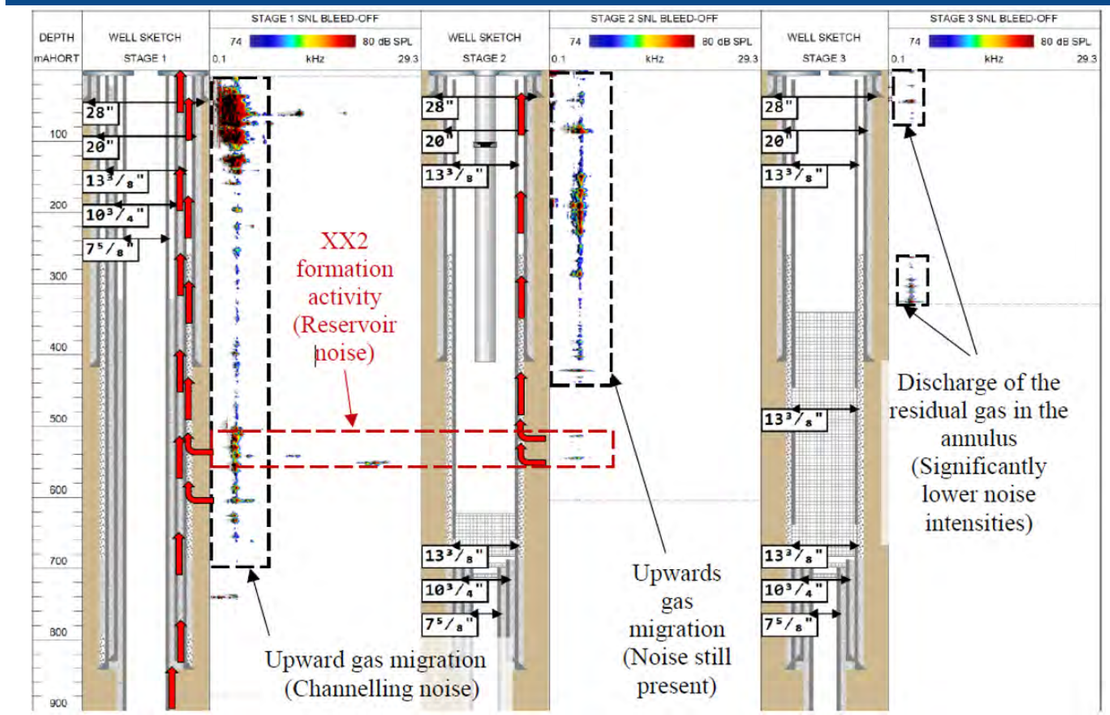
The minimum criteria for the successful leak detecting and tracking of the path to the leak source are typically 1 bar per day. If the pressure build up is not monitored but there is a continuous leakage of the surface the minimum leak rate is defined as 10 liters per hour. So the well intervention with leak detection is planned if the input parameters exceed the above-mentioned criteria. The logging is started with a shut-in or build up mode. The last one should have close to maximum (flat) sustained annulus. In such logging conditions, the undisturbed baseline temperature and background noise is measured. The next stage is induced leak survey when the differential pressure is applied across the leak zones. The High Precision Temperature and Spectral Noise Logging are acquired and compared to the baseline logs. The difference between the logs is caused by the induced leak, and allows identification of the pressure source and tracks the flow path to the surface.

Applications: Spectral noise logging for Pre-& Post Abandonment assessment.

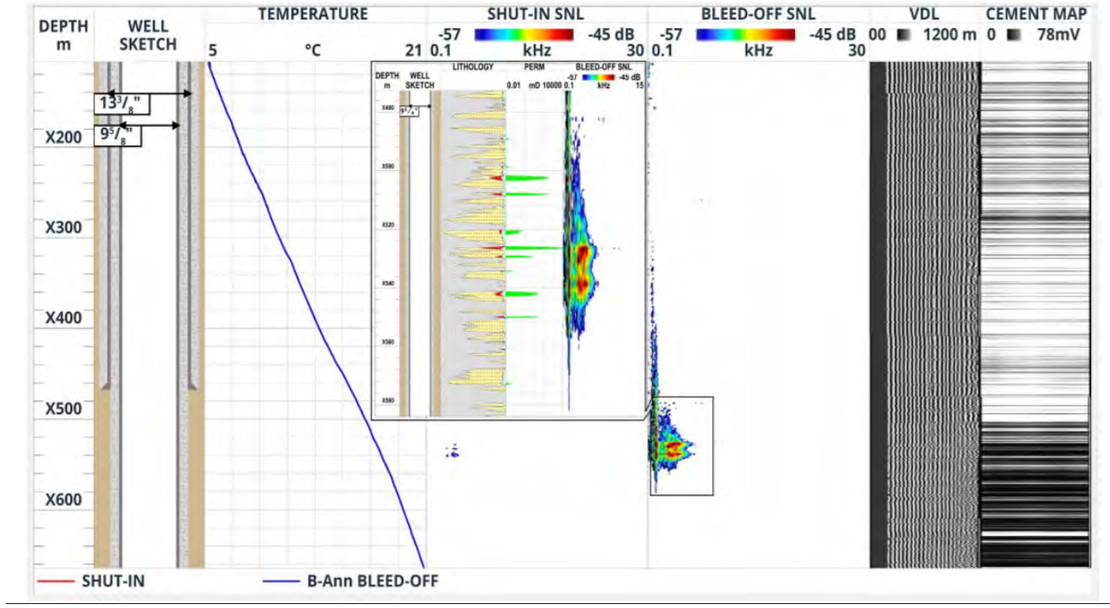
Well #1 was part of an abandonment campaign. The sustained annuli pressure was observed with a rate of 0.1 bar a day in C-annulus and 5 bars a day in B-annulus. The maximum pressure in B-annulus was 35 bars whilst in C-annulus only 3.2 bars. Multiple log and plug/section milling stages were executed in order to abandon the well. Each time, the Spectral Noise Logging and High Precision Temperature logging data analysis aided in determining the plug intervals and verifying the integrity of the plug. After the third stage, the sustained annulus pressure was eliminated in both annuli.

Well #2, a water injector, started experiencing the B-annulus pressure of 5 bars. The build-up rate did not exceed 1 bar a day. A conducted Cement Bond Log survey indicated a good cement bonding below X500 while above the cement was poor quality. A leak detection survey utilizing Spectral Noise Logging and High Precision Temperature analysis was conducted under shut-in and the bleed-off survey indicated the activity in the reservoir and channeling up in the good cement bonding area. The frequency noise pattern was in good correlation with saturation and permeability profiles suggesting the gas was produced from these formations.

The perf and cement squeeze job restored the isolation in the B-annulus and eliminated the sustained annulus pressure.



Well #1 Channelling noise and upward gas migration identified by Spectral Noise Logging and High Precision Temperature logging.



Well #2 Channelling in the good cement bonding area identified by Spectral Noise Logging and High Precision Temperature logging.

Conclusion

Today with 60$ oil price the oil and gas industry dictate the need for the Operators to reduce costs and operate in an efficient manner during the life of a producing well and abandonment phase. While conventional spinners and production logging temperature can assess first barrier leakages only, the Spectral Noise Logging enables tracking the leaks at very early stages occurring behind multiple barriers with a minor rates enabling intervention and prolonging the well life.