How Statoil determined tubing and annular integrity in a scaled and corroded completion

Unique Halliburton tool combination provided a definitive understanding of well integrity conditions with scale and corrosion concerns, eliminating ambiguous results from conventional diagnostics.

**Location:** North Sea

**Overview**

Wells in mature fields often contain corrosion and scale that can mislead the sonic and ultrasonic tools used to verify cement and casing integrity. Statoil requested Halliburton to deploy its Multifinger Caliper (MFC) tool with its CAST-M™ (Circumferential Acoustic Scanning Tool) technology and a cement bond log (CBL) in an old North Sea well. Their goals: overcome conditions that could skew results, so that Statoil could take appropriate action and satisfy government environmental regulations. The combination of these three tools enabled engineers to positively verify liner and cement integrity before partially abandoning the well. The multitool solution reduced intervention time and abandonment costs by ensuring accurate data acquisition without multiple runs in the hole. In addition, the use of mono-conductor wireline allows for rigless logging and conveyance flexibility, which can further contribute to operational savings and technical solutions.

### CHALLENGES | SOLUTIONS | RESULTS
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Verifying cement and casing integrity | Combination of three tools | Accurate readings
Statoil wanted to abandon part of a well where scale and corrosion would affect normal ultrasonic tool operation. | Together, CAST-M, CBL-M and Multifinger Caliper tools created an unambiguous picture of well conditions. | Clearly seeing the difference between scale and corrosion satisfied regulators. P&A commenced.

Identifying causes of bad readings | Caliper tool reveals scale buildup | Identified locations for plugs
Analysts could not tell whether corrosion or scale was skewing ultrasonic tool responses. | Halliburton’s Multifinger Caliper tool detected solids buildup inside pipe that was undetected by acoustic tools. | Knowing where casing/cement integrity remained intact enabled Halliburton to locate the best areas for setting plugs.

Inefficient data acquisition | New tool combination | Quick, informed decisions
Statoil once was forced to relog many wells because of ambiguous results from first-run ultrasonic logs. | Statoil acquired all necessary data in one efficient run with good data quality and depth correlation. | Statoil made informed decisions that satisfied regulators and reduced risk in one quick, efficient run.
Scale and corrosion affect ultrasonic measurements.

Before abandonment, Norwegian regulations require proof of casing and cement integrity throughout 100 continuous meters where plugs will be set. However, scale and corrosion can scatter ultrasonic waves, reducing the energy returned to the receiver. Abandoning a well with barrier damage near plugs could lead to unexpected fluid breaches and well control issues, potentially creating long-term environmental liability.

Statoil knew they were likely to find scale or corrosion due to the age of the well. So they asked Halliburton to run three tools simultaneously. Each tool’s strengths combined to produce definitive understanding of well integrity.

Running Halliburton’s well-integrity logging suite enables customers to compare information from multiple logging tools, better understanding the current state of casing and cement to make better informed decisions.

Statoil acquired all the data needed in one run instead of two or three. Using the three-tool combination, Statoil avoided ambiguity and creeping delays that could have resulted from piecemeal data acquisition – delays that would have increased abandonment expenses.
Mature wells and piecemeal data acquisition cause uncertainty and delays
Several of Statoil’s aging North Sea wells required permanent abandonment. Most have become partially clogged with scale and corroded due to excessive water production. Diagnosing under these conditions is challenging with ultrasonic tools, as they may not properly characterize cement bond due to the irregular casing conditions. Providing accurate results will help operators determine the proper plug and abandonment program.

Similar signatures create ambiguity in data
Scale scatters ultrasonic waves, resulting in a weaker return signal or none at all. With corrosion, ultrasonic waves can travel through an orifice in casing and not return to the tool’s sensor. In both cases, it may be difficult to determine the presence and bond of cement without calling for additional logging runs or the use of additional tools. Delays and extra mobilizations run up costs. During plugging and abandonment, operators have no hope of ever recovering those higher costs through increased production. Therefore, efficiency is paramount.

Statfjord C-30A was a water-alternating-gas (WAG) injector well. Statoil wanted to abandon the lower section. Norwegian environmental regulations stipulated that Statoil had to verify the integrity of cement and casing before P&A operations could commence. They required 100 continuous meters with good cement and casing to ensure isolation of the injection horizon. In previous abandonments in the area, ambiguous data made proving well integrity difficult.

Statoil approaches Halliburton to help
Casing corrosion and scale accumulation were becoming recurring problems in Statoil’s mature wells, so Statoil asked Halliburton to devise a solution that could maximize data acquisition. By working together, both companies determined that a combination of three Halliburton tools and a new way of visualizing their output could quickly provide all the data needed to bring clarity to diagnostic decisions (see page 2).

Overcoming limitations of one tool with others
Halliburton’s ultrasonic CAST-M™ tool simultaneously measures the integrity of cement and casing. It can reveal bonding and image channels in the cement sheath directly outside casing, while also measuring casing properties such as thickness, plus internal and external diameter. Halliburton’s sonic CBL-M tool also measures cement bond integrity between the casing and formation.
CASE STUDY: Effective assessment of cement and casing conditions in mature wells

But the presence of severe corrosion or scale can skew measurements from these tools. To correct for this effect, Halliburton ran its Multifinger Caliper tool as part of the string. The MFC contains a large number of “fingers” which press against the inside of the casing as the tool is pulled out of the hole. So when the tool encounters corrosion, the fingers deflect outward. When they encounter scale, paraffin, or other buildup in the wellbore, they deflect inward. When the CAST-M™ and CBL-M tools produced ambiguous data, the MFC could explain why and give engineers the certainty they needed before proceeding with P&A operations.

**Tool combination enables faster decision-making**
Simultaneous tool operation saves extra runs in hole, allowing for faster and more successful interventions. Halliburton’s Formation and Reservoir Solutions group developed a data cross-check workflow, which identifies downhole conditions affecting acoustic logs – eliminating ambiguities and providing the customer with correct data to proceed with the right solution.

**Mono-conductor solution also improves safety**
The CAST-M / CBL-M / MFC tool string runs on mono-conductor wireline. Mono-conductor can be run without a rig on cased-hole equipment, adding to efficiencies. Cased-hole equipment also makes it easier to control pressure in live wells, improving operational safety. The service is available for operation in deviated or horizontal wellbores. Choice of tool deployment is flexible to meet client requirements.

**Higher efficiency for mature wells, interventions, and P&A**
Statoil immediately saw value in how the three tools worked together. They estimated it would have taken a competitor at least two additional days to acquire the same data in multiple runs. The competitor also required the use of multiconductor cable to deploy their tool string, increasing operational complexity and job risk.

**Eliminating ambiguity in data speeds up operations**
Without data from the MFC tool, Statoil would have suspected bad cement and called for more tests. Analysts identified that the presence of scale and casing corrosion, not lack of cement, were being displayed in the logs.

**Helps make accurate diagnostic decisions quickly and effectively**
Statoil acquired the data it needed in a fraction of the time it would have taken to run the tools one at a time. They also interpreted data faster because they had everything they needed. As a result, they saved money, satisfied legal requirements, and satisfied their own passion for certainty and safety.

**For more detail, see the technical paper titled Maximizing Well Integrity**
Additional information can be found in Maximizing Well Integrity: Characterization in Scaled/Corroded Completions by Ingvar Eglund of Statoil ASA and Ivo Foianini of Halliburton, presented at the SPWLA 55th Annual Logging Symposium.