

Well Integrity Services You Can Trust

PROVEN PERFORMANCE | RELIABLE RESULTS | TRUSTED EXPERTISE

In Our DNA

We understand the vital role that well integrity plays in maximizing the profitability of oil and gas assets and storage assets. Backed by integrated expertise and a wealth of knowledge, Halliburton has more than 100 years of working in every aspect of the oilfield services business. Our Well Integrity Services team is at the heart of all E&P projects, getting the job done efficiently and economically, using leading technology in the industry designed to help mitigate risk and reduce uncertainty.

Whether assets are onshore or offshore, conventional or unconventional, multi-well platform or a single-well pad, you can trust us to always protect your reservoir or storage system's integrity and containment—it's in our DNA.

Monitoring Well Integrity Conditions

Well integrity cannot be taken for granted. Unexpected well instability, damage, or containment issues caused from corrosion, geomechanics forces, erosion, and geology can severely jeopardize your asset's infrastructure and reservoir contents. Regularly monitoring wellbore conditions can help identify potential problems before incurring costs due to repair, replacement, or downtime. Data can also lead to the prediction of failures with the right tools and analysis, enabling a planned intervention with targeted operations.

STORAGE AND INJECTION WELLS

Storage and injection wells play a significant role in multiple industries and have their own unique challenges making integrity monitoring a necessity.

Storage wells service many areas, such as midstream, downstream, utilities, industrial, fuel, base components, and other products, which helps make commerce successful. However, since the wells and reservoir can be cycled between injection and production multiple times a year, considerable stress is placed on the integrity of the barriers and containment in place.

CO₂ SEQUESTRATION WELLS

Another case is the emerging CO₂ sequestration wells. Of all the methods currently being tested and evaluated, carbon capture and storage (CCS) is widely considered to be the most practical and effective means to reduce emissions of CO₂ and other greenhouse gases (GHGs) into the atmosphere. CCS involves transporting CO₂ from power plants and other industrial businesses to depleted saline aquifers and oil and gas reservoirs. Once there, the CO₂ is injected into the reservoir via a well, where it is monitored for containment.

Examining the Integrity of the Well

Typically, a regular monitoring program is in place for all types of wells—including storage, injection, or otherwise.

In some cases, the timing and minimum monitoring requirements are guided by industry regulations. Operating companies often perform more than just these minimum requirements for a better understanding of current conditions.

Halliburton employs specialized tools equipped with advanced acoustic, ultrasonic, electromagnetic, and nuclear technologies in a sensor-driven approach to monitor, measure, and evaluate well integrity.



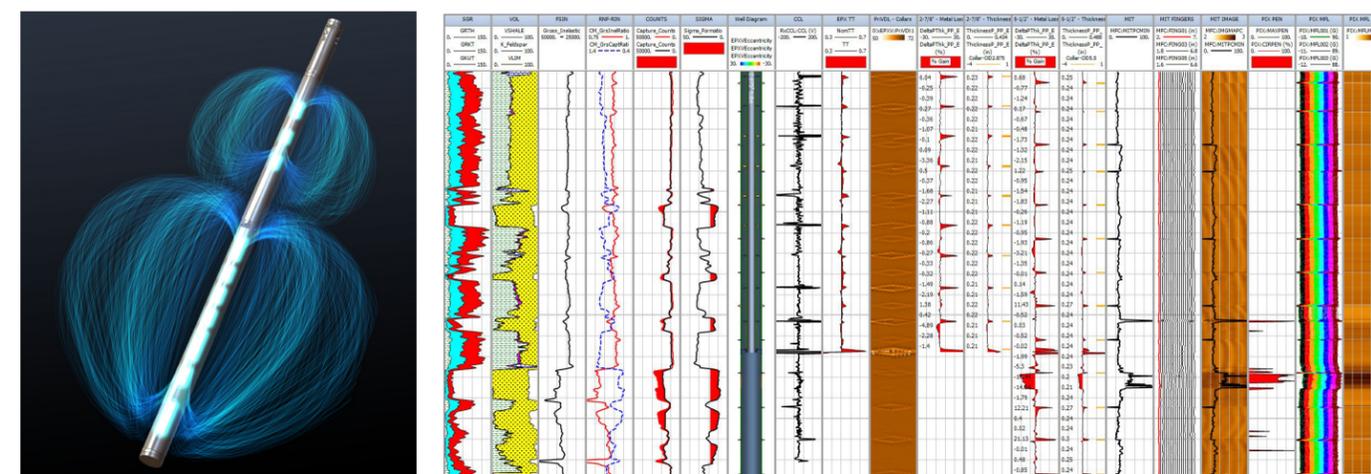
The EPX™ V, ACX™, CAST™, and MFC diagnostic tools are some of the most advanced technology methods used to evaluate well integrity.

TUBING AND CASING INTEGRITY

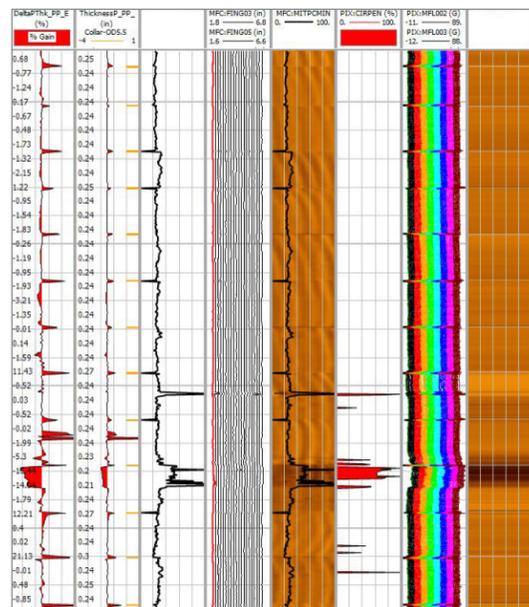
Good tubing and casing integrity helps ensure well stability throughout the life of your well. Tubing and casing are the links to the reservoir, so it is important to understand the condition of these barriers. When there is an issue, early determination of the problem can reduce remediation costs. Our tubing and casing inspection tools help this effort.

Electromagnetic Pipe Xaminer® V (EPX™ V) Corrosion Monitoring Tool

- » Quantifies metal loss in up to five concentric strings of pipe in a wellbore
- » Uses accurate high-definition frequency (HDF) technology
- » No need to pull tubing, so no costly rig is required
- » Robust in wellbore environments containing fluids, gases, and non-magnetic scale
- » Examines the whole well in one trip, reducing diagnostic time
- » Collects comprehensive information for monitoring programs
- » Helps determine the right solution for a nonconformity in completion
- » Capable for real time or memory conveyance
- » Combinable with other diagnostic tools



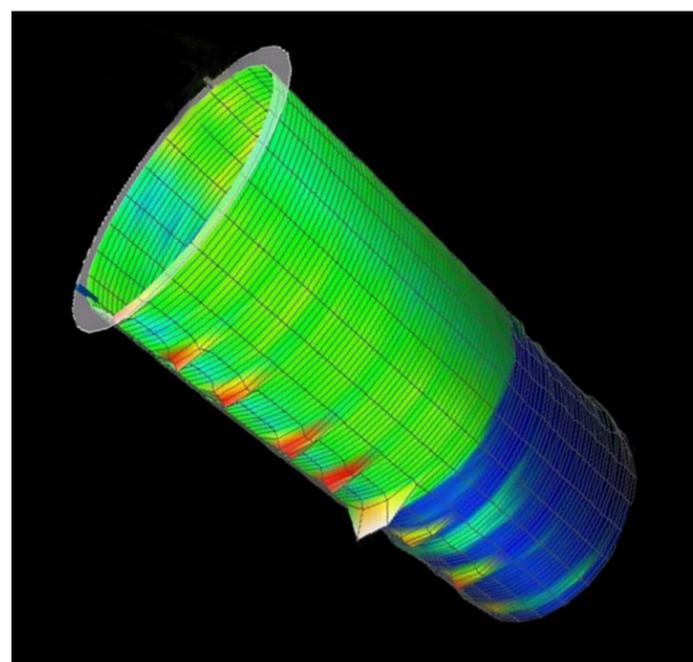
Current and new data are combined for a full picture of the well's integrity condition. Shown is the openhole data alongside cased hole reservoir data, with adjoining EPX™ V, MFC, and PIX® diagnostic tools data.



EPX™ V, MFC, and PIX® diagnostic tools data showing condition of pipe and perforations.

Multi-Finger Caliper (MFC) Tool

- » Provides high-resolution details about casing or tubing conditions, using a wide variety of multi-finger calipers
- » Includes accurate measurements of internal radius
- » Comes in most sizes for casing and tubing
- » Functions on wireline, slickline, or coiled tubing
- » Collects data for generating 3D images of casing or tubing



Sample 3D interactive mapping of an orifice detected in a tubular. The MFC tool's high acquisition rate can provide detailed imaging to help discern minute changes in casing.

Pipe Integrity Xaminer® (PIX™) Corrosion Monitoring Tool

- » Detects flux leakage in inner string for inside and outside defects
- » Provides high resolution detailed corrosion diagnostics and monitoring
- » Uses a series of overlapping sensor pads that run along the inner pipe wall, giving full coverage measurement
- » Measures flux leakage caused by corrosion or damage via multiple sensors in each pad
- » Provides accurate measurements of interruption in pipe consistency, such as from corrosion



CEMENT EVALUATION

As a vital part of well construction, cement evaluation logs are required to verify zonal isolation and well integrity. According to regulations and industry best practices, the ideal way to perform this evaluation is through sonic-ultrasonic combo logs. These logs have independent and complementary measurements, which provide full-hole coverage to determine cementing job quality, channeling, and casing integrity, to name a few.

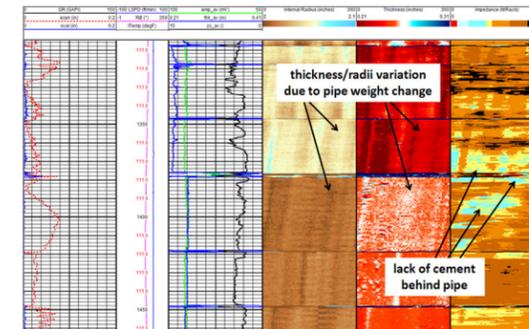
Circumferential Acoustic Scanning (CAST™) Cement Evaluation Tool

- » Provides complete circumferential coverage in cased-hole cement evaluation and pipe inspection
- » Near real-time evaluation of complex and lightweight cements accomplished through advanced cement evaluation (ACE™) processing
- » Provides high-resolution data in cased holes via ultrasonic pipe inspection
- » Provides real-time casing thickness, casing OD, and ID
- » Real-time fluid cell measures borehole-fluid transit time
- » Collects data relative to the high side of the hole using a directional subassembly
- » Delivers real-time measurements for quick decision-making
- » Combines with other diagnostic tools, such as CBL

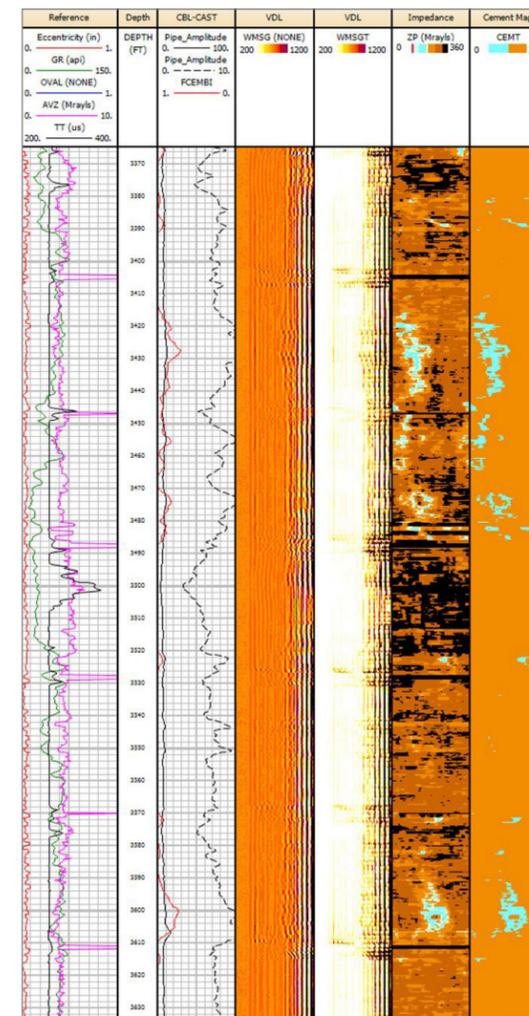


Radial Cement Bond Log (RCBL™) Cement Evaluation Tool

- » Captures full 360° data via proven sonic logging technique
- » Ensures reliable cement-bond evaluation for a full range of through-tubing logging and casing completions
- » Measures small-diameter tubing to large casings
- » Determines cement sheath integrity, leaving no room for ambiguity
- » Provides accurate information to confirm competency of cement bond
- » Delivers comprehensive borehole coverage and clear indication of channels or intervals, equipped with one omni-directional transmitter, two omni-directional receivers, and eight radial receivers



Sample CAST™-M Tool / CBL-M / Casting Inspection and Cement Evaluation Log in 4-1/2 inch tubing, depicting a change in pipe weight.



CAST™ and RCBL™ evaluation tools indicating map of cemented area around pipe (right column).

CONTAINMENT – CAP INTEGRITY

Containment is the verification that no product is migrating out of zone into other intervals. Well integrity can be positive, yet reservoir fluids can be moving into another zone. This may be an unforeseen integrity issue or communication out in the formation away from the well.

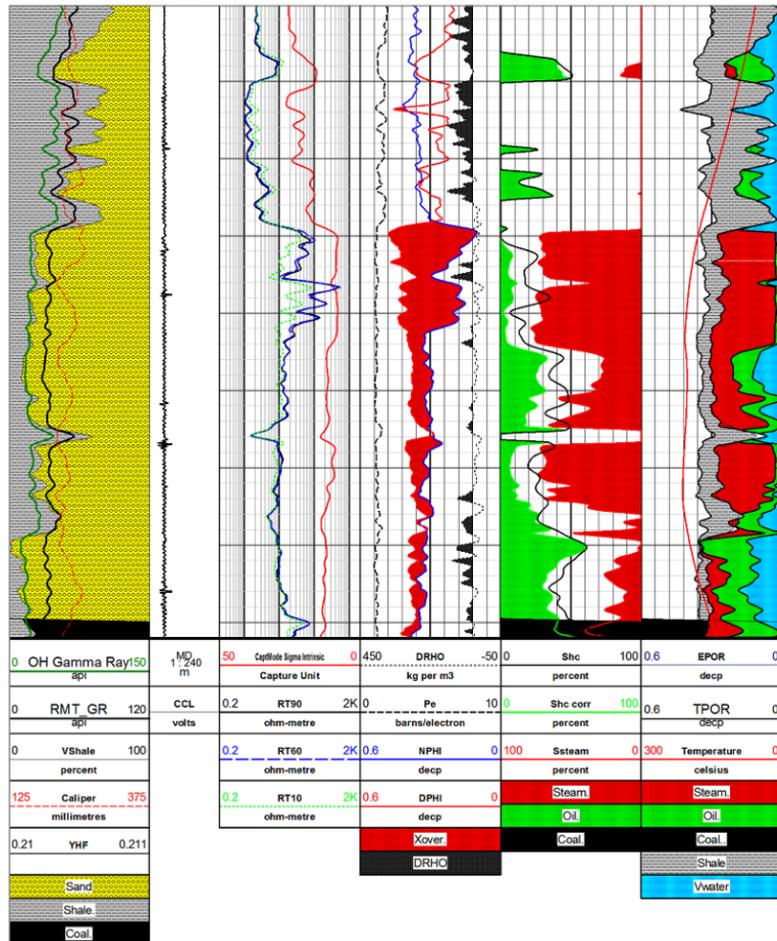
Reservoir monitoring offers insight into changing contacts, saturations, and migration through the reservoir. Regular monitoring helps validate natural barrier integrity. In storage, lost product is a direct cost, and is regarded as lost revenue and can be a liability. By monitoring the permeable formations above the reservoir cap barrier, you can have further confidence of a proper seal and confinement of the reservoir. The following monitoring tools assist with this preventative measure.

Reservoir Monitoring Tool – 3 Detector (RMT-3D™) Pulsed Neutron Tool

- » Provides detailed information on the formations around the wellbore
- » Gives measurements of saturation for multiple fluids and gases, porosities, elemental analysis, spectral analysis, and shale content
- » Identifies water flow
- » Provides a time-lapse analysis of the reservoir and zones for cap integrity
- » Characterizes the formation and fluid properties

Temperature Monitoring Tool

- » Measures borehole fluid temperatures
- » Accurately senses the temperature of the borehole fluid
- » Helps find fluid entry, gas leaks, injection zones, flow behind pipe, and even cement tops
- » Delivers fast temperature response
- » Operates simultaneously with other Halliburton products
- » Provides a convenient flow of information to the operator
- » Takes measurements from the low-mass probe, resulting in high-resolution data



Example of an RMT™ in a steam flood. Matrix shows porosity and saturations of the oil, steam, and water.

Diagnosing Well Integrity Problems

When a barrier is suspected of failure, many of the same technologies used in monitoring can help identify the location and describe the extent of the problem. Halliburton employs new technologies to expand the knowledge of such failures and more accurately determine their location.

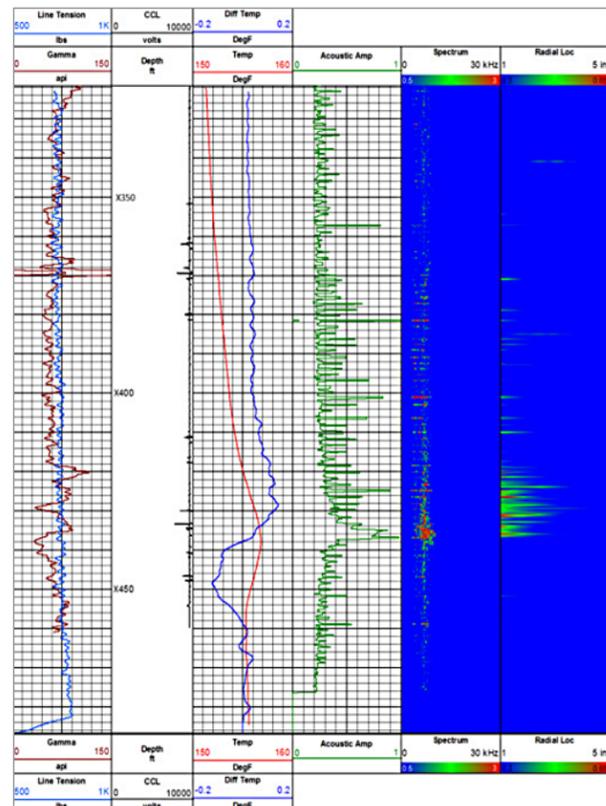
SHALLOW FLOWS

Surface casing vent flow (SCVF) and other shallow flows of gas or liquid create hazardous conditions near the surface, caused by a loss in well integrity. This problem can develop quickly or over time, on land or offshore, making it sometimes difficult to find and repair. Repairs range from simply pumping a resin-type material from surface, to more complex operations requiring multiple steps.

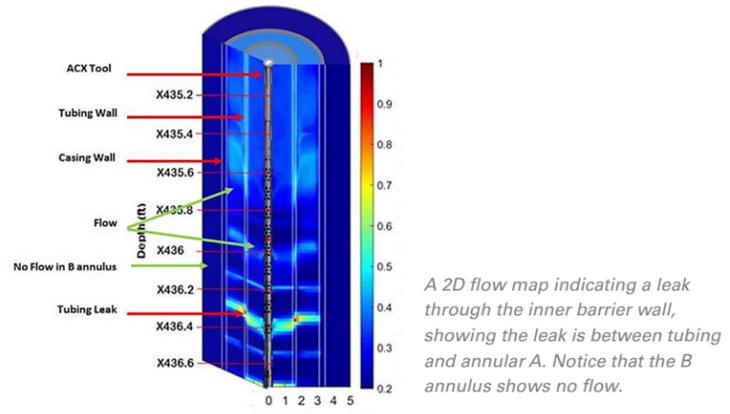
Halliburton has developed diagnostic packages to help detect and map out these events. We have the technologies, tools, and experience to effectively plan and execute these operations. A new leak detection tool developed by Halliburton is the Acoustic Conformance Xaminer® (ACX™) tool. It uses an array of hydrophones which provides several advantages for finding and understanding the leak path.

Acoustic Conformance Xaminer® (ACX™) Leak Detection Tool

- » Provides real-time data
- » Identifies vertical and RADIAL location
- » Profiles acoustic frequency and magnitude map
- » Calculates leak flow rate degree post-processing
- » Determines phase type (liquid-gas) post-processing
- » Creates 2D flow mapping post-processing
- » Combines with other diagnostic tools
- » Deployment capabilities for real time or memory



ACX™ tool log indicating a gas-lift-mandrel leak (2/3rds of the way down the log). Also shows beamforming pinpointing at tubing wall, by presenting a measured radius event in inches (far right side).

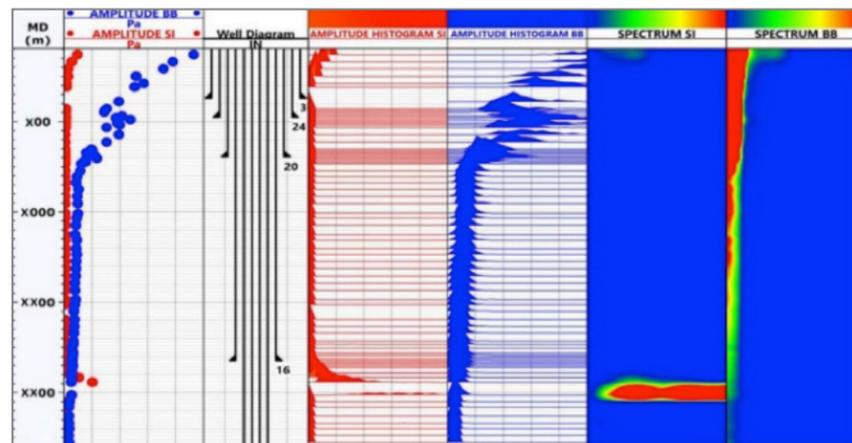


A 2D flow map indicating a leak through the inner barrier wall, showing the leak is between tubing and annular A. Notice that the B annulus shows no flow.

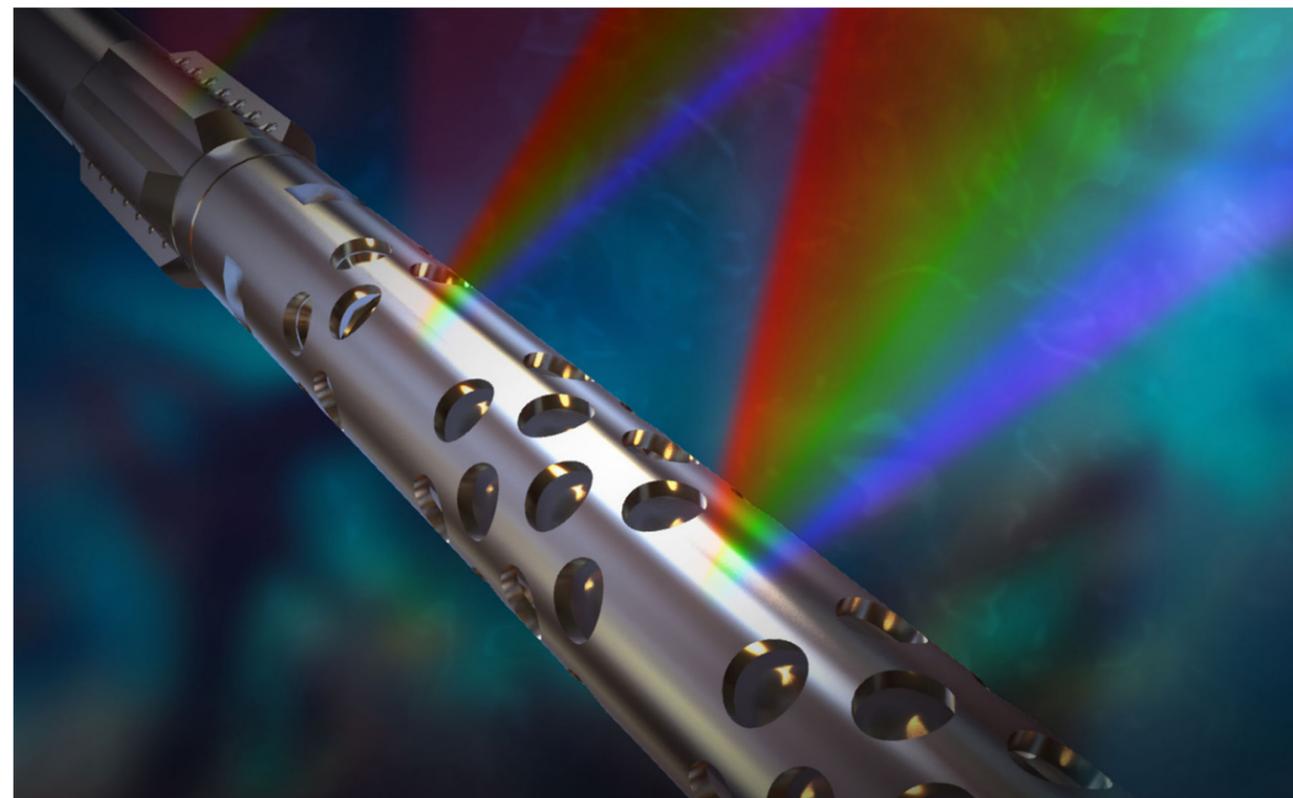
VERY SMALL LEAKS

The Halliburton Acoustic Conformance Xaminer® (ACX™) service has experience with challenges presented by very small leaks. In most cases, they require shut-in logging passes and active leak logging passes. The size of the leak may reduce the operation to stationary passes only. The stations should be analyzed to ensure there is no intermittent flow going by the tool. If so, stations can be extended or repeated.

Shut-in and active leak passes will be compared and the small leak over any length of the well will show up as a delta between passes. Temperature is always recommended with any diagnostic runs, including the ones that fall into the “very small leak” category.



*LEFT. ACX™ tool log illustrating minor acoustic events after implementing well shut-in and annulus open (reference SPE paper #202556-MS).
BOTTOM. Illustration of the ACX™ tool.*



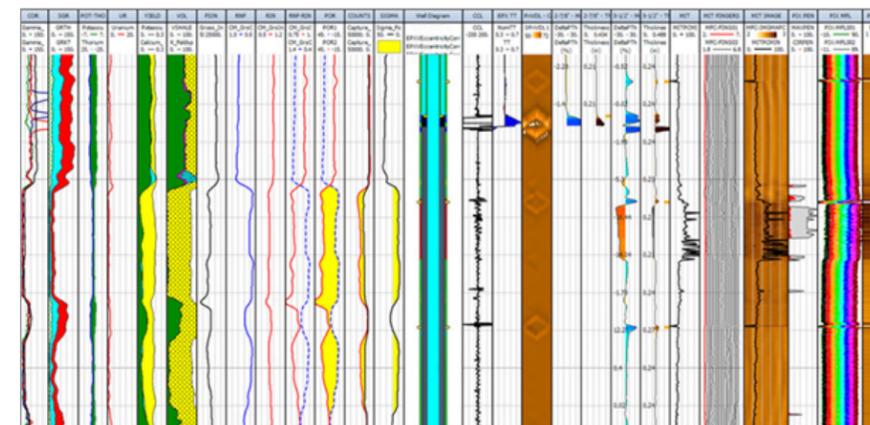
Resolving Well Integrity Issues

Once the problem has been found and explored, an economic solution needs to be provided to resolve the issue and bring back the well’s integrity. There are several technologies available for repairing integrity issues—from mechanical solutions to cementing and specialty fluids—each has its advantages. Consultation is needed to determine how long the repair will take, the objective of the repair, and risks permitted in the operation. Through collaboration, the right solution and options can be decided upon, thereby, minimizing costs for the desired operation.

CONVEYANCE INDEPENDENCE

One way to mitigate costs is through conveyance flexibility or independence. There are multiple conveyance systems to deliver mechanical or fluid-related treatments. Each conveyance system is tied to multiple solutions that are available in our Halliburton arsenal. Solutions for integrity renewal can be conveyed via:

- » Electric wireline
- » Slickline
- » Relay DSL (digital slickline)
- » Coiled tubing
- » Pump down



Putting all data together is a powerful way to show integrity and find problems at a glance. This log has data from openhole and cased hole reservoir and integrity diagnostic tools illustrating confinement and integrity.

MECHANICAL SOLUTIONS

Mechanical solutions are usually centered around plugs or expandable sleeves. Numerous safety and economic benefits accompany this capability. These benefits become even more significant as well parameters become more severe. The ever-present goal is to reduce completion expenditures and to maximize net present value. Halliburton provides several plug or expandable sleeve solutions.

- » Tandem plugs
- » Casing patch
- » Expandable screens
- » Expandable packers
- » Through-tubing bridge plugs (permanent barrier)
- » Retrievable bridge plugs (temporary barrier)





CEMENTING AND SPECIALTY FLUIDS

Cementing and specialty fluids offer additional treatments that are quite effective and economical for certain conditions. These types of repair require more steps; therefore, more risks may be present. However, some of the most effective and long-lasting well integrity repairs can be achieved using these type technologies.

Some treatments might be an easy application from surface, while others may need well preparation work before treatment. These treatments are usually required for flow behind pipe, reservoir flow problems, and other scenarios where mechanical solutions are not an effective or possible treatment. In some cases, the ultimate solution may be a combination of techniques.

The goal is to have the right application to maximize your return on investment. Our extensive range of Halliburton chemical solutions combine specialty chemical products and operations planning to enable maximum performance and efficiency from your operations. Some of our treatments include:

- » Cement
- » Polymers
- » Specialized cements
- » Resin
- » Low-viscosity sealants
- » Specialty chemicals

Halliburton has the experience and technologies to monitor, find, and resolve your well integrity issues. Collaboration efforts are necessary to ensure good planning, recommend the appropriate solutions, and achieve successful operations. You can depend on Halliburton to provide well integrity you can trust.

Sales of Halliburton products and services will be in accord solely with the terms and conditions contained in the contract between Halliburton and the customer that is applicable to the sale.

H013826

04/21 © 2021 Halliburton. All Rights Reserved.