Well Integrity Services
Casing and Cement Evaluation

Identifying structural anomalies, defining remediation strategies, and protecting your oil and gas assets with an array of advanced diagnostic tools and integrated expertise.
How Secure Are Your Assets?

Damage to a well can cause unwanted fluid flows, can negatively impact the economics of field development, and can create environmental hazards.

The purpose of drilling and completing a well is to construct a secure subsurface “pressure vessel.” We create and maintain well integrity by applying technical, operational, and organizational solutions to reduce the risk of uncontrolled release of formation fluids throughout the life cycle of the well. This is facilitated by a thorough understanding of well risks and uncertainties and by managing with multi-disciplined well engineering. Well integrity over the life of the well is achieved through well and field monitoring, appropriate well intervention, and eventual decommissioning.

Multiple factors are critical for achieving well integrity:
- Risk management
- Drilling hazard mitigation
- Operational constraints
- Well head requirements
- Completion design
- Casing and cement integrity

Well integrity problems vary in complexity. They can arise from an imperfect cement bond: The cement quality, the casing-to-cement bond, and the cement-to-formation bond determine the integrity of the hydraulic seal required to isolate a producing zone. Correct cement placement is also necessary to provide structural support to the casing. Other factors that affect lifetime well integrity include wear to the casing and tubular walls, corrosion, and tubular failures due to geomechanical stresses from within the reservoir.
Uncover Threats
Using a complete measurement suite of industry-leading technologies, well integrity management experts, and multidisciplinary data integration, Weatherford assists clients in identifying, evaluating, and mitigating risks to well integrity.

Pinpoint Casing String Problems
With advanced measurement tools and analysis software, we provide a thorough examination and diagnosis of downhole tubulars that identifies, qualifies, and quantifies any anomalies. Weatherford services can also provide critical data to determine the best course of action to stop or prevent leaks and fluid incursions.

The full suite of Weatherford tools includes premium wireline tools, unmatched in the industry for providing data for accurate, comprehensive analysis of casing and cement integrity. The Ultrasonic Radial Scanner (URS), Multi-Sensor Caliper (MSC™), Cement Bond Tool (CBT), and Casing Imaging Tool (CIT) represent a tool combination that no other service company provides. These tools can be run in combination or separately on single-conductor or multi-conductor wireline cables.

Safe Well Abandonment
Planning for well abandonment or decommissioning should be considered in the field development planning phase. That allows for identifying and mitigating abandonment risks, which minimizes decommissioning costs and long-term liabilities. Weatherford teams can identify the potential for future problems and advise clients on addressing them economically, cost effectively, and with minimum risk to the environment.

Secure Natural Gas Storage
Long-term wellbore integrity is paramount in wells used for natural gas storage. Leaks in storage wells cause product loss and pose a threat to the surrounding environment. Our well integrity services, in particular CIT service, help clients identify and resolve problems with casing integrity.
Maximizing Efficiency: Tool Combinations

To maximize efficiency and reduce costs, Weatherford has developed technology that enables running all or part of our premium well integrity tools together. The URS, CIT, and HBC (a 3-ft/5-ft sonic tool) can already be combined in a single tool string. Soon the MSC™ and the CBT, a shorter and lighter 3-ft/5-ft sonic tool, will be combinable with the URS and the CIT tools.

Our goal is to provide our clients with a comprehensive well integrity profile acquired efficiently. We then assemble and present the acquired data in a manner that provides the required answers and enables making the best possible decisions regarding your assets and our environment.

Deployment and diagnostic capabilities of three Weatherford tool combinations

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<th>Seven Conductor</th>
<th>Casing Wear</th>
<th>Casing Deformation</th>
<th>Casing Thickness</th>
<th>Internal Casing Defects</th>
<th>External Casing Defects</th>
<th>Burst Pressure</th>
<th>Cement Bond to Pipe</th>
<th>Cement Bond to Formation</th>
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In addition to combining our premier logging tools in a single string, we have developed technology allowing us to use either a traditional, single-conductor, cased-hole wireline or a more robust multi-conductor wireline generally used in openhole logging operations. We have also developed downhole memory technology to overcome the common industry challenge of limited bandwidth. Therefore, when using single-conductor wireline, we are more limited by the weight of the tool string that we can safely deploy than by the amount of data that can be transmitted on the wireline.
Circumferential Cement and Casing Evaluation

Ultrasonic Radial Scanner

The ultrasonic radial scanner (URS) delivers both cement and casing inspection data simultaneously in casing as large as 20 in., and downhole URS processing provides casing thickness measurements. In fact, URS standard-resolution measurement of casing thickness is even better than the high resolution claimed by other vendors. A patent-protected mud chamber on the URS and improved fluid measurement techniques determine not only fluid slowness, but also the fluid acoustic impedance and density—especially important for stratigraphic mud columns in wells. Moreover, improved centralization makes the URS reliable for use in highly deviated wells.

The rotating measuring head at the bottom of the URS transmits and receives ultrasonic waveforms. Evaluation of the waveforms enables us to determine cement bond to pipe, casing ID, and tool eccentricity. Pipe thickness and the subsequent interpretation of outer casing wall defects are currently post-processed deliverables. Cement bond to formation and a secondary cement bond to casing measurement are derived from 3-ft and 5-ft sonic data acquired apart from the URS but run at the same time.

The blending of ultrasonic and traditional sonic data analysis provides the location of an insufficient hydraulic seal behind the casing, as well as the size and location of vertical channels in cement that can provide paths for wellbore fluids to escape into the annulus. The URS can identify channels in the cement map as small as 5° (1 in. / 25 mm). Identifying even the smallest channels is advantageous because they could eventually expand to create larger problems.

Precision Firing for Increased Accuracy

The URS provides one of the highest circumferential rates in the industry. An advanced, high-speed DC motor rotates the primary measurement transducer, which fires upon arriving at a precise point in its rotation. This feature ensures consistent transducer firing, minimizes chances of overlooking important features, provides more accurate depiction of cement distribution around casing, and enables faster logging speeds or higher-resolution images at industry standard logging speeds. Other technologies that base transducer firing on time and a constant rotating speed are more likely to miss important features or anomalies.

Visual Proof of Defects

High-resolution wellbore imaging provides detail of internal casing corrosion, defects, and perforation patterns. URSVision processing of measurements by the high-resolution URS transducer produces a high-resolution image map of the casing dimensions and an accurate determination of burst pressure. This azimuthal image indicates the reflectivity or smoothness of the inner wall, which allows the user to identify areas of internal corrosion.

URS Tool

Applications
- Cement evaluation
- Casing inspection
  - Monitoring internal wear and corrosion
  - Locating internal and external casing defects
  - Analyzing casing thickness
- High-resolution wellbore imaging
- Foam cement analysis
- Fluid slowness
- Acoustic impedance
- Density

Channeling

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**Detailed Internal Casing Profile**

**Multi-Sensor Caliper Tool**

With a sampling rate ten times that of comparable tools, the Weatherford multi-sensor caliper (MSC™) tool delivers an accurate internal casing profile. Expert analysis of MSC data identifies internal casing corrosion or scale buildup, drilling wear, split or parted casing, and deformations caused by geo-mechanical stresses. Onboard inclinometers enable a rigorous eccentricity correction algorithm and analysis of casing deformation.

The MSC tool is available in 40- and 60-arm variants. The array of independently-measuring, precision-calibrated, carbide-tipped caliper arms can log casing ranging from 4.5-in. to 22-in. OD. The MSC and CIT tools have a resolution match and are combinable.

The cement bond tool (CBT), which provides cement bond and variable density logs (CBL-VDL) with short length and low eccentralization weight, is combinable with the MSC platform.

**Joint-By-Joint Analysis**

TVision analysis software classifies each casing joint, identifies the worst-case defect found, and provides a convenient joint-by-joint well summary. The software produces graphic cross-sectional and 3D plots of casing ID for easy identification of anomalies and advanced interpretation of deformation. From high-resolution color depictions of the inside surface of casing and cross sections, you can graphically evaluate casing defects, variations in casing trajectory, and deformation.

**Assessing Drift Diameter**

Clearance diameter is a critical parameter for determining whether a downhole assembly can be conveyed successfully in the wellbore. Determining clearance diameter requires detection of bends and changes in casing trajectory. Weatherford TVision software and data from the MSC tool let you analyze the complete well from top to bottom and determine drift diameter.

**Applications**

- Monitoring internal casing corrosion or scale buildup
- Evaluation of drilling wear
- Inspection of marine risers (with available extended-reach kit)
- Identification of split, parted, or deformed casing
- Evaluation of deformation caused by geomechanical issues (pipe axis deformation, clearance circle analysis, ovality analysis)

**A Highly Versatile Tool: MSC Capabilities**

- Internal casing corrosion monitoring
- Casing wear from drilling operations
- Casing integrity evaluation before sidetracking
- Casing trajectory
- Temperature measurement
- Drift diameter calculation
- Compaction monitoring
Weatherford TVision interactive software provides graphic views of data from the MSC tool. An interactive 3D view of the well includes trajectory, plate view, section magnification and various contour modes. Manipulating this image aids in visualizing problems that the tool uncovered in the casing inspection log. A cross-sectional view displays the remaining wall thickness and the clearance diameter at specified depths. A traditionally formatted log plot with all analysis output parameters complements the graphical views.
High Resolution Casing Inspection Inside and Out

Casing Imaging Tool

By employing state-of-the-art magnetic flux leakage technology, the Weatherford casing imaging tool (CIT) accurately locates and quantifies the penetration of casing defects seen on both the inner and outer casing walls. Our CITVision analysis software provides a graphical depiction of detected defects even in casing collars where traditional analysis techniques fail.

Locating Defects

The CIT uses a powerful rare-earth magnet to fully saturate the casing with magnetic flux. A multi-pad, multi-sensor array of Hall-Effect sensors detects localized fluctuations in the magnetic field within the casing created by internal or external defects. Additional Hall-Effect sensors are used to discriminate whether the observed defect is internal. Using the independent reading of each sensor, we can not only detect a defect but also its geometry, length, and width, which are used to calculate the burst pressure and the percent penetration for the worst defect per joint.

Fast Logging Speeds

High-resolution CIT data is output at 400 samples/meter (122 samples/ft). A maximum logging speed of 98 ft (30 m) per minute is achievable without loss of resolution. In addition to the high-resolution data and the high logging speeds attainable, the CIT delivers repeatability that is second to none.

CIT Applications

- Time-lapse monitoring of casing degradation
- Establishing requirements for remediation
- Regulatory compliance for drill wear, well abandonment, and well conversion applications
- Remedial workover requirements to assess casing condition and integrity
- Locating and identifying casing hardware
- Evaluating perforation performance
- Burst pressure
- Percent penetration of defects
- Percent penetration of defects

Internal or external defects, pitting, or wear on downhole tubulars threaten well integrity.
The standard HD image presentation provides a 360° view of each collar, hardware, or defect and the depth at which each item is located.
Quantifying Metal Loss

Acquired data is post-processed using advanced CITVision™ 3D visualization and analysis software. CITVision analysis distinguishes between general corrosion and isolated pitting, and determines the penetration depth of detected defects. Final post-processed logs include a color-coded and labeled display of individual casing joints, the percent penetration of the worst-case defect within the joint, and the depth at which the defect was located. A joint summary provides a quick-look evaluation of the inspection and graphical depictions of all worst-case defects in excess of 40% penetration. All casing collars, all detected hardware, and any observed anomalies are appended to the bottom of the final post-processed product.

A joint summary report provides a concise listing of casing joints in the well and the classification of each joint, based on the maximum penetration indicated by the TVision or CITVision processing results. The front page of the report includes basic well and casing information and a summary of joint types. The report also includes a chart of joints with depth intervals, lengths, penetration information, and classifications.
Post-processing of data by Weatherford CITVision software provides an interactive 3D image, generated from the high-resolution magnetic flux leakage measurements by the CIT tool. This image enables visually exploring the well and identifying areas of corrosion, defects, collars, and hardware. A waterfall CITVision log is provided for correlation with the 3D image.
Produced by an experienced Petroleum Consulting analyst, a casing integrity report provides a detailed overview of the results of TVision or CITVision processing. The report provides analysis parameters and notes about the data quality, casing conditions, and areas of internal and external corrosion observed within the full interval logged.
Weatherford also offers cement bond logging tools that provide quality data for interpreting cement bond to casing and formation and for detecting the vertical length of these bonds. Applicable technologies include the Sector Bond® tool and Slim Sector Bond tool.

The versatile Weatherford Sector Bond tool operates in 3.5 in. (89 mm) to 9-5/8 in. (244 mm). It indicates the quality of the cement bond around the circumference of the casing. Nine transmitters and ten receivers provide traditional 3-ft and 5-ft amplitudes, travel time, and waveform data, as well as eight individual sector measurements that depict distribution of the cement around the pipe.

Eight sector transmitter-receiver pairs, each spaced at 2 ft longitudinally and 45° circumferentially, fire and measure sequentially to scan the casing circumference for the presence or absence of cement. An additional transmitter and 3-ft and 5-ft receivers provide traditional amplitude, travel time, signature, and VDL measurements.

The Slim Sector Bond tool operates in casing from 2.5 in. (6.35 cm) to 7.0 in. (17.8 cm). It measures cement bond quality laterally around the casing circumference and performs traditional vertical extent measurement in a single pass. It provides measurements similar to those that the Sector Bond tool provides. Because of its reduced size (1-11/16 in. vs. 2.75 in. OD), however, the Slim Sector Bond tool has only six sector receivers and uses the same transmitter that is used for the 3-ft and 5-ft measurements.

Both tools can be run simultaneously with gamma ray, neutron, and casing-collar locator tools.
In this well the operator deployed the Weatherford URS to provide a clear, accurate representation of the materials behind casing by measuring the acoustic impedance of the material. The URS results demonstrated zonal isolation above and below the perforated intervals and over the surface casing shoe. If the operator had used only the conventional cement bond log, the regulatory agency would have requested that the operator perform remedial cement squeezes, which would have been costly and unsuccessful.

To assess the viability of a directional well after Hurricane Ivan tore the rig from its legs and set it adrift 40 miles (64 km) from its drilling location, Weatherford ran the multi-sensor caliper (MSC™) tool and processed the gathered data through TotalView™ visualization software. With the MSC tool, the operator could analyze the complete well from top to bottom. The resulting log indicated that the OD of the storm packer (14-3/8 in.) exceeded that of the drift (13.9 in.). The operator concluded that the storm packer could not be removed and that the well must be abandoned.
Logging the hole with the Weatherford CIT tool revealed significant external casing corrosion and located a casing hole immediately above a collar. Data analysis indicated that the pipe had sufficient integrity to allow a string shot and back-off operation. Logging the section in question with Weatherford’s Sector Bond tool showed that no cement existed from the region of the hole up to the surface, indicating a good probability of successfully backing off the pipe. No other tool or interpretation method on the market could have located the hole in such close proximity to a collar. Use of the Sector Bond tool and CIT combination allowed the operator to successfully remove the damaged pipe, replace it, and put the well back into production.

**British Columbia, Canada**

**Multi-Sensor Caliper Yields Clearer Picture of Casing Damage than Video Camera**

The operator wanted to reenter a well originally completed in 1974 and abandoned in 1984. Previous use of a downhole video camera did not yield an adequate casing damage assessment. The client ran the MSC™ tool to properly identify the extent of damage and determine the best remedy. TotalView™ visualization software processed the caliper data to identify casing restrictions, assess drift ID, and determine the depth at which the casing returned to nominal ID. Analysis determined that the casing was severely deformed from the surface to about 39 ft (12 m) and that the average diameter was reduced from about 6.29 in. (160 mm) to about 4.72 in. (120 mm). As a result, the client was able to excavate around the wellhead, cut off and replace the damaged casing, re-complete the abandoned well, and return it to profitable production.

**Venezuela**

**Wireline Services Evaluation of High-Angle Horizontal Well Helps Avoid Costly Workover**

Weatherford performed a high-resolution, cement-bond evaluation in a high-angle horizontal well to determine possible fluid communication behind casing. The Weatherford URS; high-resolution, borehole-compensated sonic tool; universal gamma ray tool; casing-collar locator; wireline communication cartridge; and a motorized unit tractor were deployed. The resulting high-resolution, cement-bond evaluation data enabled the operator to improve casing centralization, achieve a better cement job, and avoid a costly workover.

**Saskatchewan, Canada**

**Casing Imaging Tool Finds Corroded Casing Section Where Other Methods Fail**

Weatherford’s CIT tool was used to determine the exact location of production casing holes, pinpointing the problem to a section of corroded casing just 11-1/2 ft (3.5 m) below the surface. This proximity to the surface made it impossible to successfully use surface packer-pressure testing equipment or other competing devices. (With the coil-type sensors used in competing devices, measurement quality and accuracy suffer at the slow logging speeds required near the surface.) Damaged casing was successfully recovered from the well and replaced without significant diagnostic work.

**Well Integrity: from Detection to Remediation**

At Weatherford, not only do we detect defects in your wellbore, but we also fix them. We are a premier, global provider of re-entry services. Our vast portfolio includes thru-tubing intervention, casing repair, and a multi-disciplinary well abandonment service. If at any phase in your well’s lifecycle we detect a problem, we can recommend and implement an appropriate remediation strategy—whether you need a patch, a plug, or a seal.

For example, Weatherford MetalSkin® solid-tubular expandable systems permanently isolate damaged casing or perforations, and that eliminates repeated workover operations. Elastomer seals provide more reliable zonal isolation than cement squeezes. Most importantly, MetalSkin systems provide a larger ID and better access than scab liners for future drilling, completion, production, or injection operations.

On the other end of the spectrum, we also offer production logging. Because a production decline can be an early warning sign that you have a leak, this service is an integral component of well integrity...
To learn more about ensuring well integrity through our comprehensive suite of diagnostic tools, contact your nearest authorized Weatherford representative, or visit us at weatherford.com.