Cement bond logs

Proper cement placement between the well casing and the formation is essential:

- To support the casing (shear bond)
- To prevent fluid from leaking to the surface
- For isolating producing zones from water-bearing zones (hydraulic bond)

Acoustic logs (/Acoustic_logging) provide the primary means for evaluating the mechanical integrity and quality of the cement bond.[1][2][3][4][5]

Contents

Evaluating cement bond

Acoustic logs (/Acoustic_logging) do not measure cement quality directly, rather, this value is inferred from the degree of acoustic coupling of the cement to the casing and to the formation. Properly run and interpreted, cement-bond logs (CBL) provide highly reliable estimates of well integrity and zone isolation. Just as filtrate invasion and formation alteration may produce changes in formation acoustic properties, and thus variation in acoustic logs over time,[6][7][8] so too, cement-bond logs may vary over time as the cement cures and its properties change.

Modern acoustic cement-evaluation (bond) devices are comprised of monopole (axisymmetric) transmitters (one or more) and receivers (two or more). They operate on the principle that acoustic amplitude is rapidly attenuated in good cement bond but not in partial bond or free pipe. These cased-hole wireline tools measure:

- Compressional-wave travel time (transit time)
- Amplitude (first pipe arrival)
- Attenuation per unit distance

Conventional CBL tools provide omnidirectional measurements, while the newer radial cement-evaluation tools provide azimuthally sensitive measurements for channel evaluation.

When the acoustic wave generated by the transmitter reaches the casing,

- Part is refracted down the casing (amplitude and travel-time measurement)
- Part travels through the mud (fluid arrival)
- Other parts are refracted into the annulus and the formation and received back (formation arrival).

Amplitude, measured directly or as an attenuation ratio, is the primary bond measurement and is used to provide:

- Quantitative estimations of cement compressive strength
- Bond index
- Qualitative interpretation of the cement-to-formation interface

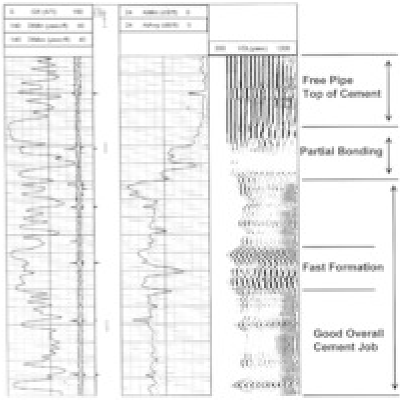
Tool response depends on the acoustic impedance of the cement, which, in turn is function of density and velocity. On the basis of empirical data, the log can be calibrated directly in terms of cement compressive strength. However, in foamed cements or when exotic additives are used, these calibrations can be inaccurate. In these situations, users are advised to consult with the logging service company regarding the appropriate calibrations.

A typical cement-log presentation includes:

- A correlation curve (gamma ray), travel time (μsec)
- Amplitude (mV)
- Attenuation (dB/ft) curves
- A full-waveform display (μsec)

Presentation of the full acoustic waveform assists in resolving bond ambiguities arising from use of an amplitude measurement alone and provides qualitative information about the cement-to-formation bond. Waveform displays (**Fig. 1**) may be in:

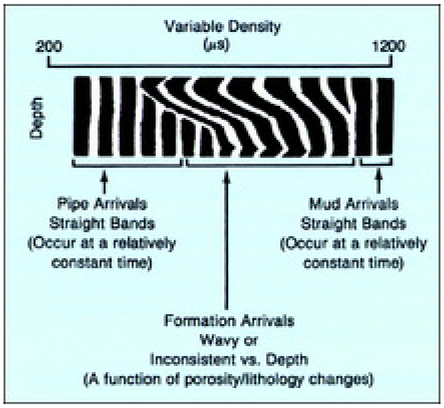
- Variable density (VDL) or intensity (also called microseismograms) formats
- Oscilloscope waves (also known as x-y or "signature")
- Both of the above



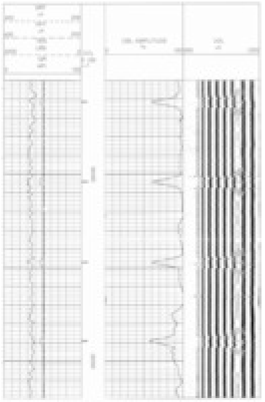
(/File%3AVol5_Page_0185_Image_0001.png)

Fig. 1 – Typical cement-bond log presentation (courtesy of Baker Atlas).

Variable density is a continuous-depth time display of full-waveform amplitude presented as shades of black and white. Positive waveform amplitudes are shown as dark bands and negative amplitudes as gray or white bands; contrast is proportional to amplitude. On a variable-density log, free pipe and fluid arrivals (if present) are easily identified as straight dark and light lines (indicating homogenous acoustic properties) at either side of the display (**Fig. 2**). The zigzag, wavy, or chevron pattern between these two arrivals is the formation signal (indicating varying acoustic transit time). In cases of poor bonding, casing-collar signals may also be identified as "w" patterns (anomalies) (**Fig. 3**).[9]



(/File%3AVol5_Page_0186_Image_0001.png)



(/File%3AVol5_Page_0187_Image_0001.png)

Fig. 2 – Identification of important features on a variable-density log (courtesy of Baker Atlas).

Fig. 3 – Casing-collar arrivals indicated on peak amplitude curve (Track 2) and variable density (Track 3). The height of the collar disturbance is a function of measurement TR spacing (amplitude, 3-ft interval; variable density, 5-ft interval) (courtesy of Baker Atlas).

Conventional cement-bond devices

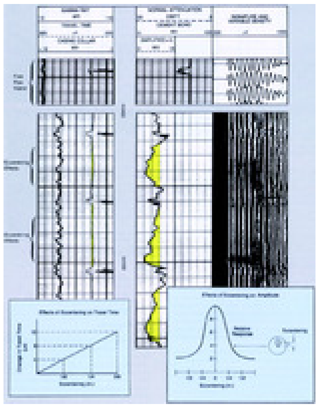
Early CBL designs (1960s) used a single transmitter and single receiver for an amplitude measurement. In an evolution similar to that of openhole acoustic logs, new designs were subsequently introduced that measured signal amplitude at a near receiver and a full waveform from a far receiver. Eventually, borehole-compensated devices using dual transmitters and dual receivers were introduced in the 1980s, and today most commercial devices use multiple transmitters and receivers in a variety of arrangements to provide compensated measurements. These devices measure the attenuation between two transmitters and receivers as a way of eliminating, or at least minimizing, the effects of:

- Tool eccentering
- Fluid attenuation
- Receiver sensitivity
- Temperature drift
- Calibration

In addition to specialized cement-bond devices, modern openhole array tools are designed to also provide conventional cement-evaluation measurements in cased hole. The cement-bond instrument sleeve is typically slotted to suppress and delay the tool signal that might otherwise be confused with the important casing signals.

TR spacing typically ranges from 3 to 5 ft. The shorter spacing (e.g., 3 ft) provides optimum signal level and resolution at high attenuation rates and is normally used for amplitude and travel-time (TT) measurements. A longer spacing, commonly ≥ 5 ft, is used for the full-waveform recording because longer TR spacing provides greater separation of the casing and formation-signal arrival times. This separation allows for easier analysis of the formation-signal strength and is used to monitor cement-to-formation bonding.

These tools typically operate at higher frequencies than conventional openhole tools—between 20 and 30 kHz. As with openhole tools, cement-bond tools require centralization to ensure accurate measurements. Centering in the cased hole is more critical because the higher-operating frequencies (i.e., shorter wavelengths) and the tool measurement are based on signal amplitude. Tool eccentering reduces signal amplitude and travel time (**Fig. 4**).



(/File%3AVol5_Page_0188_Image_0001.png)

Fig. 4 – Effects of tool eccentering (courtesy of Baker Atlas).

Cement-bond logging tools use gated systems to measure the specific parts of the acoustic waveform needed for the primary bond-amplitude measurement. Gates are time periods during which measurements are made—they can be either of the following:

- Fixed
- Sliding (floating)

Fixed-gate systems are commonly used for amplitude measurements and floating gates for travel-time measurements. Fixed gates are set (generally at the wellsite) to open, remain open, and close at designated times; opening time for the gate is a function of the casing size and the borehole-fluid velocity. If the gate opening is too large, there may be interference between early and late-arriving signals. Floating gates remain open, but recording is only triggered by an amplitude value greater than a designated threshold value.

A casing cement job can result in one or more of the following situations:

- Free pipe
- Good bond
- Bond to casing only
- Partial bond

1. In the first scenario, free pipe, there is no cement bond between the casing and cement. Consequently, there is no acoustic coupling with the formation and most of the transmitted acoustic energy is confined to the casing and the borehole fluid. As a result, a free-pipe acoustic signal is:

- Long-lived
- High-amplitude
- Of uniform frequency

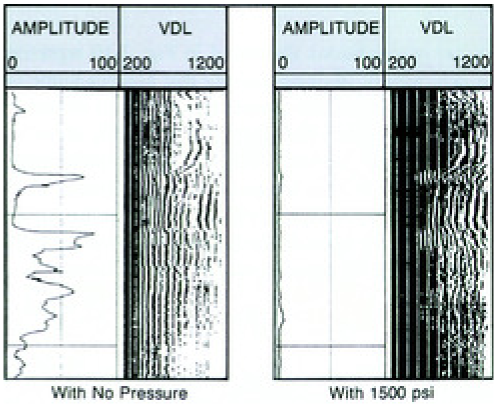
2. In the second scenario, good bond, cement is properly bonded to casing and to the formation. This provides good acoustic coupling and most of the acoustic energy is transmitted to the formation, resulting in little (weak) to no casing signals and little amplitude until the arrival of the strong formation signal.

3. The third scenario, bond to casing only, is a common condition in which cement is bonded to the casing but not to the formation. This can occur because the mudcake dries and shrinks away from cement, or because the cement did not bond with mudcake in poorly consolidated formations. In this situation, energy traveling through the casing is attenuated

drastically because of the highly attenuating cement sheath. At the same time, the annulus outside the cement sheath provides poor acoustic coupling. The result is that little energy is transferred to the annular fluid and virtually none is transferred to the formation. This condition is indicated by the lack of later-arriving formation energy. A similar response can be caused by the presence of formation gas in shallow, high-porosity zones.

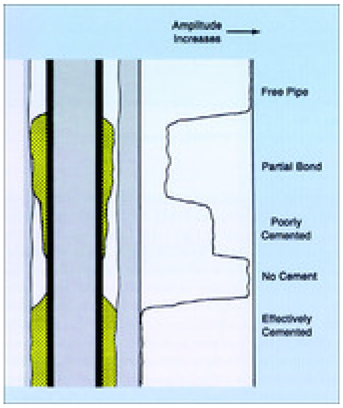
4. In the last scenario, partial bond, a space exists within an otherwise well-bonded casing. This may occur with the presence of a microannulus or channels within the cement. The resulting waveform is comprised of a casing signal and a formation signal; the casing signal arrives first, followed by the formation signal.

When channeling occurs, it is generally localized and nonuniform; that is, it occurs over relatively short intervals and can frequently be identified by variations in the amplitude response. Channeling is significant because it prevents a hydraulic seal. In contrast, a microannulus (a small gap between the casing and cement sheath) may extend over long sections of casing but may not prevent a hydraulic seal. Microannulus may result from thermal expansion or contraction of the pipe during cementing or to the presence of contaminants, such as grease or mill varnish, on the casing's exterior surface. A common practice is to run cement-bond logs with the casing under pressure to expand the casing against the cement, thereby decreasing any microannulus that might exist. If the initial log run was not under pressure and the log indicates poor bond, the presence of a microannulus can be evaluated by running a second bond log under pressure to see if there is a difference. Pressuring the casing improves the acoustic coupling to the formation and the casing signal will decrease and the formation signal will become more obvious (**Fig. 5**). However, if only channeling exists, pressuring the casing will not significantly change the log. When conducting a cement evaluation, information on the type of cement used is essential. For example, foam cements, which intentionally create void spaces in the cured cement, can be misinterpreted as partial bond if normal cement is assumed. **Fig. 6** summarizes this discussion, and **Table 1**[10] lists additional factors that may affect interpretation of bond quality from the amplitude response.



(/File%3AVol5_Page_0189_Image_0001.png)

Fig. 5 – Field example showing microannulus effect on amplitude and VDL log displays (courtesy of Baker Atlas).



(/File%3AVol5_Page_0190_Image_0001.png)

Fig. 6 – Summary of qualitative interpretation based on the amplitude curve (courtesy of Baker Atlas).

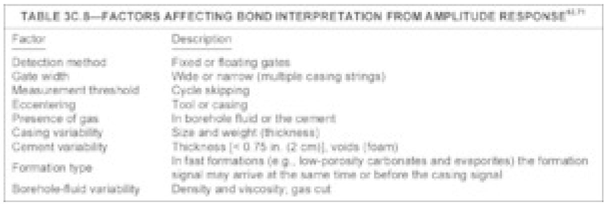


TABLE 3C.8—FACTORS AFFECTING BOND INTERPRETATION FROM AMPLITUDE RESPONSE

Factor	Description
Detection method	Fixed or floating gates
Gate width	Wide or narrow (multiple casing strings)
Measurement threshold	Cycle skipping
Eccentering	Tool or casing
Presence of gas	In borehole fluid or the cement
Casing variability	Size and weight (thickness)
Cement variability	Thickness [< 0.75 in. (2 cm)], voids (foam)
Formation type	In fast formations (e.g., low-porosity carbonates and evaporites) the formation signal may arrive at the same time or before the casing signal
Borehole-fluid variability	Density and viscosity; gas cut

(/File%3AVol5_Page_0190_Image_0002.png)

Table 1[1][10]

One caveat regarding the use of the amplitude curve for bond evaluation: pipe amplitude represents the quality of the bond of pipe to cement but provides no indication of the quality of the bond between the cement and the formation. Whenever possible, amplitude data should be used in conjunction with the other measurements presented on the log (e.g., travel time or full waveform) for a more-reliable bond evaluation. For example, the presence of shear-wave amplitudes on the full-waveform display is an indication of good acoustic coupling to the formation. **Table 2** lists the limitations of conventional cement-bond logs.

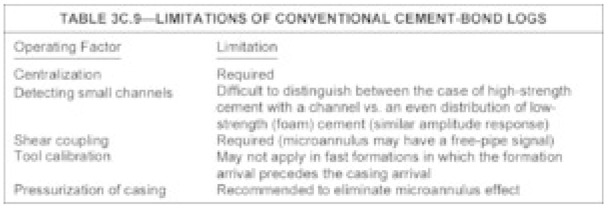


TABLE 3C.9—LIMITATIONS OF CONVENTIONAL CEMENT-BOND LOGS

Operating Factor	Limitation
Centralization	Required
Detecting small channels	Difficult to distinguish between the case of high-strength cement with a channel vs. an even distribution of low-strength (foam) cement (similar amplitude response)
Shear coupling	Required (microannulus may have a free-pipe signal)
Tool calibration	May not apply in fast formations in which the formation arrival precedes the casing arrival
Pressurization of casing	Recommended to eliminate microannulus effect

(/File%3AVol5_Page_0191_Image_0001.png)

Table 2

Formations with transit times less than casing (57 µsec/ft) can cause problems when interpreting the amplitude curves because the formation signal can arrive in the amplitude gate. The VDL should be examined to ensure that the formation arrival is impacting the amplitude curve.

The bond index (BI) is a qualitative measure of cement bond based on signal amplitude. This dimensionless quantity is the ratio of measured attenuation to maximum attenuation:

$$\text{Attenuation} = 20/\text{TR} \ \log\left(\text{measured amplitude}/\text{free-pipe amplitude}\right).$$

(/File%3AVol5_page_0192_eq_001.png)....................(1)

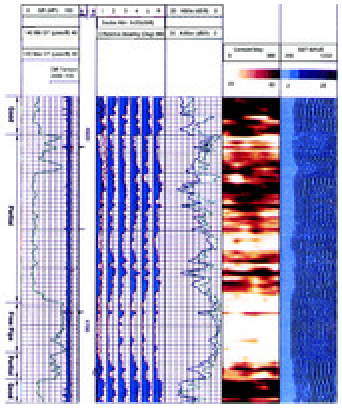
A BI value of 1.0 represents a perfect cement bond. A value of less than 1.0 indicates an incomplete bond. This

Edit Support is Offline

technique requires attenuation measurements in zones with 100% bond and in free pipe.

Radial-cement evaluation

Radial-cement-evaluation devices were developed to overcome some limitations of conventional cement-bond tools and to permit more accurate evaluation of cement distribution behind casing by providing the precise location of partial bond and channeling. These tools use one or more azimuthally sensitive transducers to evaluate cement quality around the circumference of the casing. Data from these tools are presented as individual log curves or as azimuthal images ("maps") of cement quality generated by interpolating between the individual azimuthal measurements (**Fig. 7**). In addition, each tool design also provides a conventional 5-ft VDL waveform measurement to provide information about the cement-to-formation bond.



(/File%3AVol5_Page_0192_Image_0001.png)

Fig. 7 – Log presentation for the Baker Atlas SBT tool containing individual log curves, cement map, and VDL display (courtesy of Baker Atlas).

There are four radial-evaluation-tool designs in current use:

- Televiewer-types that use a single rotating ultrasonic transducer[11][12]
- Circular ultrasonic pulse/echo transducers arranged in a fixed helical pattern around the sonde[13][14]
- A multipad device that provides six compensated attenuation measurements,[15]
- An array of eight TR pairs arranged azimuthally around the sonde, that provide compensated CBL amplitude[16][17]

The ultrasonic tools compute the acoustic impedance of the material beyond the casing. To do this, repeated acoustic pulses are directed at the casing to make it resonate in its thickness mode and the energy level (attenuation) of the decaying reflected wave is measured. Good cement bond to casing produces a rapid damping (higher impedance) of this resonance; poor cement bond results in longer resonance decay (lower impedance). Measurements from these devices are influenced by the same factors as openhole televiewer devices.

The pad device makes multiple measurements that are:

- Short-spaced
- Compensated
- Azimuthal-attenuation

Because the pads are in direct contact with the casing—in contrast to ultrasonic measurements—measurements are unaffected by:

- Gas in the borehole
- Fast formations
- Heavy-mud conditions
- Minor tool eccentricity

The attenuation in each segment is measured in two directions using a pair of acoustic receivers and two transmitters. The two measurements are combined to form a result that compensates for:

- Surface roughness
- The effects of minor residual cement on the inside of the casing

Transmitting elements and the firing sequence are controlled to direct (steer) and enhance the acoustic-energy output of both the pad transmitters and the VDL transmitter. This has the effect of improving the signal strength of both the casing and cement-to-formation arrivals, respectively. This technique improves VDL interpretation, particularly in soft formations in which the standard VDL may wash out.

The use of new high-performance low-density, foam, and complex cements is increasing. However, the presence of gas in cement slurries, as an inert component or as contamination, may seriously affect ultrasonic-tool interpretation. New interpretation methods integrate ultrasonic and attenuation measurements from conventional tools to provide improved cement evaluation in these conditions.[18][19][20][21] The latest ultrasonic tool has a conventional pulse-echo transducer plus a flexural transmitter and two flexural receivers that provide greater depth of investigation. Interpretation techniques combining these different measurements provide improved evaluation in lightweight cements, especially in the annulus, beyond the casing-cement bond.[22] **Table 3** summarizes the capabilities and guidelines for running the different types of cement-bond evaluation tools.

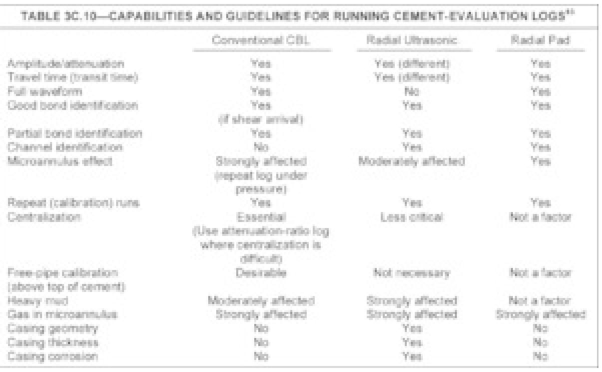


TABLE 3C.10—CAPABILITIES AND GUIDELINES FOR RUNNING CEMENT-EVALUATION LOGS

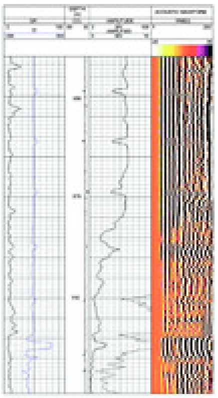
	Conventional CBL	Radial Ultrasonic	Radial Pad
Amplitude/attenuation	Yes	Yes (different)	Yes
Travel time (transit time)	Yes	Yes (different)	Yes
Full waveform	Yes	No	Yes
Good bond identification	Yes (if shear arrival)	Yes	Yes
Partial bond identification	Yes	Yes	Yes
Channel identification	No	Yes	Yes
Microannulus effect	Strongly affected (repeat log under pressure)	Moderately affected	Yes
Repeat (calibration) runs	Yes	Yes	Yes
Centralization	Essential (Use attenuation-ratio log where centralization is difficult)	Less critical	Not a factor
Free-pipe calibration (above top of cement)	Desirable	Not necessary	Not a factor
Heavy mud	Moderately affected	Strongly affected	Not a factor
Gas in microannulus	Strongly affected	Strongly affected	Strongly affected
Casing geometry	No	Yes	No
Casing thickness	No	Yes	No
Casing corrosion	No	Yes	No

(/File%3AVol5_Page_0193_Image_0001.png)

Table 3

Cement-evaluation logs

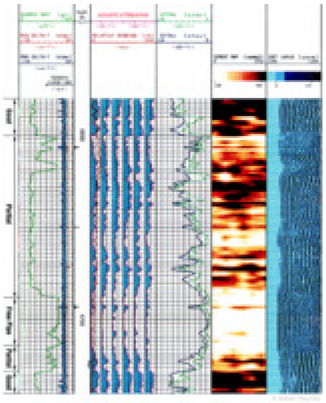
Conventional cement-bond logs (CBLs) comprise a pulsed transmitter and several receivers of acoustic energy positioned as a vertical array of transducers. The acoustic signal travels through borehole fluid, casing, cement, and the formation itself. The signal is received, processed, and displayed as a microseismogram. The recorded waveforms are presented together with the travel time and a casing-amplitude curve, which displays the amplitude of the acoustic signal that has traveled through the casing but not through the cement and formation. The waveform and amplitude data allow two bonds to be investigated. These are the bond between casing and cement and, to a lesser extent, that between cement and formation. A "straight" waveform display is traditionally interpreted to mean no cement bonding. Variations in the acoustic display are interpreted as indicating the presence of bonded cement.[23] These displays have been enhanced by the application of statistical variance processing to ultrasonic data.[24] CBLs clearly indicate the top of cement, where there is unbonded pipe, and they indicate where the pipe is well cemented (**Fig. 8**). However, they are not reliable as indicators of hydraulic sealing by the cement, because they cannot detect small channels therein. Part of the problem is that conventional CBL transducer arrays are vertical, whereas bonding problems need to be investigated circumferentially.



(/File%3AVol5_Page_0395_Image_0001.png)

Fig. 8 –Example of CBL. Track 1 contains the gamma ray (for correlation) and acoustic travel time (for quality control). Track 2 contains the amplitude curve and amplified amplitude, which indicates cement-to-casing bond. Track 3 contains the CBL waveform, which indicates cement-to-casing bond as well as cement-to-formation bond. Straight lines in the CBL waveform, along with high amplitude readings, indicate poor cement-to-casing bond. There is nearly free pipe above an apparent top of cement at a depth of approximately X80 depth units. At greater depths, the pipe is well bonded. (Courtesy of Halliburton.)

Baker Atlas' Segmented Bond Tool (SBT™) uses six pads, on each of which there is a transducer arrangement of receivers and transmitters of acoustic energy.[15] The pads are in contact with the casing. Energy is transmitted at one pad and is received at an adjacent pad. The pad spacing is such that the first arrival is the wave that has passed through the casing. The rate of attenuation can be computed across each 60° segment of the casing circumference. A high rate of attenuation is indicative of a good cement bonding to the casing and an absence of channels within the cement. The method allows localized zones of good hydraulic seal to be identified in a way that is independent of borehole-fluid type. The bonding between cement and formation is investigated through a CBL-type receiver array for wave-train presentation (**Fig. 9**).



(/File%3AVol5_Page_0396_Image_0001.png)

Fig. 9 – Example of cement evaluation using the Segmented Bond Tool (SBT™). Track 1 contains the gamma ray and two quality curves for pad contact with the borehole wall and for centralization, both of which are of high quality in this example. Track 2 contains the acoustic attenuation logs for the six pads. Track 3 shows the average and minimum attenuation at each sampling level. Track 4 presents a variable-attenuation log or cement map of the casing periphery vs. depth. Dark zones are the most strongly bonded. Track 5 is a CBL-type display. In this example, the partial bonding is sufficient to provide hydraulic isolation. There is poor cement condition between X688 and X714 depth units. Attempts to rectify this problem will be impeded by the hydraulic isolation above and below this interval. (Courtesy of Baker Atlas.)

Ultrasonic tools are superior to the acoustic CBLs, although they remain adversely affected by highly attenuating muds. They are often grouped as "cement evaluation tools." One of the earlier ultrasonic tools was actually called the Cement Evaluation Tool (CET™). This Schlumberger tool comprised an array of eight ultrasonic transducers that allowed a limited radial inspection of the casing and its annulus. The most recent tools have a single rotating transducer that incorporates both the source and receiver of ultrasonic energy. The tool has to be centered. The data for circumferential inspection of the casing, as described above, and for the evaluation of cement bonding are obtained on the same logging pass. Acoustic energy is reflected at interfaces that correspond to changes in acoustic impedance (the product of acoustic velocity and density). The first reflection is at the casing itself. The second reflection may be at the outside of the casing. If cement is bonded to the casing, there will be a strong reflection. If there is unset cement or water behind the casing, there will be a weak reflection. The received waveform is the sum of the reflected waveform from the original burst and the exponentially decaying waveform from the resonant energy that is trapped between the inner and outer edges of the casing. By analyzing the entire waveform, an acoustic-impedance map of the cement can be constructed. This map can indicate the presence of channels and their orientations.

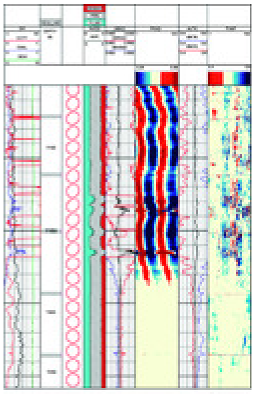
Schlumberger's Ultrasonic Imager (USI™) is one such tool.[11] It operates from 200 to 700 Hz and provides a full high-resolution coverage of the casing and cement integrity. Channels as narrow as 1.2 in. [30 mm] can be detected. It is used with a conventional CBL tool. An interesting example of the complementary nature of these data has been presented by De Souza Padilha and Da Silva Araujo. It deals with the problem of gas-contaminated cement, which has been a longstanding interpretation problem in the industry. Essentially, the CBL reads low-amplitude values in gas-contaminated cements. The USI cannot distinguish between gas-filled cement and fluids, but it can quantify the acoustic impedance of the cement. Therefore, the presence of gas-contaminated cement is indicated where the CBL reads low and the USI indicates fluids. If there is only gas behind the casing, the CBL reads high and the USI shows gas. The CBL and USI were used conjunctively to distinguish these cases. The application of statistical variance processing to the conjunctive use of CBL and ultrasonic impedance data has led to an improved cement evaluation.[20]

Simultaneous casing inspection and cement evaluation

Ultrasonic tools can be operated to address two objectives concurrently: casing integrity (/Casing_inspection_logs) and cement evaluation. A further example is Halliburton's Circumferential Acoustic Scanning Tool—Visualization version (CAST-V™), which allows separate or simultaneous casing inspection and cement evaluation.[12] The tool can operate in two modes:

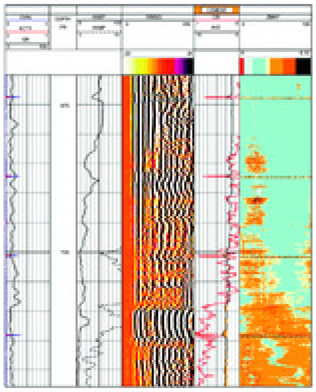
- Image mode, whereby the scanner evaluates only the inner surface of the casing.
- The cased-hole mode, whereby circumferential maps of casing thickness and acoustic impedance are used to assure casing integrity and to distinguish between fluids and cement in the annulus.

Figs. 10 and 11 show examples of CAST-V data displays. This tool can also operate in open hole as a formation imager (see Borehole Imaging (/Borehole_imaging)).



(/File%3AVol5_Page_0398_Image_0001.png)

Fig. 10 – Example of casing inspection using the visualization version of the Circumferential Acoustic Scanning Tool (CAST-V™). The casing-evaluation presentation includes casing ovality, eccentricity, hole deviation, and gamma ray in Track 1. In this case, the eccentricity comprises both tool and casing eccentricity resulting from formation movement (salt flow). Track 2 shows a cross-sectional presentation of the pipe shape. Track 3 shows a cross section of the pipe wall. Track 4 provides the average, minimum, and maximum values of the pipe radius that is shown in Track 5. Track 6 provides the average, minimum, and maximum values of the pipe thickness that is the image shown in Track 7, where red indicates pipe thinning and blue indicates pipe thickening. (Courtesy of Halliburton.)



(/File%3AVol5_Page_0399_Image_0001.png)

Fig. 11 – Example of cement evaluation using the visualization of the Circumferential Acoustic Scanning Tool (CAST-V™). The data relate to an interval that overlaps with the conventional CBL in Fig. 8. The cement-evaluation presentation includes casing ovality and tool eccentricity in Track 1. The conventional CBL output is shown in Tracks 2 and 3 as per Fig. 8. Data from CAST-V are shown in Tracks 4 and 5. The image in Track 5 is an acoustic-impedance map from 0 to 360° (left to right) with 0° representing the high side of the hole. Track 4 contains the average impedance of the image in Track 5 and a cement-bond index (CBI) as a quick indication of the degree of bonding. Tracks 4 and 5 imart clarity to the interpretation of Fig.8 by more clearly showing no cement above X80 depth units, good cement below Y20 depth units and questionable bonding in between. (Courtesy of Halliburton.)

References

1. ↑ 1.0 1.1 Bigelow, E.L. 1990. Cement Evaluation, 1-142. Houston: Atlas Wireline Services.
2. ↑ Hill, A.D. 1990. Cement-Quality Logging. Production Logging—Theoretical and Interpretative Elements, Vol. 14, 123-140. Richardson, Texas: Monograph Series, SPE.
3. ↑ Jutten, J. and Morriss, S.L. 1990. Cement Job Evaluation. Well Cementing, E.B. Nelson ed., Ch. 16, 16-1-16-44. Amsterdam: Elsevier, Developments in Petroleum Science No. 28.
4. ↑ Rouillac, D. 1994. Cement Evaluation Logging Handbook, 1-176. Paris: Editions Technip.
5. ↑ Smolen, J.J. 1996. Cased Hole and Production Log Evaluation, Ch. 10 and 11, 161-213. Tulsa, Oklahoma: PennWell Publishing Co.
6. ↑ Baker, L.J. 1984. The Effect of the Invaded Zone on Full Wavetrain Acoustic Logging. Geophysics 49 (6): 796–809. http://dx.doi.org/10.1190/1.1441708 (http://dx.doi.org/10.1190/1.1441708)
7. ↑ Alberty, M. 1996. The Influence of the Borehole Environment upon Compressional Sonic Logs. The Log Analyst 37 (4): 30–44.
8. ↑ Chi, S., Torres-Verdín, C., Wu, J. et al. 2006. Assessment of mud-filtrate invasion effects on borehole acoustic logs and radial profiling of formation elastic parameters. SPE Res Eval & Eng 9 (5): 553–564. SPE-90159-PA. http://dx.doi.org/10.2118/90159-PA (http://dx.doi.org/10.2118/90159-PA)
9. ↑ Walker, T. 1968. Origin of the ‘W’ Pattern on Cased Hole Micro-Seismogram Logs. The Log Analyst 9 (2): 30–32.
10. ↑ 10.0 10.1 Pilkington, P.E. 1992. Cement Evaluation - Past, Present, and Future. J Pet Technol 44 (2): 132-140. SPE-20314-PA. http://dx.doi.org/10.2118/20314-PA (http://dx.doi.org/10.2118/20314-PA).
11. ↑ 11.0 11.1 Hayman, A.J., Hutin, R., and Wright, P.V. 1991. High-Resolution Cementation and Corrosion Imaging by Ultrasound, paper KK. Trans., 1991 Annual Logging Symposium, SPWLA, 1–25.
12. ↑ 12.0 12.1 Graham, W.L., Silva, C.I., Leimkuhler, J.M. et al. 1997. Cement Evaluation and Casing Inspection With Advanced Ultrasonic Scanning Methods. Presented at the SPE Annual Technical Conference and Exhibition, San Antonio, Texas, 5-8 October 1997. SPE-38651-MS. http://dx.doi.org/10.2118/38651-MS (http://dx.doi.org/10.2118/38651-MS)
13. ↑ Froelich, B., Dumont, A., Pittman, D. et al. 1982. Cement Evaluation Tool: A New Approach to Cement Evaluation. J Pet Technol 34 (8): 1835-1841. SPE-10207-PA. http://dx.doi.org/10.2118/10207-PA (http://dx.doi.org/10.2118/10207-PA)
14. ↑ Sheives, T.C., Tello, L.N., Maki Jr., V.E. et al. 1986. A Comparison of New Ultrasonic Cement and Casing Evaluation Logs With Standard Cement Bond Logs. Presented at the SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, 5-8 October 1986. SPE-15436-MS. http://dx.doi.org/10.2118/15436-MS (http://dx.doi.org/10.2118/15436-MS)
15. ↑ 15.0 15.1 Bigelow, E.L., Domangue, E.J., and Lester, R.A. 1990. A New and Innovative Technology for Cement Evaluation. Presented at the SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, 23-26 September 1990. SPE-20585-MS. http://dx.doi.org/10.2118/20585-MS (http://dx.doi.org/10.2118/20585-MS)
16. ↑ Schmidt, M.G. 1989. The Micro CBL—A Second Generation Radial Cement Evaluation Instrument, paper Z. Trans., 1989 Annual Logging Symposium, SPWLA, 1–16.
17. ↑ Tello, L.N. et al. 1995. New Efficient Method for Radial Cement Bond Evaluation. Canadian Well Logging Soc. J. 20: 60–69.
18. ↑ Butsch, R.J. 1995. Overcoming Interpretation Problems of Gas-Contaminated Cement Using Ultrasonic Cement Logs. Presented at the SPE Annual Technical Conference and Exhibition, Dallas, Texas, 22-25 October 1995. SPE-30509-MS. http://dx.doi.org/10.2118/30509-MS (http://dx.doi.org/10.2118/30509-MS).
19. ↑ Frisch, G.J., Graham, W.L., and Griffith, J. 1999. Assessment of Foamed - Cement Slurries Using Conventional Cement Evaluation Logs and Improved Interpretation Methods. Presented at the SPE Rocky Mountain Regional Meeting, Gillette, Wyoming, 15-18 May 1999. SPE-55649-MS. http://dx.doi.org/10.2118/55649-MS (http://dx.doi.org/10.2118/55649-MS)
20. ↑ 20.0 20.1 Frisch, G., Graham, L., and Griffith, J. 2000. A Novel and Economical Processing Technique Using

Conventional Bond Logs and Ultrasonic Tools for Enhanced Cement Evaluation, paper EE. Trans., 2000 Annual Logging Symposium, SPWLA, 1–14.

21. ↑ Frisch, G.J., Fox, P.E., Hunt, D.A. et al. 2005. Advances in Cement Evaluation Tools and Processing Methods Allow Improved Interpretation of Complex Cements. Presented at the SPE Annual Technical Conference and Exhibition, Dallas, Texas, 9-12 October 2005. SPE-97186-MS. http://dx.doi.org/10.2118/97186-MS (http://dx.doi.org/10.2118/97186-MS)
22. ↑ Kuijk, R.v., Zeroug, S., Froelich, B. et al. 2005. A Novel Ultrasonic Cased-Hole Imager for Enhanced Cement Evaluation. Presented at the International Petroleum Technology Conference, Doha, Qatar, 21-23 November 2005. IPTC-10546-MS. http://dx.doi.org/10.2523/10546-MS (http://dx.doi.org/10.2523/10546-MS)
23. ↑ Frisch, G., Graham, L., and Wyatt, D. 1998. Economic Evaluation of the Use of Well Logs for Diagnosing Conformance Problems. Presented at the SPE Gas Technology Symposium, Calgary, Alberta, Canada, 15-18 March 1998. SPE-40036-MS. http://dx.doi.org/10.2118/40036-MS (http://dx.doi.org/10.2118/40036-MS)
24. ↑ Harness, P.E., Sabins, F.L., and Griffith, J.E. 1992. New Technique Provides Better Low-Density-Cement Evaluation. Presented at the SPE Western Regional Meeting, Bakersfield, California, USA, 30 March–1 April. SPE-24050-MS. http://dx.doi.org/10.2118/24050-MS (http://dx.doi.org/10.2118/24050-MS)

Noteworthy papers in OnePetro

Use this section to list papers in OnePetro that a reader who wants to learn more should definitely read

External links

Use this section to provide links to relevant material on websites other than PetroWiki and OnePetro

See also

Types of logs (/Types_of_logs)

Casing inspection logs (/Casing_inspection_logs)

Category

Categories (/Special%3ACategories):
1.13.4 Cement and bond evaluation (/Category%3A1.13.4_Cement_and_bond_evaluation)
| 2 Well completion (/Category%3A2_Well_completion) | YR (/Category%3AYR)

(https://www.onepetro.org/search?q=Cement bond logs) (http://scholar.google.ca/scholar?q=Cement bond logs) (http://www.worldcat.org/search?q=Cement bond logs) (http://wiki.seg.org/index.php?title=Special%3ASearch&redirs=1&fulltext=Search&ns0=1&ns4=1&ns500=1&redirs=1&title=Special%3ASearch&advanced=1&fulltext=Advanced+search&search=Cement bond logs) (http://wiki.aapg.org/index.php?title=Special%3ASearch&profile=advanced&fulltext=Search&ns0=1&ns4=1&ns102=1&ns104=1&ns106=1&ns108=1&ns420=1&ns828=1&redirs=1&profile=advanced&search=Cement bond logs)

Edit Support is Offline