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Evaluation of Cementation Job Using Cement Bond Log

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Abstract

Well cementing is an important process during oil and gas well drilling due role in supporting the well casing and preventing formation collapsing. Generally, there are two types of cementing process that are primary cementing and remedial cementing. The type of cement uses in oil and gas well is Portland cement mixed with improvements additives to enhance its characteristics. Various types of cements are used depends on different factors of the cemented region. This cementing process is evaluated using various methods such as (CBL , Image, VDL, RBT , UST , RIB , URS logs). Each one of them have its features, specifications and applications. In this paper, we evaluated the cement process for an Iraqi oil well by using CBL, Image and VDL logs by selecting two different sections of the well; section A (depth 1780 m to 1800 m) , and section B (depth 1800 m to 1825 m). Our results show that in section A the cementing process is failed because there is no cement behind the casing (a free pipe case is available with fast formation), while section B show a good cementing process.

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1. Introduction

Oil well cementing is the placement of a cement slurry in the annulus space between the well casing and the geological formations. Cementing surrounding the wellbore to form a solid mass which has supporting and sealing properties. When a certain section of the depth of an oil or gas well has been drilled successfully, the drilling fluid filtrate will penetrate into the formation from a few inches to several feet which cause interaction with the formation minerals in the producing horizons. Thus, the formation of the drilling mud cake cannot permanently prevent the wellbore from collapsing.[1]

Cementing operations may be undertaken for several reasons including sealing the annulus after a casing string has been run, sealing a lost circulation zone, setting a plug in an existing well so that it may be abandoned. Before cementing operations commence, engineers determine the volume of cement to be placed in the wellbore and the physical properties of both the slurry and the set cement needed, including density and viscosity.[2]

Cementing operations can be divided into two broad categories: primary cementing and remedial cementing. Most primary cement jobs are performed by pumping the slurry down the casing and up the annulus; however, modified techniques can be used for special situations. These techniques are cementing through pipe and casing (normal displacement technique), stage cementing (for wells with critical fracture gradients), inner-string cementing through tubing (for large-diameter pipe), outside or annulus cementing through tubing (for surface pipe or large casing), reverse-circulation cementing (for critical formations), delayed-set cementing (for critical formations and to improve placement), and multiple-string cementing (for small-diameter tubing) as shown in Fig. 1.[3]

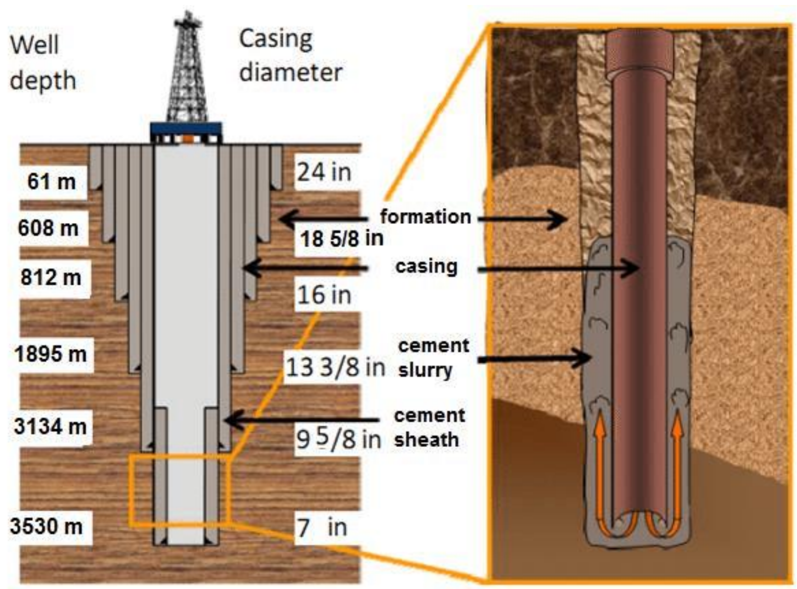

Fig. 1: Schematic simulation of the oil well cementing process [3]

The Cement Bond Log (CBL) is a tool that have become the standard method used to evaluating cement jobs of well and does the cementing process Failed or not and to detect the position of weakness and failure points in cement. A cement bond log (CBL) documents an evaluation of the integrity of cement job performed on an oil well. It is basically a sonic tool which is run on wireline. Similar to a ringing bell, when no cement is bonded to the casing, pipe is free to vibrate (loud sound). When the casing is bonded to hard cement, casing vibrations are attenuated proportionally to bonded surface.

A cement bond log (CBL) uses an acoustic amplitude curve to indicate cement bond integrity. CBL uses conventional sonic log principals of refraction to make its measurements. Sound travels from the transmitter, through mud and refracts along the casing mud interface and back to the receivers. The amplitude is recorded on the log in millivolts or as attenuation in decibels/foot or as a bond index. A travel curve is also presented. The actual value measured is the signal amplitude in millivolts. Attenuation is calculated by the service company based on its tool design, casing diameter and transmitter [4]

In conventional CBL tools, a transmitter is pulsed to produce an omnidirectional acoustic signal that travels along various paths through the borehole fluid, pipe, cement, and formation, to a set of receivers. The logging system records the received waveforms and displays them on the log along with a pipe-amplitude curve. Interpretation of the CBL uses these two measurements to evaluate two bonds; the first bond measures the cement-to-pipe bond, and the second measures the cement- to-formation bond. These tools include cement bond (CBL), segmented bond (SB), and the radial bond (RB). Traditionally the pipe amplitude curve has been used to determine the quality of the pipe to cement bond, while the waveform display is used to determine both the pipe to cement bond and the cement to formation bond. The classic interpretation of the waveform display is that straight traces indicate there is no cement in the borehole, while any variation in the acoustical waveform indicates that some cement is present. [5]

Modern acoustic cement-evaluation (bond) devices are comprised of monopole (axisymmetric) transmitters (one or more) and receivers (two or more) as shown in Fig 2. 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), and Attenuation per unit distance. 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 [6]. The objective of this study is to evaluate the cementing process, and detect the areas of weakness and failure for the cementing process by using cement bond log (CBL).

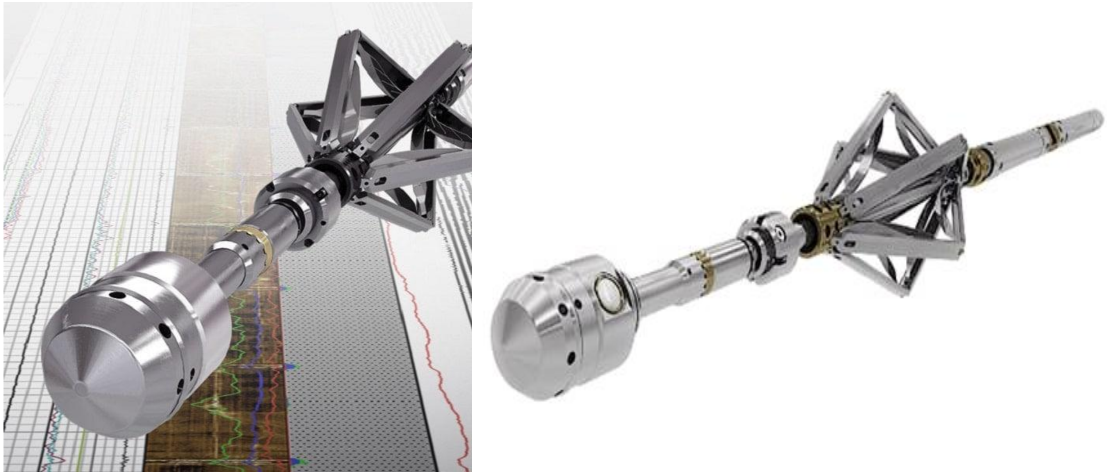

Fig. 2: Cement Bond Log (CBL) [4]

1.1. Cement Process

Cementing is the process of mixing and displacing a slurry down the casing and up the annulus, behind the casing, where is allowed to “set”, thus bonding the casing to the formation. Some additional functions of cementing include: protecting producing formations, providing support for the casing, protecting the casing from corrosion , sealing off troublesome zones, protecting the borehole in the event of problems, support the vertical and radial loads applied to the casing, isolate porous formations from the producing zone formations

The main ingredient in most cement is “Portland” cement, a mixture of limestone and clay. This name comes from the solid mixture resembling the rocks quarried on the Isle of Portland, off the coast of England. [7]

1.2. Portland cement

The Ordinary Portland cement (OPC) is by far the most important oilwell binding material in terms of quantity produced; indeed, it is possibly the most abundant manufactured material.

The term “ordinary” indicates that the cement is manufactured in a rotary kiln from a molten matrix of suitably proportioned ingredients. OPC is used in nearly all well cementing operations; therefore, throughout this textbook, the terms OPC and Portland cement shall be used interchangeably. The conditions to which Portland cements are exposed in a well differ significantly from those encountered at ambient conditions during construction operations; as a result, special Portland cements are manufactured for use as well cements. Certain other special cements, used to solve particular well cementing problems. Portland cement is the most common example of hydraulic cement. Such cements set and develop compressive strength as a result of hydration, involving chemical reactions between water and the compounds present in the cement. The setting and hardening occur not only if the cement/water mixture is left to stand in air, but also if it is placed underwater. The development of strength is predictable, uniform, and relatively rapid. The set cement also has low permeability and is nearly insoluble in water; therefore, exposure to water does not destroy the hardened material. Such attributes are essential to achieve and maintain zonal isolation [8,9,10,11].

1.3. Types of cement logs

1.3.1 Radial Bond Tool (RBT)

Each The prime use for the Radial Cement Bond Tool is to assure the asset owner of hydraulic isolation between producing and non-producing zones, and the integrity of the well, by the effective placement of the cement between the well tubulars (typically casing) and the formation. Poor cement can result in unwanted water or gas production, fluid migration in the annulus and inadequate support of the casing. In some instances the safety and integrity of the entire well can be threatened as shown in Fig. 3 [12].

Fig. 3: Radial Bond Tool (RBT) [12]

An omni-directional piezoelectric transmitter crystal generates acoustic energy in response to an electrical signal sent from the tool electronics. The pulsed sonic signals are at 18 Khz (31/8” tool) or 22 kHz (111/16” tool) as shown in Fig.4. This acoustic energy travels at different speeds as a wavefront through the mud, casing cement and formation. During this time the signal is also attenuated. Sonic dampers within the tool prevent the transmitted signals travelling down through the tool to the receivers below. At 3ft (1m) from the transmitter is a segmented piezoelectric radial receiver. Each segment captures the returning acoustic energy and converts it into an electrical signal. As each segment detects the acoustic energy of a portion of the casing it allows the creation of a cement map. Internally the individual signals from the segments are electrically combined to obtain the omni directional amplitude which is equivalent to the standard 3ft signal from non segmented CBL tools. At 5ft from the transmitter is an omni directional piezoelectric receiver. This position has a greater depth of investigation and is used to record the waveform trace from which the Variable Density Log (VDL) is produced. In general the VDL is used to assess the cement-formation bond and CBL for the casing-cement bond. The sonic signals are received by the main analogue circuit board, conditioned and then portions of the waveform are digitized. From the 3ft segmented receivers the portion of the signal between 170-370 µs is digitized and from the 5ft receiver the full waveform 200-1200 µs is digitized. The digitized waveform data is stored in temporary memory and on command from the UltraWireTM controller or UMT memory recorder the digitized waveform data is transmitted to surface via the XTU or recorded into the UMT memory recorder. Additional UltraWireTM Gamma Ray and CCL tools are run in the string for depth correlation. The RBT can also be run with an UltraWireTM temperature logging tool. The RBT is run between strong centralisers; if the tool is not properly centralized data integrity is compromised. As little as 1/4" off centre can reduce the casing arrival amplitude by up to 2/3 of the signal. Additional Sondex UltraWireTM tools can be run in series with the RBT if required. The top and bottom tool connections are Sondex-GO. [13].

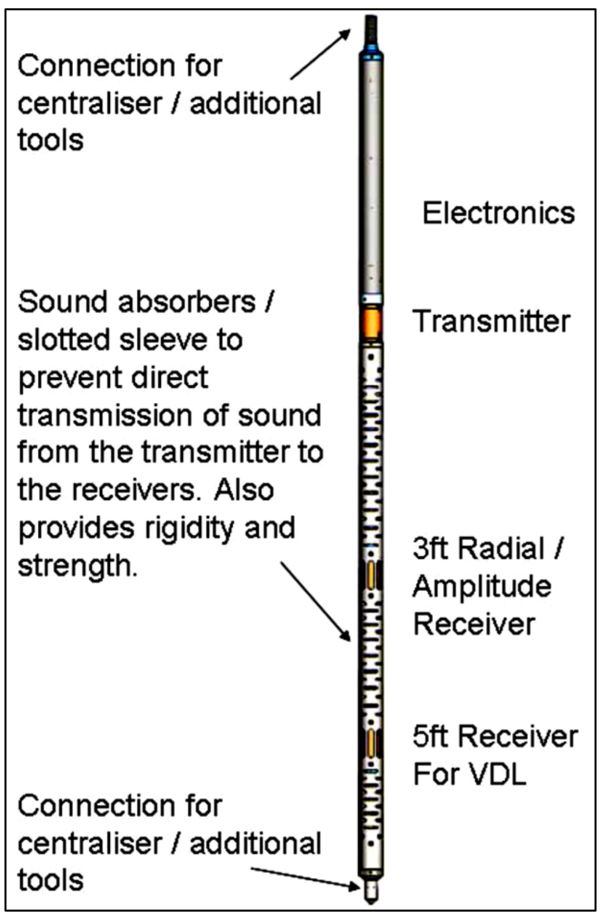

Fig. 4: Construction of Radial Bond Tool [13]

Fig. 5 below illustrates the different components of the received signal. The receivers record the composite signal comprised of casing, formation, cement and fluid arrivals. In general, the casing has the highest sonic velocity so this signal arrives first followed by the formation signals. In very hard formations with high sonic velocity (called 'fast' formations) the formation signals can arrive first and interfere with the casing returns, for instance: sonic energy reverberates within the casing, if the casing is unbounded the amplitude of the casing arrival will be high, and finally, if the casing is bonded the amplitude of the casing arrival will be low [13].

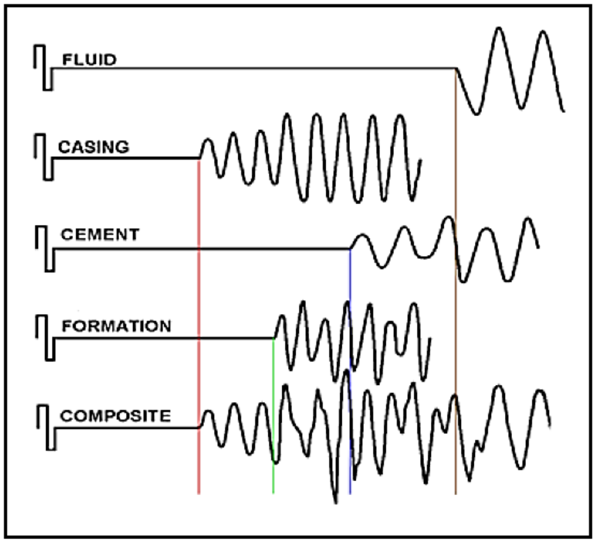

Fig. 5: Different components of the received signal

1.3.2 The Variable Density Log (VDL)

The VDL is used to illustrate the composite wave. This allows qualitative evaluation of the casing-cement and cement-formation bonds. The VDL is a 'top down' (Z-axis) plot of the amplitude of the composite sonic wave in grey scale. Fig.6 shows the basic principle of VDL [14].

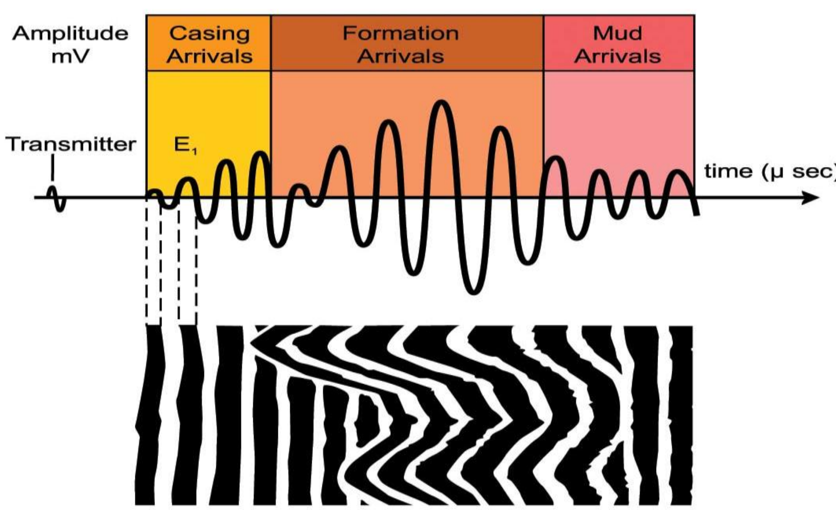

Fig. 6: Basic principle of VDL [14]

Typically, these are formations with travel times that are faster than the travel time of casing. These formations make the amplitude curves invalid due to the shift in the waveform outside of the gate setup as shown in Fig.7 [15].

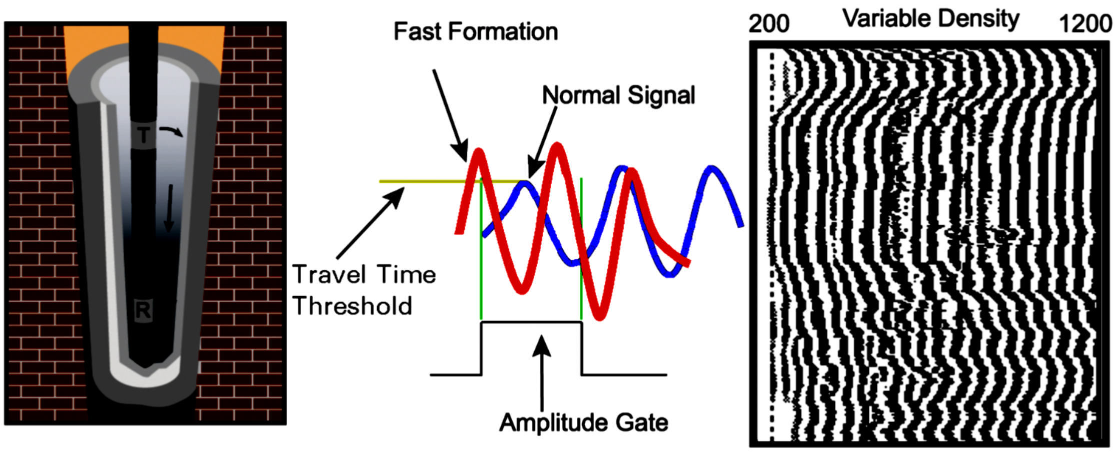

Fig. 7: VDL reading at Fast Formations [15].

1.3.3 The Variable Density Log (VDL)

Cement bond logging (CBL) is an important part of a well-completion program and is also recommended for most workover programs. Most of the cementing-related problems encountered can be diagnosed by use of the CBL [16]. Conventional CBL tools rely for their operation on the fact that a compressional (acoustic) wave transmitted along the wall of a steel pipe becomes attenuated if the pipe has cement bonded to it. The relationship between the compressive strength of the cement and the attenuation rate (measured in db/ft) is shown in Fig. 8.

Note that the type of cement is relatively unimportant and that, given the attenuation rate, a cement compressive strength can be deduced.

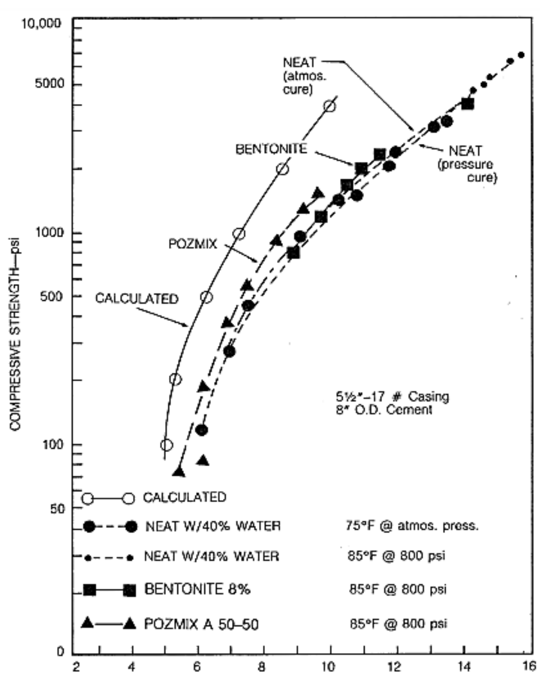

Fig. 8: Compressive strength vs. attenuation rate for various cements [16]

Figure 9 shows that after a thickness of ¾ in. is exceeded, attenuation rate is constant. Thus, measurement of the attenuation rate of a compressional wave propagated along the casing gives information regarding the bonding of the cement to the casing. Information regarding the bonding of the cement to the formation has to come from a separate source such as a wave-train recording which can be viewed as a variable density display (VDL). In order to understand this more fully the tools used must be studied [16].

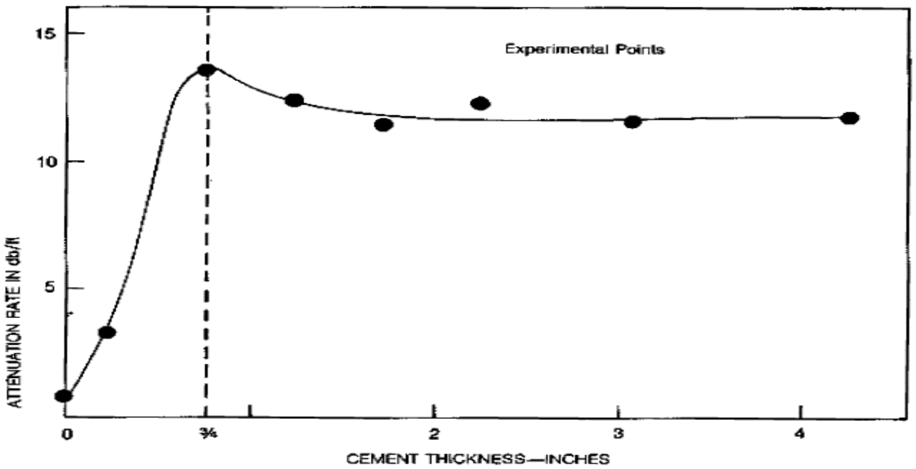

Fig. 9: Attenuation rate vs. cement thickness [16]

In general, conventional CBL, tools are available as either through-tubing versions (for workover jobs) which have a 1–11/16″ or 2–1/8″ diameter or as full-diameter tools for primary completions with a 3–5/8″ OD. Apart from these classifi cations, based on the physical dimensions, CBL tools are also available as the more modern ultrasonic scanning type. Both will be discussed. Figure10 illustrates a conventional CBL tool. It consists of an acoustic transmitter and two receivers. In actual practice, the tool may be identical with an openhole sonic tool but with only one transmitter and two receivers being used. The near receiver is placed 3 ft from the transmitter and is used for amplitude measurements. The far receiver is placed 5 ft from the transmitter and is used for wave-train recordings [16].

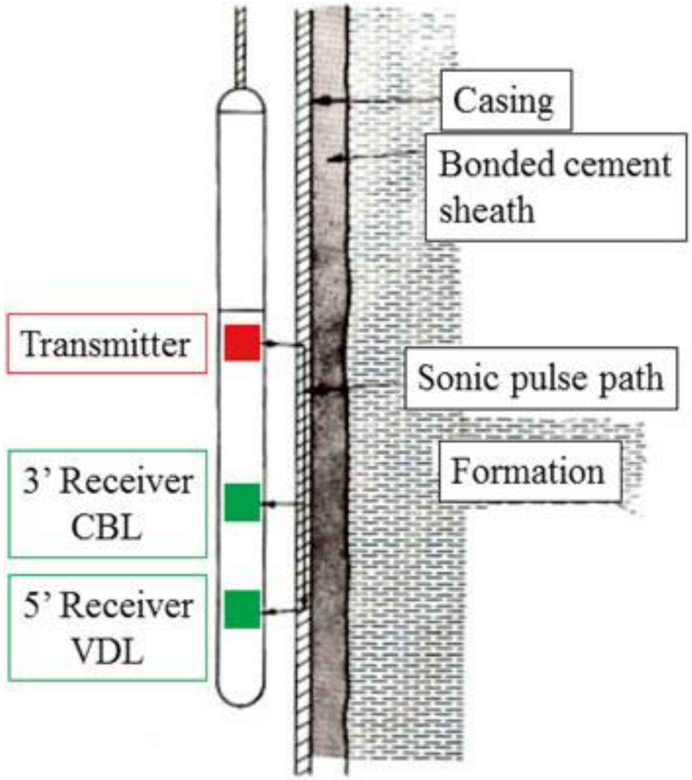

Fig. 10: Conventional CBL tool [16].

Typical travel times for these three media are 56 µs/ft for casing, 60–100 µs/ft for the formation, and 170–200 µs/ft for the borehole fluid. The shortest time path for the acoustic energy to travel is through the casing and the longest is through the operating principles borehole fluid. Thus, at the receiver, the signal recorded will have three major components, the casing signal, the formation signal (if present), and the borehole signal. The initial transmitted pulse will be spread out into a wave train [17].

1.3.4 Ultrasonic Imager Tool (UST)

Ultrasonic borehole imaging tools are widely used to produce images of the borehole wall in open-hole logging applications as shown in Fig. 11. These images are useful for providing the analyst with textural, structural, and sedimentary information about the column logged as well as offering geomechanical data regarding the presence and orientation of fractures and/or breakouts. The tools used to produce these images consist of a rotating emitter of ultrasonic waves that travel though the fluid in the borehole and are reflected back from the borehole wall. The time taken to travel from the emitter back to a receiver is an indication of the borehole diameter and the amplitude of the returning signal and indication of the material found at the refl ecting interface [17]. This same technology can also be applied in cased-holes to evaluate cement behind casing. An ultrasonic transducer emits a beam of ultrasonic energy in a 300– 600 kHz band. This energy pulse causes the casing to ring or resonate in its thickness dimensions. The vibrations die out quickly or slowly depending on the material behind the casing. Most of the energy is refl ected back to the transducer where it is measured; the remainder passes into the casing wall and echoes back and forth until it is totally attenuated. Figure 12 gives a schematic of the transducer and the compressional wave paths through the completion fl uid, refl ection at the inner casing wall (fi rst interface), refl ection at the outer casing/cement boundary (second interface), and refection at the cement/formation boundary (third interface).[18]

Fig. 11: Ultrasonic Imager Tool (UST) [17].

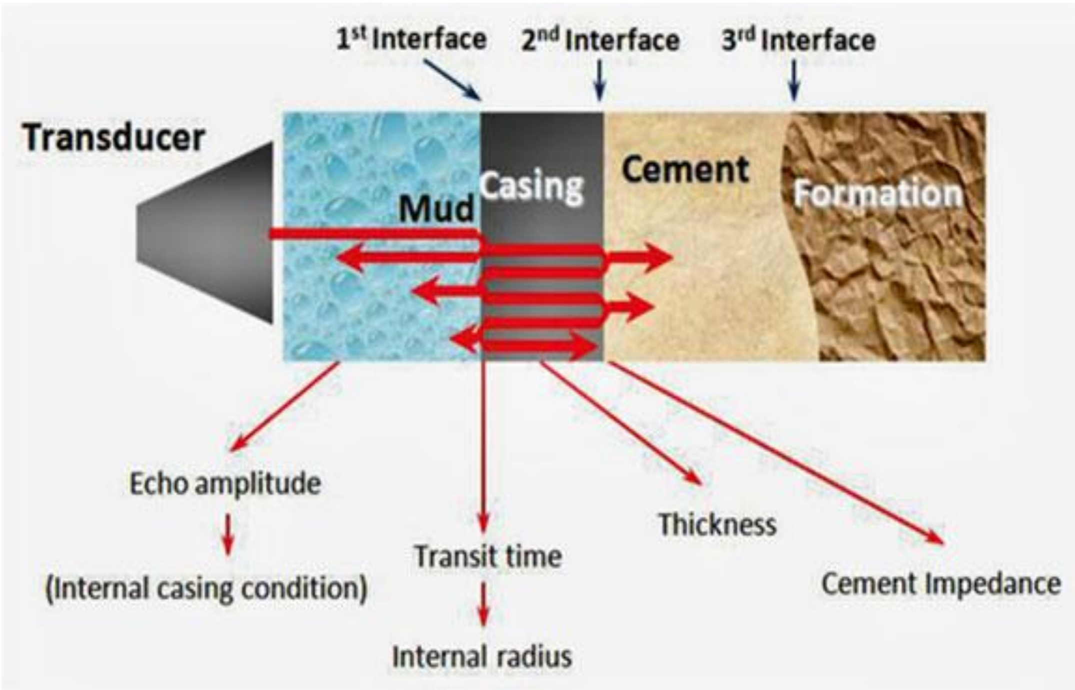

Fig. 12: Ultrasonic travel paths [18].

By integrating both directional (rotational) and amplitude data of the complete wave train, 3D views of the state of the materials behind the casing can be constructed as shown in Fig. 13 which shows a portion of the cemented pipe with a channel.

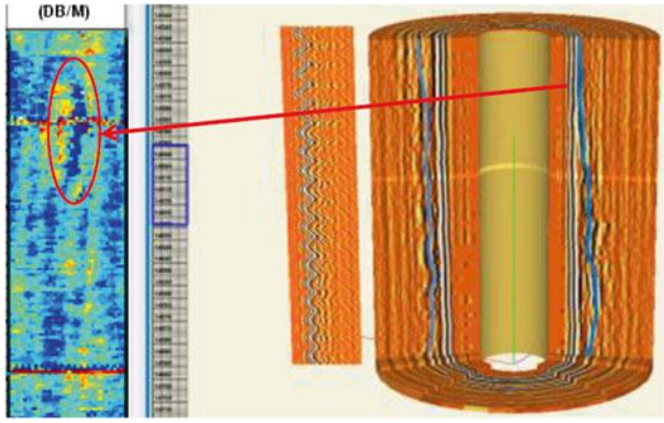

Fig. 13: Channel detection using the third echo interface [18].

An added refinement to the standard ultrasonic “pulse-echo” imaging technique is the generation and measurement of flexural waveforms using focused compressional waves and conventional amplitude detectors. Figure 14 shows the physical arrangement of the rotation transducers.

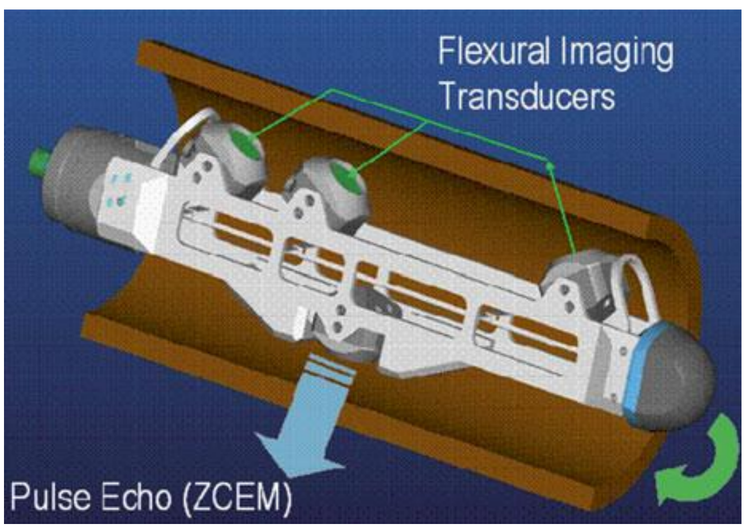

Fig. 14: Combined pulse-echo and fl exural transducers [18]

1.3.5 HUNTING Sectors Radial Incremental Bond Tool (RIB)

The standard single transmitter Cement Bond Log (CBL) tool accurately determines casing bond by measuring the amplitude of the first arrival at the 3-ft receiver. A deeper investigating 5-ft receiver confirms the interpretation and also shows formation bond by a full Variable Density Log (VDL) wave display. Hunting’s family of CBL tools come in a range of sizes to accommodate casing sizes ranging from 2-3/8 in. (60 mm) to 9-

5/8 in. (244.48 mm). The tools can be configured to several timing schemes for different logging systems.[19]

Fig. 15: Sectors Radial Incremental Bond Tool (RIB) [19]

Weatherford's 1.69-in. high-temperature, slim Sector Bond tool (SBT) provides the same reliability and responsiveness as the larger version. The smaller size and advanced construction permits operation in deeper, hotter wells with smaller casing sizes [20]. High-resolution wellbore imaging provides detailed images of internal casing corrosion, defects, and perforation patterns. Enhanced view gives a more realistic depiction of internal casing features. [21]

(Gray Frisch, 2002) Examination of eleven wells reported in his study indicates no serious technical problems. The overall correlation between the CAST-V and CBL is excellent. The logs show how the two different cement evaluation tools complement each other to provide a detailed and complete zonal isolation study. It is believed that the casing is in contact with either the formation and/or outer casing string causing erroneous readings in both the thickness and/or impedance calculations. This wellbore artifact will also create errors in the CBL for cement evaluation.[22]

(Francisco et al., 2003) studied the impact of lithology on cement bond logs It is often observed that cement logs are of poor quality across lithologic intervals with low gamma ray response (sands) and are very good across intervals with high gamma ray response (shales). This effect was quite evident in most of the logs obtained for the liner intervals in his study.Cement bhond logs showing high gamma ray interval (shale at 7230 to 7236 m) and low gamma ray interval (sandstone at 7224 to 7230 m).[23]

(B. Vidick and K. Krummel, 2005) worked on a case study in north sea , Oil based fluid was used to drill the well to final depth. The deviation in the interval of interest (3696 - 4569 m) The cement job was logged a few days after the job using a sonic tool with VDL capability. The tool was calibrated prior to the job and perfectly centralized while collecting data. The cement bond log was run without and with pressure (on a specific interval and did not show any improvements). Around 4320 to 4330 meters he find a good example where the Gamma-ray shows the presence of shales and the cement bond log indicates good cement [24].

(R. Ashena and G Thonfihaurser, 2014) had done investigated the effects of important parameters on cement bond log reliability, supported by field case studies in south of Iran, detection and the method of mitigation of these effects on the log have been advised.they found that ultrasonic cement bond logs (CBL/VDL) are shown be outperform sonic cement bond logs in terms of reliability risks(casing size, well deviation, type of drilling fluid, and weight, surface applied pressure and microannulus, type of formation, tool eccentricity, casing/liner eccentricity, multiple casings, pressure and temperature, effect of cementing operations) and thus are suggested particularly for wells with special cases [25].

(Dario Reolon, et al , 2020) studied on studied on A data-driven approach based on MRGC and integrated into a Bayesian framework has been described in order to provide a robust and fast cement bond evaluation from a quantitative standpoint. In detail, a training set consisting of sonic and ultrasonic data and related conventional interpretation, is the input for the learning phase. The system is then able to identify 8 different cement scenarios: good, partial, poor, very poor cementation, dry, wet and thick microannula, and free pipe. This represents a valuable way to save time and reduce subjectivity in performing cement placement evaluation for long and complex wells. Two selected case histories have been used to support the use and added value of this data analytics technique [26].

(Lorena Bicalho, et al, 2020) studied case study where by use Logging While Drilling (LWD) Acoustic technology and found it was successfully used to evaluate thecement bond in a high deviated well in Brazil and the results show the capabilities of the technology togenerate a qualitative cement bond data quality. These results were successfully validated using sonic andultrasonic wireline technologies. This evaluation is qualitative and can beused as prior evaluation, as an alternative to save time during the operations [27].

2. Methodology

The device sends acoustic waves that penetrate the liner, cement and layers extending for a distance of 3 or 5 feet, depending on the type of operation and the size of the cementing processed.CBL devices are comprised of monopole (axisymmetric) transmitters (one or more) and receivers (two or more). The principle of CBL devices is that acoustic amplitude is rapidly attenuated (high acoustic wave impedance)in good cement bond but not in partial cement bond or free pipe (bad cementing , low or not acoustic wave impedance) .

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), and other parts are refracted into the annulus and the formation and received back (formation arrival).

In short, the principle of work is to send waves through the transmitter in the device, and these waves will pass through the casing and the cement, and these waves will be refracted and then returned to the receivers, when acoustic wave have ahigh impedance this means that the naming process is successful and good, and vice versa , if impedance is low or not found soo that's mean the cementing processe is failed.

Finally the result appear as a tracks for CBL tool and other tools like VDL and USI with depth as shown in Fig. 16.

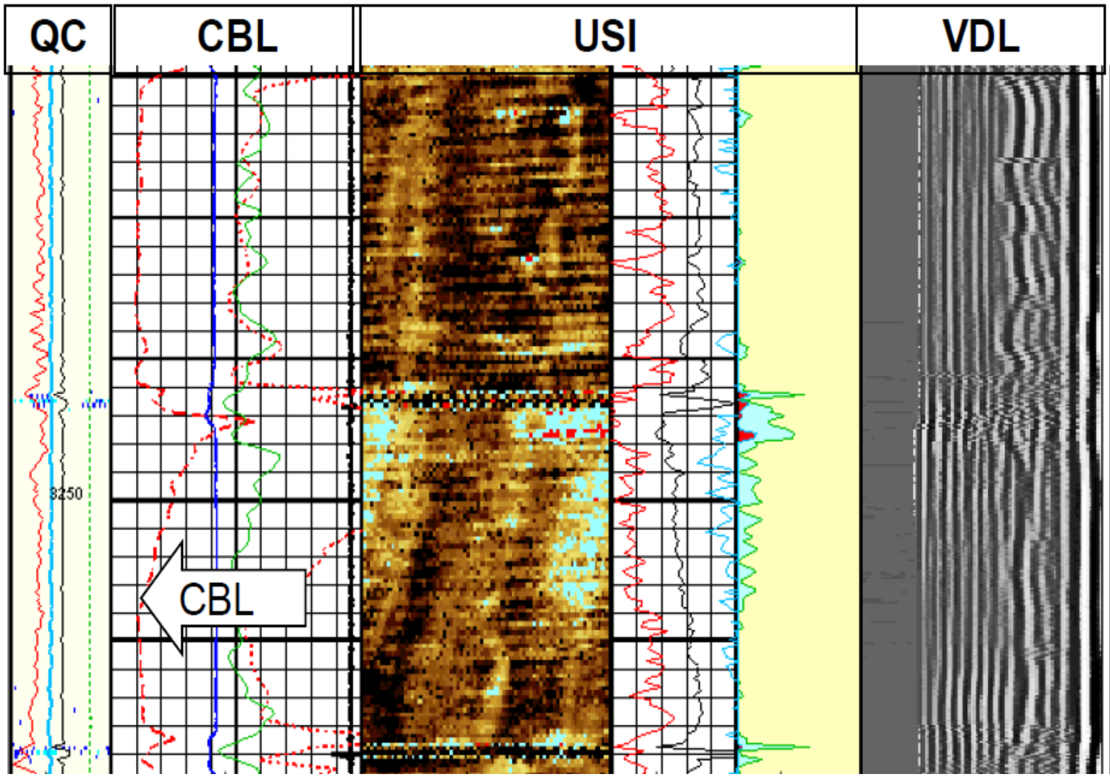

Fig. 16: Shape of result tracks for CBL, VDL and USI with depth

3. Results and Discussion

Various logs data of cementing job are taken from a well of an Iraqi oilfield. The log reading is divided into four tracks (i.e. Gamma ray , CBL , Image and VDL) . These tracks show the cementing job of the well which is used for cementing process interpretation. The well is divided into two sections (A and B). Section A starts at depth 1780 m to 1800 m , section B starts at depth 1800 m to 1825 m, Figure 17.

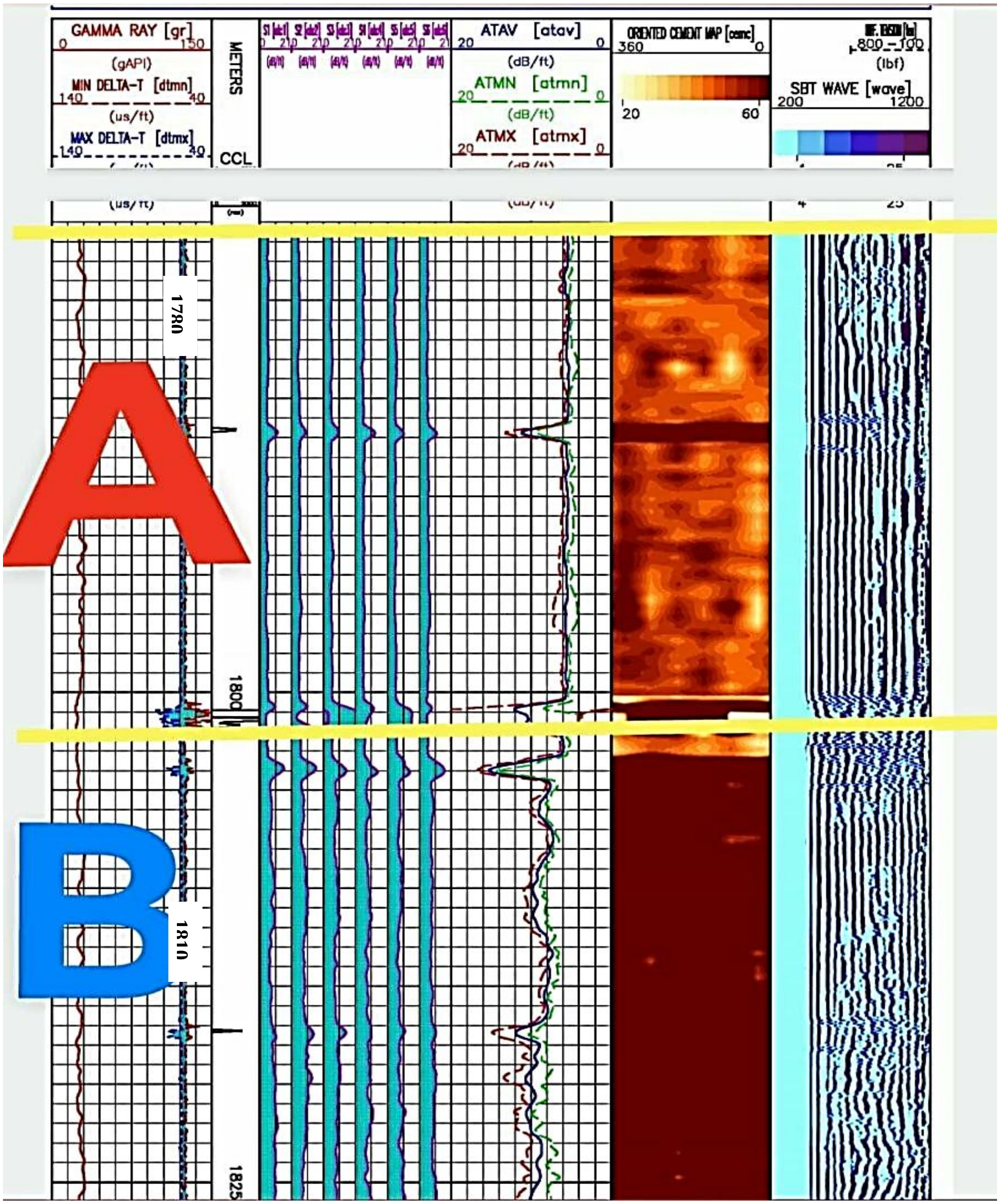

Fig. 17: The case study of cement job taken from an Iraqi oilfield

In section A**,** from depth 1780 m to 1800 m, CBL track shows a very low values which means there is no impedance for waves. However, in small region of section A, a high values for CBL log have been noticed which indicates a fast formation hear (strong rocks) such as dolomite, limestone or tough sandstone. In addition, Figures 17 shows that the image logs of section A are in light colors indicating a bad cementing process. Furthermore, the VDL reading is mostly straight line with small zigzags which indicates the cementing process on this section is failed. In this section, the log shows a free pipe case which means no cement behind the casing.

This failure is because of high drilling mud filtration in this section.
However, In section B, from depth 1800 to 18250, the results show we good reading of CBL track, signal and dark color in image log, high wavey lines in vdl track. Thus, from these reading, the cementing process of section B is considered as a very good and successful cement job.

4. Conclusion

Cementing process is process of pump cement in the annular space to support casing and prevent the formation collapsing. In this study, we evaluate the cementing job of an oil well by using CBL , Image, VDL logs to interpretation. The well has been into two sections A (1780 m to 1800 m depth) and B , (1800 m to 1825 m depth). The results show that the cementing job in section A is bad (i.e. failed cementing process). However, section B shows a successful cementing process (perfect cementing process). Thus, we conclude that the cementing job of section B is better than that of section A.

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