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Study of Micro Annulus Analysis of Cement Bond Evaluation by using Logging Tools

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Abstract: This paper outlines and measures the significance of the cement-bond-log (CBL) tool for cement evaluation programs. And these tool evaluations are often challenged, as is their ability to determine the association between the cement's compressive strength and the existence of poor cementing bonding. Casing dimensions have an impact on the connection, but cement type and drying conditions have no bearing on them. Significance of certain geometrical parameters on the cement bond log's primary output, or the attenuation of a sonic wave traveling along an interface between cement and casing. For a variety of cement densities, sonic attenuation rates were connected to compressive strengths. There is a discussion of certain experimental logging samples and cementing operation details. Moreover, data connecting attenuation rates to cement densities and compressive strengths are shown.

Keywords: Pressure, Cement, Lost Circulation, Integrity, Bonding

I. INTRODUCTION

Characterizing the development of the casing-cement sheath is the cornerstone of wellbore integrity, which is essential for ensuring the safety of drilling, completion, and oil production. The results will demonstrate the formation is penetrative, the cement stress is stable, and at some point, the cement sheath stress may equal the pore pressure. A casing-cement sheath at formation is to test the state of cement sheath stress. Applying a boundary condition all at once does not directly create a stress state. One of the key challenges in determining the cement annulus sheath hardening stress is reaching the state after the waiting on cement (WOC) moment.

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This issue is referred to as the initial stress state of the system, and the problem of annulus isolation failure is known based on several studies. These studies include calculating the necessary cement bond strength to prevent destruction during perforation and fracturing operations. [1].

As cementing maintains the casing and promotes hydraulic sealing, it is a crucial component of good construction. The cement examination has been done using wireline sonic instruments (CBL and VDL). Well, integrity and zonal isolation are confirmed using quantitative cement examination. [2].

For good integrity and operational safety, cement sheath stability throughout well workover, production, and intervention is crucial. The casing is supported by cement sheaths, which also offer zonal isolation, seal off annuli, and guard against corrosive fluids. To avoid unforeseen operational issues, it is crucial to comprehend how cement interacts with production and intervention fluids in reservoir settings. [3]

In sour settings, cement production could degrade severely, which could lead to deposits related to iron and calcium. The degree of degradation and the circumstances surrounding production determine how serious the issue is. The deterioration process can also increase the amount of time that casing surfaces are exposed to corrosive fluids. This increases the concentration of dissolved cations in generated fluids, increasing the possibility of inorganic deposit development and producing water-oil emulsions. The possibility of providing simple channels for harmful gases to reach the surface can be further increased by severe cement breakdown. [1] A variety of measurement techniques, such as evaluation logs, sampling analysis, mechanical loads, and fluid seepage tests, are used to determine cement sheath quality. The log reaction might be connected with the cement sheath's sealing ability as determined by pressure testing. An engineering strategy is needed to guarantee the quality of the cementing process. the duration of the cement job's circulation after the casing has run, the spacer fluid volume, the composition and WOC slurry, the kind and quantity of casing tool for rotation of the casing, the rate at which displacement fluid is pumped, etc. All these factors are optimized, and the BOP/casing pressure test performed after WOC will nonetheless cause the loss of good cement bonding due to excessive internal pressure. To meet the goals of zonal isolation, a novel collaborative technique must be adopted, with the mud weight program strategically changed both before and during the cementing operation.

II. LITERATURE SURVEY

Finding cement tops served as the starting point for cement evaluation. There were no calipers at that period. Midway through the 1930s, temperature surveys were used to determine in technical publications. The TOC can be found using well-conducted temperature surveys, but cement distribution cannot. The Acoustic Cement Bond Log (CBL), which was first published in the early 1960s, is still in use. Research projects in the past can be broadly categorized into two categories: techniques and materials to reduce formation pressure leakage through the cement itself and techniques to stop gas migration at the cement/casing and cement/formation interfaces. While some saw these as two distinct failure processes, others saw them as different instances of the same mechanism. In either scenario, it is obvious that measures taken to stop leakage channels from forming within the cement itself will also aid in stopping leakage paths from forming at interfaces. To reduce or avoid leakage at the interfaces, however, further preventive measures might be required.

The most study has focused on preventing leakage through the cement column itself, and one very well-defined theory explains why these types of failures must be avoided. According to this idea, annular gas flow is generated by a hydrostatic pressure drop that occurs between the introduction of the slurry in the wellbore and the creation of adequate static gel strength to prevent gas percolation. There is industry literature on the principles and applications of CBL/VDL logs.

III. WELLBORE STABILITY

Maximizing reservoir deliverability, decreasing remedial operations, and minimizing NPT during the drilling and cementing process are the main goals of the well building. Low bottom hole circulating temps (BHCTs), temperature variance, constrained pressure margins, annular pressure build-up (APB), and other issues make it difficult to design and install reliable barriers in deeper locations. In these circumstances, cementing procedures should be designed so that the equivalent circulating density (ECD) does not exceed the fracture gradient during the placement of cement slurry. To regulate loss zones, lost circulation materials (LCMs) need also to be added to the cement slurry. [4]

If the reservoir has a small gap between pore and fracture pressures, which compromised zonal isolation objectives zones during well building by causing formation instability and significant lost circulation problems. [5]

IV. CEMENTATION DESIGN

Effective cementation of reservoir sections provides issues for the operators. The occurrence of relatively fracture gradient formations will limit the top range density of such systems, and such cement systems must be capable of withstanding the forces produced over the life of the well. [6] Annulus around the horizontally positioned casing, cement must create an effective barrier, particularly in unusual reservoirs. Secondly, during hydraulic fracturing and ultimately throughout the well's life, cement must tolerate a variety of mechanical loads. [7]

Cement slurry prepared for bottom hole temperatures at deeper depths fail to set at the top of the cement column. This results in rig NPT and such situations lead to wellbore integrity problems. The temperature of the bottom hole may not be properly established when installing unplanned kick-offs at wells. The temperature has an impact on the slurry setting, if the bottom hole temperature is different from the designed temperature, the setting time may vary. This causes the cement plugs to fail. [8]

To accomplish the main goals, it could be required to execute unscheduled corrective cementing operations while building the wellbore. Squeeze cementing must be thoroughly analyzed in planning to understand the parameters required to implement the plan. Well conditions may rise during the drilling phase or primary cement job time For successful cementing well drilled under-balanced properties of the cementing fluids should be optimized. The significance of characteristics like fluid loss, density, and formation fluid influx. To aid in preventing fluid inflow from the formation, spacer fluids and cement slurry are needed based on reservoir conditions. The place at which the static gel strength develops at slurry to prevent gas from entering through the annulus. The hydrostatic and circulation pressure should be kept to a minimum while drilling into depleted, weak zones to assist prevent formation losses. These parameters are affected by the rheology and density of the cementing fluids. [9]

In wells without persisting casing pressures, the cementing fluid composition and placement processes were altered. The following standards were established for measuring a successful cement job:

- Cement setting beyond the pay zone with No losses.
- Using acoustic cement bond logs, there is a good zonal isolation indication observed.
- well test and production Sustained annulus pressure during.
- Well results gathering. [10]

When designing for a secondary cementing job, the operation relies on

1) Understanding the importance of squeezing.
2) Determination depth of placing of cement.
3) Development of placing procedure with proper techniques and tools.
4) Design of cementing washers and spacers
5) Execution of pressure/rate/volume record of fluid injection
6) Interpretation of the squeeze operations with results.

Several slurry weight and spacer combinations have been tested. To be successful, a lot of cement additives were tested, some were removed, and new ones were added. Substantial laboratory testing and software simulation should be done to finalize slurry designs. Slurries were chosen to satisfy drilling and production needs. criteria for choosing the appropriate slurries by the best standards for effective cementing.

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Describe slurry selection techniques for a variety of real-world scenarios, such as formation fluid effects, gas migration prevention, slurry property changes due to changes in hydrostatic pressure, and effects of a high percentage of non-cement elements in the slurry. [11].

V. CEMENT PROPERTIES

Changes in cement sheet integrity caused by fatigue failure loading affect the cement's elastic and strength properties.
The definition of mechanical characteristics of cement material responds to applied stresses and deformations. Elastic and strength qualities can be used to further divide them. Studies of cement materials for well cementing consistently have importance for the Young's modulus, for an elastic property. [12].
A proper water-to-cement ratio will permit insertion to create sufficient strength in a short amount of time for bonding the pipe to the formation.

A. Cement Hydration

When water is mixed with cement, the hydration (reaction with water) process starts. While the hydration process continues, the cement slurry eventually solidifies. As hydration begins, the setting process slows, and the strength of the cement continues for many days to set.

B. Acceleration And Retardation

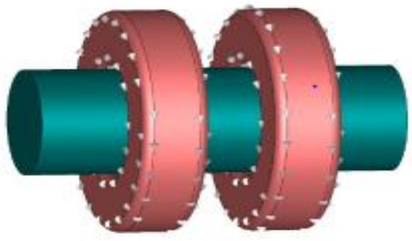
The degree of acceleration is influenced by everything that will have an impact on the chemical reaction. The pressure and temperature of each chemical or ionized particle present may affect how a reaction occurs.
The introduction of an additive, either during the manufacturing process or during use, slows the setting of cement. Chemical retarders such as borax and starch are used for slow-set cements which are added at the time of manufacturing. Changing the cement's particle size (grind) is another option. If the cement is coarsely powdered, it will set more slowly.
The manufacturing of cement retards it in a similar manner to how it accelerates it. A chemical accelerator is also added. That is accomplished by adjusting the composition, particle size, and composition. The most efficient method for hastening cement setting is the insertion of a chemical accelerator.
The most efficient and cost-effective Portland cement accelerator is calcium. Portland cement slurries have a slightly reduced viscosity thanks to calcium chloride. The acceleration increased in intensity as more calcium chloride was added to the cement. Between 2% and 4% of the dry cement's weight is when the calcium chloride content reaches its optimum level for early strength. More or less won't result in greater strength. Each increase in strength over 5% reduces strength. Normal results of 2% calcium chloride include a 50% reduction in thickening time and a doubling of 24-hour strength.

VI. COMMONLY MEASURED CEMENT PROPERTIES

Portland cement has several characteristics that are frequently measured. These characteristics include hydraulic flow parameters like thickening time, the strength of compression, volume of slurry, and separation of free water. The length of time required for the slurry to thicken under 100 poises at various temperatures, depths, and pressure conditions for the time of thickening.
The compressive strength needed to pressurize a cement specimen is measured in pounds per square inch (psi). The cement's water loss is measured in terms of volume per unit of time as free water separation. The ratio of water to cement directly affects it. Calculating critical velocities requires knowledge of the cement's rheological properties, which are known as the hydraulic flow parameters.

VII. CEMENT EVALUATION TOOLS

Evaluation tools are used to detect zonal isolation problems like bonding between casing and cement annulus, annuli thickness, the effect of fracture in the rock formation, and the effect of varying magnetic permeability of cement slurry. Tools like the magnetic field to magnetize particles in the annulus of cement



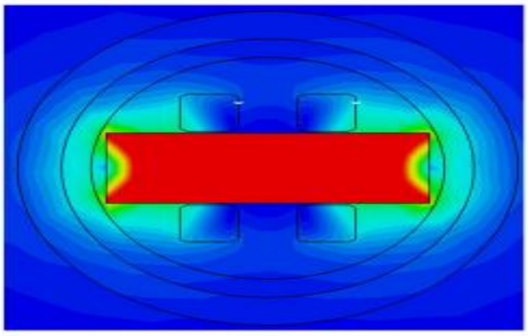


Figure:1 Magnetic coils and contour lines at borehole section(SPE-187047-MS)

The cement bond log tool is a sonic tool to evaluate cement in quantitative with wirelines.
Amplitude is measured directly for bonding to know:

- Quantitative Cement compressive strength estimation.
- Bond Index
- Qualitative cement-to-formation interpretation.

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Tool response is influenced by the cement's acoustic impedance, which is dependent on density and velocity. The log can be easily interpreted as cement compressive strength using empirical data. Nevertheless, these calibrations may not be precise when using foamed cement or unusual additives.
A cement log includes:

- A correlation curve, travel time
- Amplitude
- Attenuation
- display of full-waveform

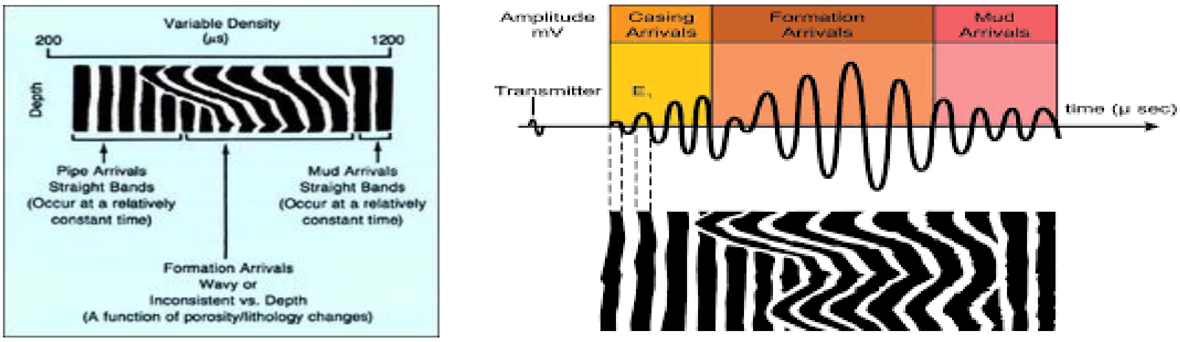

Figure: 2 Identification of cement bonding on a variable-density log (courtesy of Baker Atlas)

VIII. IDENTIFICATION OF PROBLEMS BY CEMENT EVALUATION

A high continuous cement bond with casing shows high-quality bonding and pressure inside the casing causes the pipe to expand and the contract will impact the cement bond quality. Casing pressure test effects on cement bonding, annular space integrity, and formation isolation.

- Channels filled with liquid in cement sheet due to poor casing centrality.
- Cement gets contaminated by mud.
- Borehole irregularity.
- Uncemented sections
- Poor zonal isolation
- Additional loads on cement rock
- Pressure tests
- Mechanical impact during WOC

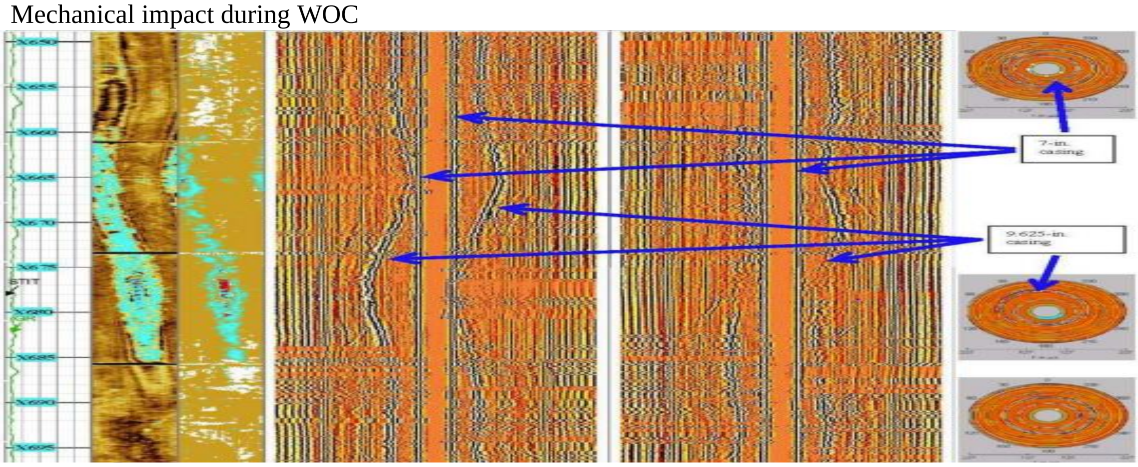

Figure: 3 Some of the liquid channels in the cement sheet observed by flexural waves in the outer casing ecencrity (SPE-172309-MS)

IX. INVESTIGATION OF MICRO ANNULUS IN THE FORMATION

A micro-annulus is a very small annular space (between 0.01 and 0.1 mm) between the casing and cement sheath. This micro-annulus may cause CBL data to be interpreted incorrectly. High amplitude and a direct line on the VDL display reveal the existence of the casing and a false reading of cement absence. The casing test after WOC shows micro-annuli in the cement bond log tool regarding bonding. Hydraulic calculations support the process of micro-annuli occurrence.
Additional factors that can contribute to micro-annuli occurrence:

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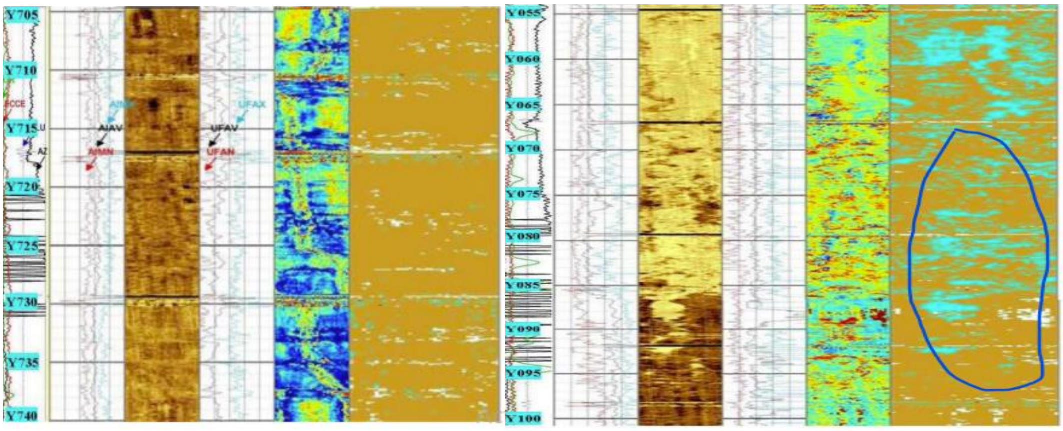
- Temperature (drilling, production)
- Contaminating drilling mud (due to poor-quality displacement)
- Coatings on pipe surface (varnish or oily film from OBM)
- Restraining forces (as cement hardens it shrinks slightly)

All cementation logs are sensitive to micro annuli, hence it is preferable to run the logs before the micro annulus is formed to avoid misunderstanding. (Jutten et al, 1993).[13]

There are techniques to execute CBL at a pressure of 1000-1500 psi (68-100 atm), established inside the casing, which permits the micro- annuli's closure to eliminate the influence of micro-annuli. (Boyd et al, 2006)[14].



(A) (B)

Figure: 4 shows (A) not contaminated results (B) contaminated results can be observed for analysis of liquid presence.

X. GAS MIGRATION PROBLEM

If the cement is permeable, gas can spread through annular cement. Gas migration is a phenomenon that can happen during the setting phase of cement, particularly in gas-prone areas, and involves annular gas flow through and around the cement. Gas can go through features like channels and induced fractures.

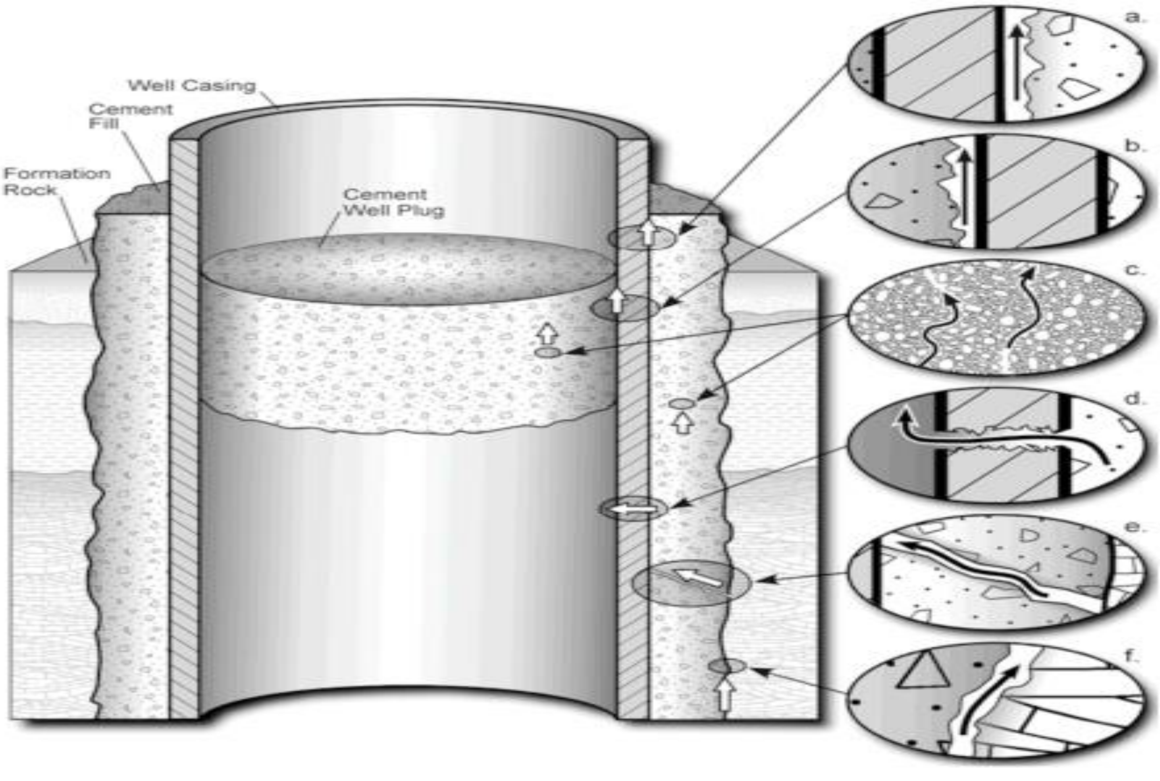


Figure: 5 Leakage between the cement and the casing of a well bore [15]

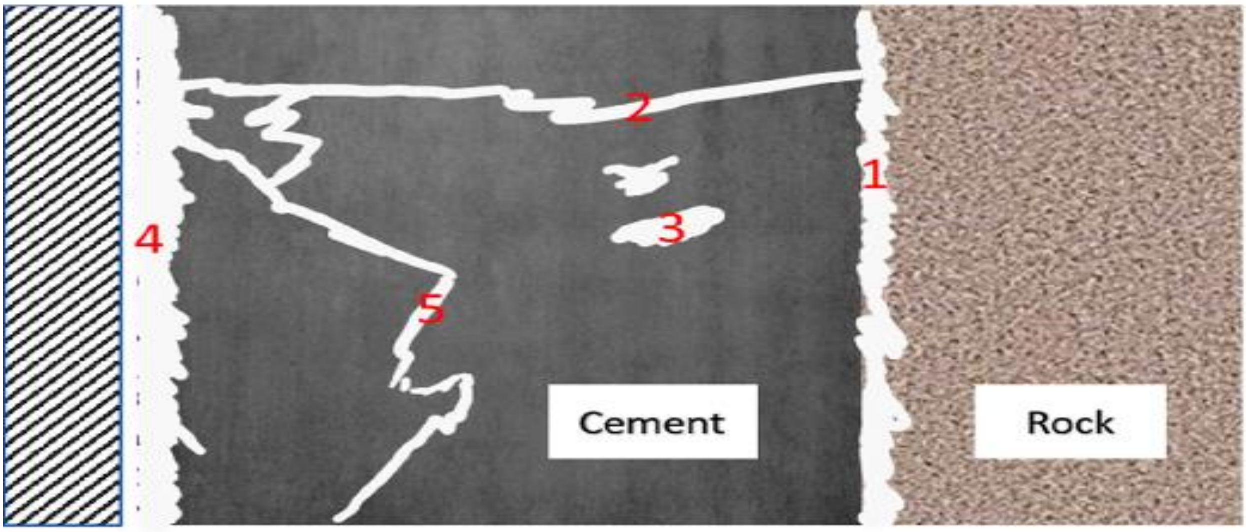


Figure: 6 Gas migration through cement sheet [16]

Numerous procedures can produce micro annuli. One is that the casing may expand during the cement setting because of a rise in temperature brought on by the hydration of the cement. The casing may contract and peel away from the cement sheath once the temperature returns to its previous level. by maintaining pressure inside the casing while the cement is setting. This might be because the float shoe failed, necessitating closing the valve at the surface to stop cement from entering the casing again. The cause expands as a result of the added pressure. Drilling or other mechanical operations within the casing may generate enough vibration to dislodge the cement pipe bond.

XI. RESULTS AND DISCUSSIONS

After interpretation, the results demonstrate the evaluation capability of cement sheet instruments. There was also a strong correlation between the presence of formation arrivals and QBI-detected zones of appropriate bonding. This validated the robustness of the LWD cement recording and ensured its applicability for the remainder of the successful campaign.

Some CBL tools can operate at 1000-1500 psi to identify micro annuli.

In comparison to the non-pressurized logging pass, which exhibits a fair to poor cement bond response due to the presence of this micron-scale annular breach between the casing and the cement, the pressurized logging pass exhibits an excellent cement bond response. Bonding between casing and cementing is sluggish due to the delayed hydration of cement for setting.

XII. CONCLUSION

After these studies and observations from different tools and wells it is known that cement material and temperature related to formation makes the bond between casing and formation for support tools like magnetic and sonic types in conventional and advanced will help full for detecting zonal problems, liquid channel, gas migration, and uncemented sections by log images make to interpret and identify the problem for safe production.

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Authors Contributions	All authors have equal participation in this article.

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