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Dissertation Topic:

Study of channeling problem in cementing oil wells in long sections

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DEDICATION

This work is dedicated to my beloved mother and father, who has endured so much and paved the way for my success. To my family, friends, mentors, and teachers.

Idris BOUZID

DEDICATION

I dedicate this work to my parents for their unwavering support and belief in my abilities. To my family, thank you for always being there and guiding me through challenges. To my friends, your encouragement has meant the world to me. And to all my loved ones, your support has been invaluable. This research is dedicated to each of you. Thank you for being a part of my journey.

Aymen BOULAMA

DEDICATION

In all love and respect I dedicate this work to my parents first and to all my loved ones. May Allah give me the strength to bring joy and smiles to the faces I so much admire, to my dear mates IDRIS and AYMEN for their patience and hard work without them this work would never see the light.

And to thank all the people who taught me the slightest knowledge.

Abdenour AGABA

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ABSTRACT

The process of cementing the well is one of the most important stages that the driller must perform to the fullest extent, as the cement works to stop and isolate the expected leaks resulting from the formation, especially the leakage of gas, which is considered a severe problem in the drilling field, as it seizes the opportunity to cross during the dryness of the cement (from the case liquid to solid) which results in a drop in well pressure to form transit channels towards the surface called channeling.

Hydrostatic pressure being less than pore pressure and the existence of a path to gas migration are two major factors that must be stopped simultaneously to prevent migration. On the other hand, Understanding the mechanisms of cement hydration in early times is necessary to investigate these factors. It can lead to swelling and shrinkage at the same time. At the beginning of cementation chemical shrinkage occurs, followed by swelling and autogenously shrinkage. The most important factors that make the annulus pressure less than the pore pressure are: cement placement, Cement hydration in liquid state, and Cement hydration in solid-liquid state

In our topic, we dealt with the problem of gas migration in the Ain Saleh area, where we touched on a new technique used recently called Flex Stone which is a substance that reduces gas permeability in cement to be the most effective method for this event.

Keywords: Flex STONE, Gas migration, Invasion, Consistency, Transition time,corrosion,channeling.

ملخص

تعتبر عملية تدعيم البئر من أهم المراحل التي يجب أن يقوم بها مهندس الحفر على أكمل وجه، حيث يعمل الإسمنت على إيقاف وعزل التسربات المتوقعة الناتجة عن التكوين وخاصة تسرب الغاز الذي يعتبر مشكلة حادة في مجال الحفر، حيث يغتنم فرصة عبوره أثناء جفاف الإسمنت (من الحالة السائلة إلى الصلبة) مما ينتج عنها انخفاض في ضغط البئر ليشكل قنوات عبور نحو السطح تسمى القناة.

ويعتبر الضغط الهيدروستاتيكي أقل من الضغط المسامي ووجود مسار لهجرة الغاز عاملين رئيسيين يجب إيقافهما في آن واحد لمنع الهجرة. من ناحية أخرى، من الضروري فهم آليات اماهة الإسمنت في الأوقات المبكرة لدراسة هذه العوامل. يمكن أن يؤدي إلى التورم والانكماش في نفس الوقت. في بداية التدعيم يحدث انكماش كيميائي، يليه انتفاخ وانكماش ذاتي المنشأ، وأهم العوامل التي تجعل ضغط الحلقة أقل من ضغط المسام هي: وضع الإسمنت، واماهة الإسمنت في الحالة السائلة، وترطيب الإسمنت في الحالة الصلبة والسائلة.

تناولنا في موضوعنا هذا مشكلة هجرة الغاز في منطقة عين صالح، حيث تطرقنا إلى مادة جديدة استُخدمت مؤخرًا تسمى فليكسستون وهي مادة تقلل من نفاذية الغازات في الإسمنت لتكون الطريقة الأكثر فعالية لهذا الحدث.

الكلمات المفتاحية: فليكستون، هجرة الغاز، غزو الغاز، الاتساق، زمن الانتقال، التآكل، التقنين.

RÉSUMÉ

Le processus de cimentation du puits est l'une des étapes les plus importantes que le foreur doit mener à bien, car le ciment permet d'arrêter et d'isoler les fuites attendues de la formation, en particulier les fuites de gaz, qui sont considérées comme un problème grave dans le domaine du forage, car elles saisissent l'occasion de passer pendant le séchage du ciment (du liquide au solide), ce qui entraîne une chute de la pression du puits pour former des canaux de transit vers la surface, appelés « channeling » (canalisation).

La pression hydrostatique étant inférieure à la pression interstitielle et l'existence d'une voie de migration du gaz sont deux facteurs majeurs qui doivent être stoppés simultanément pour empêcher la migration. D'autre part, il est nécessaire de comprendre les mécanismes d'hydratation du ciment dans les premiers temps pour étudier ces facteurs. Elle peut conduire à un gonflement et à un retrait en même temps. Les facteurs les plus importants qui font que la pression annulaire est inférieure à la pression interstitielle sont : la mise en place du ciment, l'hydratation du ciment à l'état liquide et l'hydratation du ciment à l'état solide-liquide.

Dans notre sujet, nous avons traité le problème de la migration du gaz dans la région d'Ain Saleh, où nous avons abordé une nouvelle technique utilisée récemment appelée Flex Stone qui est une substance qui réduit la perméabilité au gaz dans le ciment pour être la méthode la plus efficace pour cet événement.

Mots-clés : Flex STONE, migration des gaz, invasion, consistance, temps de transition, corrosion, canalisation.

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General introduction

In the fuel market that depends on oil and gas wells they possess a serious impact on the global economy as they are considered as the main source of energy and a necessary element in every other industry for those reasons the hydrocarbons reserves are so strategic and should be rationalised and preserved.

One of the main phases in completing oil and gas wells is drilling the well which is the primary and the most important step that must be the responsibility of drilling engineer. Making the connection to the reservoir from the surface in a good techno-economical conditions may so much ease the production and expend the well life.

In the chain of making the oil and gas wells. The cementation operation is one of the most important operations that effect the well life and insure the good production in the upcoming years of the well life. And throughout cementing operations some technical problems may take place. One of the major problems that can be frequent specially in the Sothern west of Algeria is the channeling problem that could take place in a long section of the well up to 900 m.

Our goal in this thesis is to reach to understand how to identify the channelling problems and consider the options to resolve the problem and take a closer look to the experience of flex stone and isoblok in TMSK-1 in AIN SALEH Ahnet.

To achieve this goal our work is divided to three chapters firstly in chapter one generally about the geographical and geological aspects of the region followed by the second chapter is an overview to the cementing operation; cement integrity and general picture of channelling problems and solution and lastly analyse of the experience of flex stone in TMSK-1 well.

CHAPTER I:

Geography and geology of Ahnet

CHAPTER I: Geography and geology of Ahnet

I.1. INTRODUCTION

The study area is part of the Saharan platform, which is made up of several basins, the main ones being: Illizi Basin, Berkine Basin, Oued Mya Basin, Mouydir Basin, Reggane Basin, Tindouf Basin, Timimoun Basin and Timimoun Basin Ahnet. In this chapter we will present the geography and geology study of the Saharan platform as well as the location of the Ahnet basin, the local geology and regional of the Ahnet basin.

I.2. Geological overview of the study area:

I.2.1. Geographical and geological situation of the Ahnet Basin:

The structure of the Ahnet basin covers an area of 75.000Km2, geographically bounded by the following coordinates:

Table I.1: geographical coordinates of the ahanet basin.[1]

	geographical coordinates
Longitude	1° 0' -1" -1" and 3° 0' -1" -1" East
Latitude	24° 0' -1" -1" and 27° 0' -1" -1" North

From a geological point of view, the Ahnet basin is bounded by:

- To the north by the Tidikelt plateau, which separates it from the Timimoun basin.
- To the east by the Idjerane-Arak axis, which separates it from the Mouydir basin.
- To the West by the Bled El Mass-Azzel-Matti axis, which separates it from the Reggane basin.
- To the south, the Great Hoggar.

The map below shows the location on the study area and its respective basins marked in the green enclosure with reference to the country map.

From a sedimentary point of view, the Ahnet basin is bounded by :

- To the north by the Djoua Ensellement and the Azzene Ride.

- To the east and west by the Eperon d'Idjerane and the Azzel-Matti ensellement respectively.
- In addition to the geographical and geological boundaries described, it's essential to highlight the topographical features that characterize the Ahnet Basin.

The Ahnet Basin is predominantly characterized by flat to gently undulating terrain, with occasional elevated areas and low-lying valleys. The landscape is shaped by erosion processes, with intermittent wadis and dry riverbeds crisscrossing the basin floor. These features contribute to the overall hydrological and sedimentary dynamics of the region.

Furthermore, the Ahnet Basin is known for its arid climate, with hot temperatures prevailing throughout much of the year. Sparse vegetation, mainly consisting of drought-resistant shrubs and grasses, dots the landscape, interspersed with barren stretches of desert terrain.

Additionally, the Ahnet Basin is situated within a region of cultural and historical significance, with ancient caravan routes traversing the desert landscape and archaeological sites dating back to prehistoric times. These cultural elements add to the richness and diversity of the basin's geographical and geological context.

Overall, the detailed topographical, climatic, and cultural characteristics of the Ahnet Basin provide a comprehensive understanding of its unique geographical situation, enriching the overall assessment of its geological and sedimentary attributes.

Figure I.1: Map of the sedimentary basin of the algerian sahara.[1]

I.2.2. Geological frame of the basin

The Ahnet Basin is a Paleozoic depression, located in the north-west of the Hoggar, and considered one of the most prolific gas-producing provinces in the Sahara Algerian. The basin is bounded by the structural shoals that surround it ; northward the Tidikelt plateau, made up of land brought back to the Mesozoic, separates it from the basin of Timimoune, to the east, the Idjerane-Arak axis separates it from the Mouydir. The basin is limited to to the west by the Bled El Mass-Azzel-Matt axis which distinguishes it from the Reggane basin. This area oriented globally N-S, represents the southern extension of the Ugarta Trench and forms the beginning of the Tanezrouft plateau.

I.3. Description lithostratigraphiques

Most of the data from boreholes drilled in the Ahnet basin confirms the presence of a series of deposits represented by terrains of Mesozoic age resting unconformably on terrains of Paleozoic age.

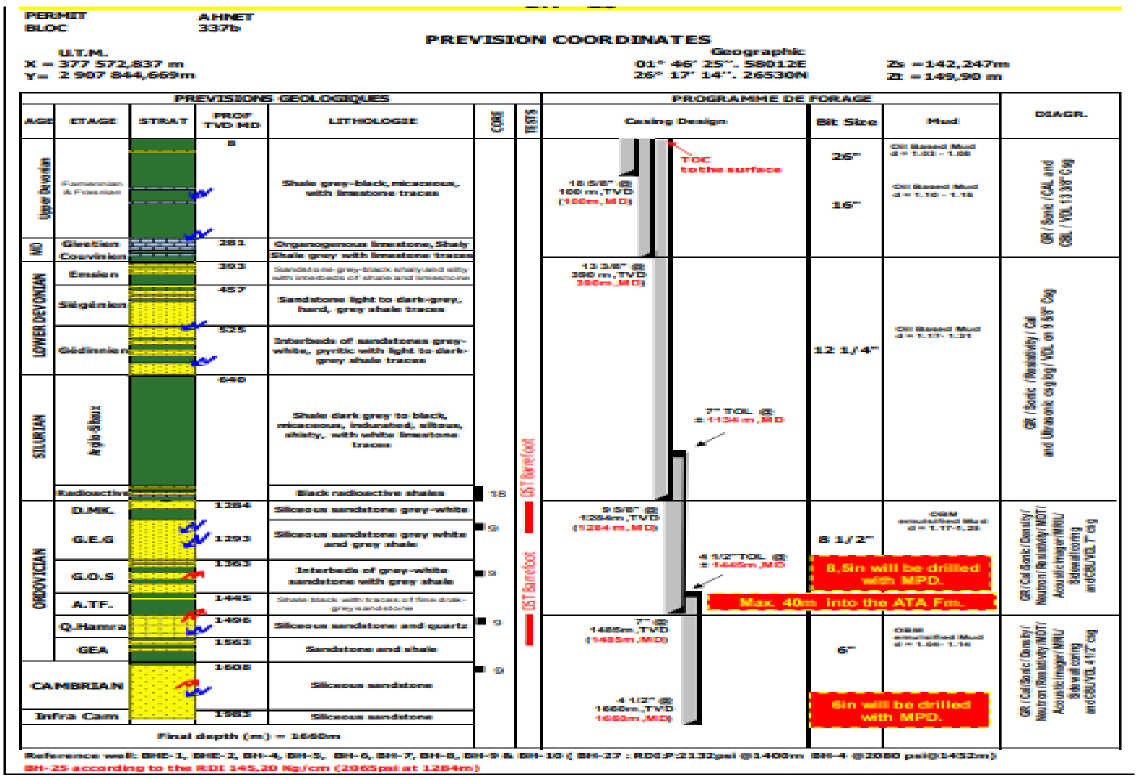

Figure I.2:Synthetic stratigraphic log of the premier.[1]

I.4 Petroleum system of the Ahnet zone.

I.4.1. Reservoir rocks in the Ahnet basin.

The Ahnet basin contains both conventional and unconventional reservoir rocks.

I.4.1.1 Conventional reservoirs

A petroleum system in a conventional reservoir is made up of three (03) main compartments (Figure I.3):

- Source rock: this is where the hydrocarbons are generated.
- Reservoir rock: the place where hydrocarbons accumulate after primary migration.
- cap rock: this is the rock that seals the reservoir and prevents migration.

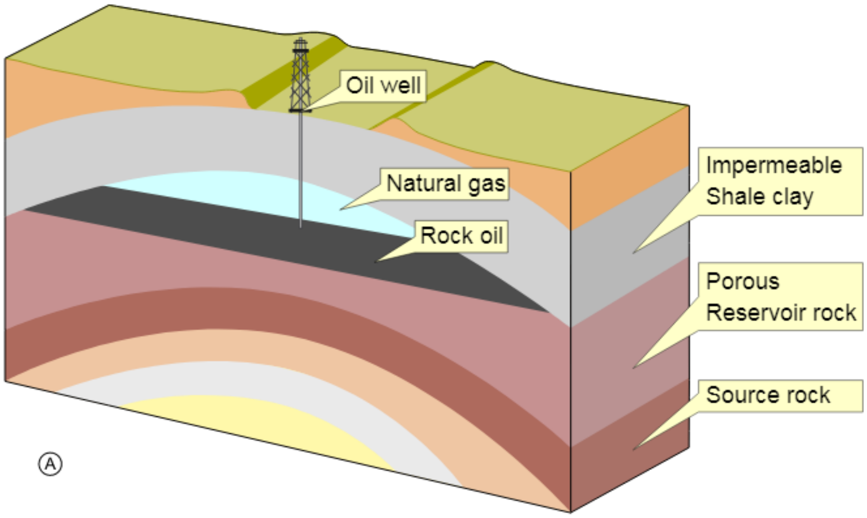

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Fig.I.3: Representation of a conventional reservoir rock in an anticline trap.[24]

I.4.1.1.1. The Devonian reservoirs in the Ahnet basin

Famennian/Frasnian

is composed of clay dark grey to black towards base, medium hard, occasionally soft, silicious, micaceous, fissile, pyretic, carbonated, fossilified in place.

Siltstone: rarely carbonated, tending to hard siltstone, traces of calcite

Sandstone: grey to grey/brown to white, hard, fine, argillaceous,pyretic.

Limestone grey to cream, hard, white crystalline. Occasionally sandstone: grey to dark/grey, medium-hard, fine to very fine, silico-argillaceous, miaceous, occasionally pyretic.

Givetian

Limestone: cream to dark grey, soft, argillaceous, occasionally white grey microcrystalline, fossilified, slightly pyretic, hard. Clay: dark grey to black, occasionally siliceous, micaceous and fossilified

Siltstone: grey/white to white, hard, very fine to fine, siliceous, and silico quartzic, occasionally carbonated.

Couvinian

Clay: dark grey to black, occasionally siliceous, micaceous and fossilified.

Siltstone: grey/white to white, hard, very fine to fine, siliceous to silico quartzic, occasionally carbonified**.**

Emsianlay:

Clay dark grey to black, occasionally siliceous and micaceous, grading to sandstone.

Sandstone: grey to white, fine to very fine, sillico carbonated, hard

Siltstone: dark grey, medium hard, grading to calcareous clay, with grey to cream, occasionally white, soft, locally oily, fossilified and hard .

Siegenian

Clay: dark grey to black, occasionally siliceous, micaceous,locally pyretic, tending to sandstone.

Sandstone:grey to grey/white, hard, well consolidated, fine,occasionally coarse, sillico argillaceous and sillico carbonated,traces of medium to hard shells

Gedinnian

Sandstone: clear/grey to white and brown, fine, occasionallycoarse, changing interbedded layers from sillico argillaceous to argillaceous, medium consolidated to friable, locally quartzitic, and hard.

Clay: dark grey to black, indurate, siliceous, micaceous, slightly pyretic.

Silurian

micaceous, fissile and indurate grey/black and black, siliceous clay which is micaceous pyretic and fossiliferous. Siltstone: dark grey to white/grey and white, medium to hard, fine, occasionally siliceous to sillico argillaceous. Thin layers of white and dark grey calcareous and crystalline fossilified (Graptolites) hard formation. Rich with organic material and fossilified (Graptolites) becoming siliceous at top parts occasionally calcareous, vary radio active at base.

Sandstone: grey white to white, hard, very fine to fine, siliceous, and calcareous material: clear grey to white, medium hard, bioclastic, argillaceous

Ordovician

Sandstone: grey white to dark grey, hard, fine, siliceous to silico argillaceous occasionally quartzitic, tending to black clay: indurate, siliceous, micacious, fissile, pyretic, presence loose quartz grains and traces of calcite.

Clay: grey black to black, indurate, very siliceous, micacious, tending to sandstone: grey white to white, hard, fine, slightly siliceous.

Quartzitic Sandstone: grey white to dark grey, medium hard, very fine to fine, siliceous to silico argillaceous, micaceous, becoming White and medium Slightly traces of Clay grey/black to black, indurate, to coarse, siliceous to silico quartzitic, hard at the base. Siliceous, micacious, fissile, pyretic. Reservoir pressure estimated a 1.09 sg

Cambrian

Sandstone: Grés gris foncé très fin à moyen dur a compact siliceux à quartzitique, argile noire, silteuses indurée micacée.

I.5. CONCLUSION

In summary, Chapter I provides a detailed exploration of the geography and geology of the Ahnet Basin within the broader context of the Saharan platform. Through an examination of its geographical boundaries, geological features, and structural characteristics, a comprehensive understanding of the basin's significance and potential is established.

The Ahnet Basin, covering an area of 75,000 km2, emerges as a prominent Paleozoic depression situated in the north-western region of the Hoggar. Bordered by various structural features such as the Tidikelt plateau, the Idjerane-Arak axis, and the Bled El Mass-Azzel-Matt axis, the basin exhibits a complex tectonic history shaped by Hercynian orogeny and subsequent tectonic events.

Furthermore, the lithostratigraphic description highlights the presence of Mesozoic deposits overlying Paleozoic terrains, indicating a dynamic geological evolution over time. This understanding is crucial for identifying potential hydrocarbon reservoirs and guiding exploration efforts within the basin.

Moreover, the chapter delves into the petroleum system of the Ahnet zone, emphasizing the presence of both conventional and unconventional reservoir rocks, particularly Devonian reservoirs, which hold significant potential for hydrocarbon accumulation.

Overall, Chapter I sets the stage for further exploration and analysis, providing a solid foundation for understanding the geological and geographical intricacies of the Ahnet Basin. This knowledge serves as a vital resource for future research endeavors and informs decision-making processes related to the sustainable development of Algeria's hydrocarbon resources in the Ahnet region.

Chapter II

CEMENT AND CEMENT CHANNELING PROBLEMS

II. Cementing Overview

II.1. Introduction

Cementing of casing strings is commonly perceived as a low-technology operation. A cement "job" is rarely witnessed and is less understood (by many in the industry) than drilling, for example. Cementing is a critical operation, since it is the only way the well can be sealed to prevent the migration of fluids between formations. Poor zonal isolation is a primary factor for the need to repeat a well (sidetracking from the original wellbore). It is also a significant contributor to environmental damage. Govan et al. describe a computer simulation showing 50% of Gulf of Mexico wells have sustained some degree of sustained casing pressure [2]. This simulation calculated at \$2.5M per incident over the 7,600 or so producing wells would suggest expenditure of nearly \$1 billion. During the life of a well there are also environmental considerations for instance when a well is abandoned or later re-completed. If zones of depleted reservoir have previously been depleted of their original well, the new well may need to be drilled deeper and it is often necessary to plug and abandon the original well [3]. This could be to prevent crossflow between reservoirs of different type, or to suppress pressure in an overpressured reservoir. A recent example of this is BP's decision to abandon the original Macondo prospect after the Deepwater Horizon Disaster [3]. Abandoning a well entails removal of casing and sealing the wellbore. The more remote the well, the less accessible it becomes for remedial work to repair sustained casing pressure or to re-abandon if it was not done correctly [4]. It should now be clear that much emphasis should be placed on correct design and placement of cement. As wells are drilled deeper and into more hostile high-pressure and high-temperature environments, the cost of zonal isolation failure has and will continue to increase [5].

II..2. Importance of Cementing in Well Construction

Measures of success and job quality are not always easy to quantify and at times subjective, so drilling personnel must use their judgment and experience in pressure control and observation of the cement job in order to attain the best result and be alert in preparation for any problems that might arise [6].

In the land well where fresh water sands may be close to the producing horizon, a good cement job is extremely important in preventing water encroachment [5]. In offshore wells where hydrostatic pressures of the drilling fluid can exceed 15 ppg to control high pressure zones, the risk of fluid channeling behind the casing and possibly a blowout is a serious threat if the cement job is not successful [9].

Any failure in the cement can cause any one of these situations and result in difficulty in well operations, danger to the well, or damage to the environment [10]. Most of the time, remedial cementing is required to fulfill these objectives because of a problem in primary cementing, although economics may dictate against it and the operator may have to live with a poorly cemented well.

Cement is meant to:

1. Support the casing [10].
2. Prevent contamination of water sands [10].
3. Seal off high pressure zones behind the casing [10].
4. Provide a smooth surface for running tools [10].

II.2.1. Cementing Process and Equipment

Well cementing consists of two principal operations : primary cementing and remedial cementing.

Primary cementing is the process of placing a cement sheath in the annulus between the casing and the formation [5].

Remedial cementing occurs after primary cementing, when engineers inject cements into strategic well locations for various purposes, including well repair and well abandonment [5].

Primary cementing is a critical procedure in the well construction pro-cess. The cement sheath provides a hydraulic seal that establishes zonal iso-lation, preventing fluid communication between producing zones in the borehole and blocking the escape of fluids to the surface. The cement sheath also anchors and supports the casing string and protects the steel casing against corrosion by formation fluids. Failure to achieve these objectives may severely limit the well's ability to reach its full producing potential.Most primary cementing operations employ a two-plug cement placement method (right). After drilling through an interval to a desired depth, a drilling crew removes the drillpipe, leaving the borehole filled with drilling fluid. The crew then lowers a casing string to the bottom of the borehole. The bottom end of the casing string is protected by a guide shoe or float shoe. Both shoes are tapered, commonly bullet-nosed devices that guide the casing toward the center of the hole to minimize contact with rough edges or washouts during installation. The guide shoe differs from the float shoe in that the former lacks a check valve. The check valve can prevent reverse flow, or U-tubing, of fluids from the annulus into the casing. Centralizers are placed along critical casing sections to help prevent the casing from sticking while it is lowered into the well. In addition, centralizers keep the casing in the center of the borehole to help ensure placement of a uniform cement sheath in the annulus between the casing and the borehole wall.As the casing is lowered into the well, the casing interior may fill with drilling fluid. The objectives of the primary cementing operation are to remove drilling fluid from the casing interior and borehole, place a cement slurry in the annulus and fill the casing interior with a displacement fluid such as drill-ing fluid, brine or water [5].

Cement slurries and drilling fluids are usually chemically incompatible. Commingling them may result in a thickened or gelled mass at the interface that would be difficult to remove from the wellbore, possibly preventing place-ment of a uniform cement sheath throughout the annulus. Therefore, engi-neers employ chemical and physical means to maintain fluid separation. Chemical washes and spacer fluids may be pumped after the drilling fluid and before the cement slurry. These fluids have the added benefit of cleaning the casing and formation surfaces, which helps achieve good cement bonding. Wiper plugs are elastomeric devices that provide a physical barrier between fluids pumped inside the casing. A bottom plug separates the cement slurry from the drilling fluid, and a top plug separates the cement slurry from the displacement fluid. The bottom plug has a membrane that ruptures when it lands at the bottom of the casing string, creating a pathway through which the cement slurry may flow into the annulus. The top plug does not have a membrane; therefore, when it lands on top of the bottom plug, hydraulic communication is severed between the casing interior and the annulus. After the cementing operation, engineers wait for the cement to cure, set and develop strength—known as waiting on cement (WOC). After the WOC period, usually less than 24 hours, additional drilling, perfo-rating or other operations may commence [10].

Basic two-plug primary cementing operation. After a well interval has been drilled to the desired depth, the drillpipe is removed and a casing string is lowered to the bottom of the borehole (top). The bottom of the casing string is usually

II.3 Cement Quality and Integrity

II.3.1. Importance of Cement Quality

Global industry analysts say the overall oil and gas well abandonment market is expected to reach around 13,400 wells per year in 2014-2018. The cost of abandoning a well in terms of rig time, personnel and equipment, lost production, and lost reserves can be staggering and is estimated to range from 1 to 10 million dollars. Well workover and intervention costs due to sustained casing pressure in the US alone are estimated to be around 4 billion dollars per year [16].

Zonal isolation is related to cement quality and bond and has a major influence on well success, integrity, and economics. Poor zonal isolation can lead to numerous well failures such as sustained casing pressure, gas or water coning, surface gas migration, water breakthrough, and crossflow between producing zones. These issues may require expensive remedial intervention work, reduce well and reservoir productivity, and in the worst case result in abandonment of the well [16].

There are several primary objectives in cementing oil and gas wells, which are to restrict fluid movement between subsurface formations, isolate formations for stimulation or production operations, support the casing, and protect the casing from corrosion. These objectives are all related to zonal isolation and are considered the most important factors in determining the success of a well. The quality of cement and its placement are the only factors which relate to zonal isolation that the operator can control. Therefore, the importance of using the right cement and knowing how it is performing cannot be overstated [16].

Cement is the most widely used material in the construction and sealing of oil and gas wells. It is estimated that around 10 million tonnes of cement are used each year in well engineering. The oil and gas industry has recognized the importance of using the right cement and ensuring its effective implementation. This is demonstrated by the great quantity of research into cement behavior and the constant development of cementing guidelines and best practice[16].

II.3.2. Ensuring Well Integrity

Modern oil well cement technology is a combined study in both chemistry and engineering. To ensure that the cement performs as expected over the duration of the well, the cement must be designed specifically to the downhole conditions. A thorough understanding of the expected downhole environment is required to both design the cement and to evaluate its expected performance. This process is becoming ever more important as the industry moves towards high pressure/high temperature (HPHT) wells and unconventional resources that place the cement much closer to its mechanical limits [17].

The ultimate objective of placing cement in a well is to create a hydraulic seal that isolates the producing formations from the other formations, the open hole, and the surface environment. Age and production changes require that abandoned wells be permanently sealed to prevent interzone migration of oil, gas, and water. In recent years, the need to permanently plug these wells has become an important environmental and regulatory issue. Leakage of hydrocarbons from plugged wells can have serious environmental effects. The sealing of wells to prevent interzone migration and leakage can be accomplished by properly designing the cement slurry, placement, and evaluating the hardened cement. This is the essence of well integrity and is an area fraught with common problems and possible solutions. Well integrity problems can be thought of as either the lack of hydraulic zonal isolation due to the formation of undesirable flow paths or the mechanical failure of the cement to support the loads imposed on it during the life of the well [17].

II.3.3 Preventing Gas Migration

After the cement has been set and the casing has been drilled out or the float equipment has been drilled through, it is sometimes necessary to spot a squeeze cement job to seal irregular or leaking zones. This could be done by using a balanced cement plug placed across the zone and displaced with high pressure fluid, or by using a cement slurry with small particle size and high retentivity.

If the well is being drilled with a drilling fluid of density less than that of the reservoir fluid, it is possible that a low pressure zone or swabbing action will be created around the well and gas or formation fluid will flow into the well. This scenario defines the phenomenon of U-tubing, where the drilling fluid and the pump pressure are actually the cause of the migration. However, the cement job can be a remedial factor by isolating the permeable zones from the high pressure drilling or casing operations with a balanced cement column. This will protect against further migration during well operations.

Steaming the cement to increase the compressive strength can reduce the time that the well is at risk from gas migration and can, in theory, reduce the waiting time before drilling the next section.

Expulsion of gas from formations into the wellbore is a frequent problem. This usually results in a poor cement job because the lighter end of the slurry has been washed up the outside of the casing, leaving a low strength channel behind the casing. The first step in preventing this is to correctly balance the cement slurry so that the hydrostatic pressure exerted by the set cement is greater than the reservoir pressure.

If the mud weight is to be changed after cementing, it is important to use a type of cement which can resist the increased pressure [21].

II.3.4. Enhancing Wellbore Stability

Minimizing near wellbore damage and increasing hydrocarbon production rates through improved drilling completion and reservoir management methods has become a major focus in the oil industry. Fluid and gas flow analysis in and around the wellbore and near wellbore region has shown that pressure build up due to invasion of external fluids can create local tensile hoop stresses around the inside of the casing, borehole breakouts and fractures, prevalent in both vertical and deviated wells are the result of compressive hoop stress on the formation rock. Any formation damage which leads to changes in the stress field can result in wellbore collapse and a reduction in the size and shape of the well. This can make drilling difficult at a later stage while trying to sidetrack and also limits the productivity of the well when the drilling phase is over [21].

A number of problems can arise when the annulus pressure exceeds the formation fracture pressure. High-pressure zones in the formation can cause directional changes in the wellbore, excessive mud filtrate invasion, lost circulation, and swelling or dispersion of shales. All of these problems can lead to serious damage in the near-wellbore region jeopardizing wellbore stability. The higher the differential pressure across weak, depleted, or stressed formations, the more likely it is that wellbore instability will occur. A narrow range of fracture gradients coupled with recent advances in drilling and completion technologies have increased the need for effective zonal isolation across a wide spectrum of downhole pressure and temperature conditions. These factors have heightened industry awareness of the importance of a comprehensive zonal isolation strategy commencing with engineered mud systems and concluding with proper cement placement and annular fill [18].

II.3.5. Improving Production Efficiency

A case study which provides a good example of how cement quality can affect production efficiency is the Norne field in the Norwegian Sea. It was discovered that water was moving into the production zone of the reservoir in the A-11 well. This had a large impact on the potential rate of production and required a costly sidetrack to resolve the issue. Analysis showed that poor cementing was the cause of the problem. High torque and drag forces indicate difficulties in running and cementing casing across trouble zones and should be a warning sign for well construction problems in deviated wells [20].

Defines production efficiency as the rate at which hydrocarbons are produced and sold compared to the maximum possible rate of production. Cement quality has a significant impact on increasing production efficiency through the control of wellbore fluids and the prevention of wellbore failure. Wellbore fluids, if allowed to move, can solidify into a thick layer on the inside wall of the wellbore, resulting in reduced rates of production if not dealt with through expensive remedial work. This is of particular issue in deviated wells that increase the likelihood of fluid movement. Control of the fluid is achieved through proper placement of the cement slurry with the correct viscosity to provide a complete seal. The prevention of wellbore failure due to collapse or blowout is an obvious benefit to production. High-quality long-term zonal isolation will ensure that the life of the well is prolonged and there are no issues with drilling into old abandoned wells [20].

II.3.6 Factors Affecting Cement Quality

The main raw materials for cement production are limestone (CaCO3) and clay or calcareous materials. However, others such as coral, chalk, or shells can be utilized. The fineness to which these materials are ground is one of the factors that affect the quality of the cement. After the raw materials have been ground and mixed, a slurry is formed. This is the stage at which the ingredients are mixed to produce a uniform substance. At this stage, it is also important that the correct types and amounts of additives are mixed with the materials. This mixture (slurry) has to be heated to a very high temperature in a kiln to convert the raw materials into clinker. The heating must be rapid so that the materials are not overburnt and should not be excessive, as this can cause the formation of melt or the destruction of the mineral phases. The clinker is then mixed with a small quantity of gypsum and ground to produce the final cement. Steps should be taken to ensure that the ground clinker is very fine, as this will further affect the cement quality [16].

II.5. Cementing tests

Cementing is controlled by the release of heat and the increase in cement bond strength as it sets, making it possible to study the cementing of a casing and its quality using the following :

- Sonic: CBL (Cement Bond Log) & VDL (Variable Density Log).
- Ultrasonic: USIT (Ultra Sonic Imager Tool) & IBC (Isolation Scanner).

II.5.1. Sonic [CBL-VDL(Cement Bond Log-Variable Density Log)]

II.5.1.1. Définition et origine du terme ‘’Diagraphie’’

Diagraph (diagraphe): an instrument used to project the image of an object onto a screen and reproduce it by following its contours.

Diagraphy: from the Greek dia (through) and graphein (to draw).

Logging is the continuous recording, along a well, of the physical parameters of the subsoil (resistivity, radioactivity, acoustic velocity, density, etc.) and their interpretation in terms of geological characteristics (porosity, water saturation, argillosity, thickness, dip, fracturing, etc.)[25].

II. 5.1.2. Sonics definition

Sonic meters measure the time it takes for an acoustic wave to travel through the base of a formation. The frequency of the wave is generally between 20 and 40 kHz. The speed of wave propagation depends on the density and lithology of the formation traversed, being high in solids and low in fluids. The CBL and VDL are sonic tools that record the amplitude of a sound wave in the casing. These recordings are used to determine the quality of casing cementing.[25].

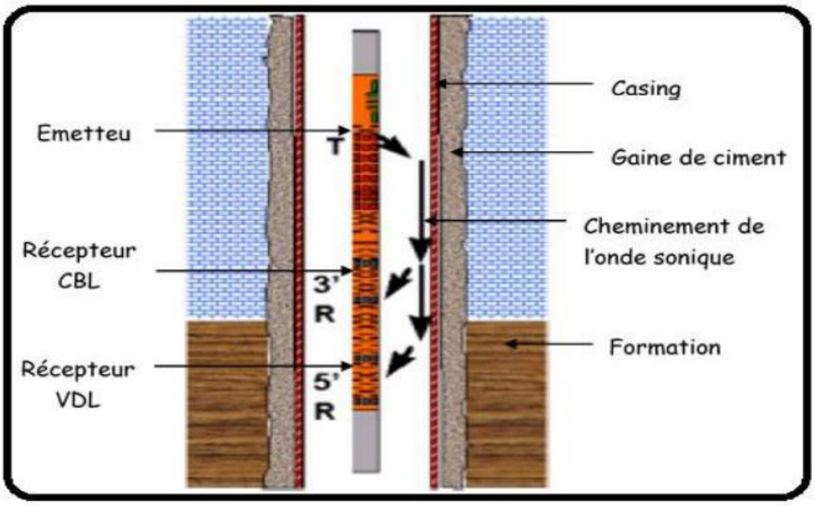


Figure II.1: CBL-VDL tool [25].

II.5.1.3.Measuring amplitude and transit time

The amplitude of an acoustic wave decreases as it travels through the medium through which it passes. This attenuation is a function of the elastic properties of the medium. Its measurement is used to determine the cementing quality of a casing.

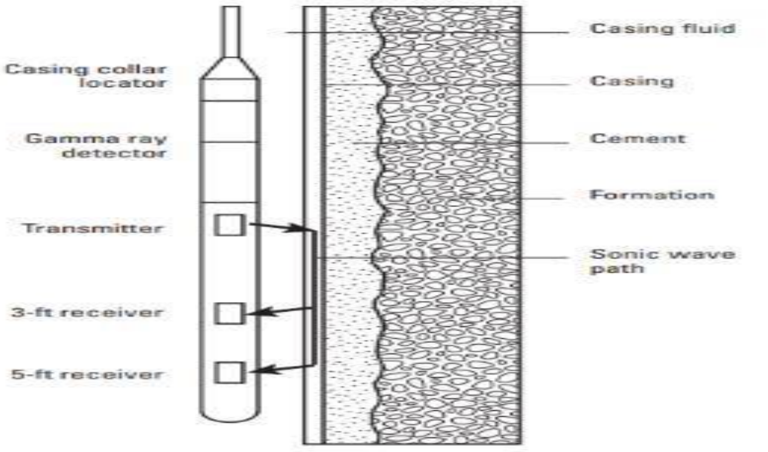


Figure II.2: The CBL and VDL wave train [25].

II.5.1.4. Principle of CBL - VDL Tool (Cement Bond Log-Variable Density Log)

CBL - VDL is a tool that emits waves through an acoustic transmitter, which are then picked up by two receivers spaced approximately 2in apart, from which the travel time and amplitude of the waves reflected by the various elements of the well (casing, cement, formation) are measured.

There are two receivers on the recording train, the first is 3 feet from the transmitter and receives the waves which will be converted into log CBL, the second is 5 feet from the transmitter and the waves received will be converted into log VDL[25].

II.5.1.5. CBL-VDL (Cement Bond Log-Variable Density Log) measurements

The main variables provided by the tool are:

- Transition time (tt).
- Amplitude of the casing signal (AMP).

II.5.1.5.1. Transition time (tt)

This is the time measured for the wave to reach the nearest receiver (3 ft from the transmitter). This variable provides fundamental information about the centralization of the tool and the arrival of fast formations in the MSG.

II.5.1.5.2. Amplitude of the AMP casing signal

The AMP curve is proportional to the level of energy detected at the receiver. In fact, the maximum amplitude is obtained in a casing that is not in contact with the cement sheath or the formation (free pipe).

On the other hand, minimum amplitude is obtained by a casing that is completely cemented and adheres well to the cement.

Waves travelling along the entire length of a pipe propagate faster than those in the formation and mud[25].

II.5.1.6. Principle of CBL (Cement Bond Log)

This method is used to study and quantify the quality of cementing by measuring bonding.

A wave train with a frequency varying between 15 and 30 KHz depending on the equipment is periodically generated by a transmitter. This wave passes through the mud, the casing, the cement and the formation if these various media are acoustically coupled, and is then detected by a receiver located on the body of the tool (generally 3 feet from the transmitter).[25].

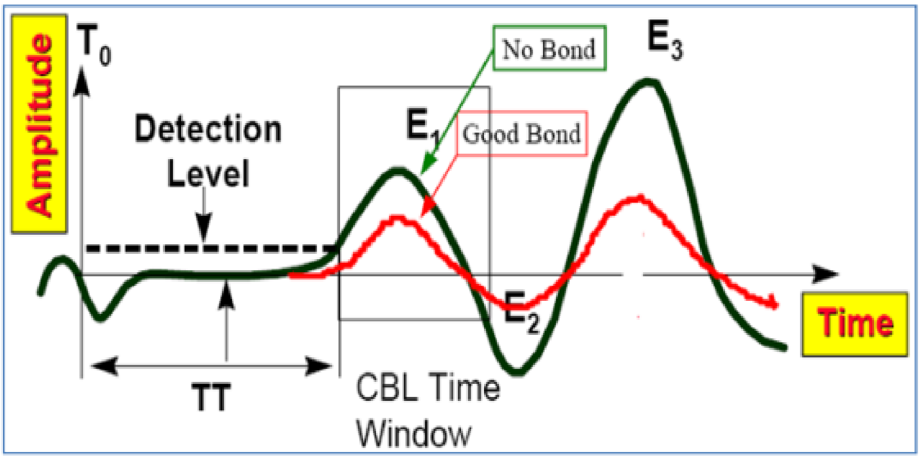


Figure II.3: CBL principle[25].

Acoustic energy travelling along a tube propagates faster than formation waves, which are themselves faster than mud waves.

Possible acoustic paths

1. In the body of the tool: Not seen, due to the design of the tool.

2. In the mud: Seen but arrives very late

3. In the casing: Seen and measured

4. In the cement casing: Not seen

5. In the formation: Seen in the case of good cement

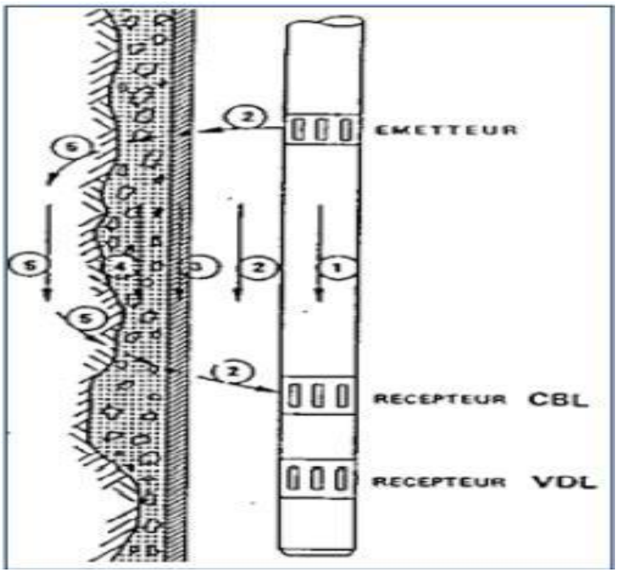


Figure II.4: Possible wave paths[25].

II.5.1.7. Interpretation of CBL (Cement Bond Log)

In the case of a ‘free’ (uncemented) casing, all the acoustic energy flows along the steel. Wave attenuation is very low and the amplitude of the first arc is high.

For fully cemented casings, this energy is transmitted through the cement into the formation. Amplitude attenuation is high.

Poorly cemented casings distribute the energy between the casing and the formation. The amplitude A measured will be between Amaxi and Amini.

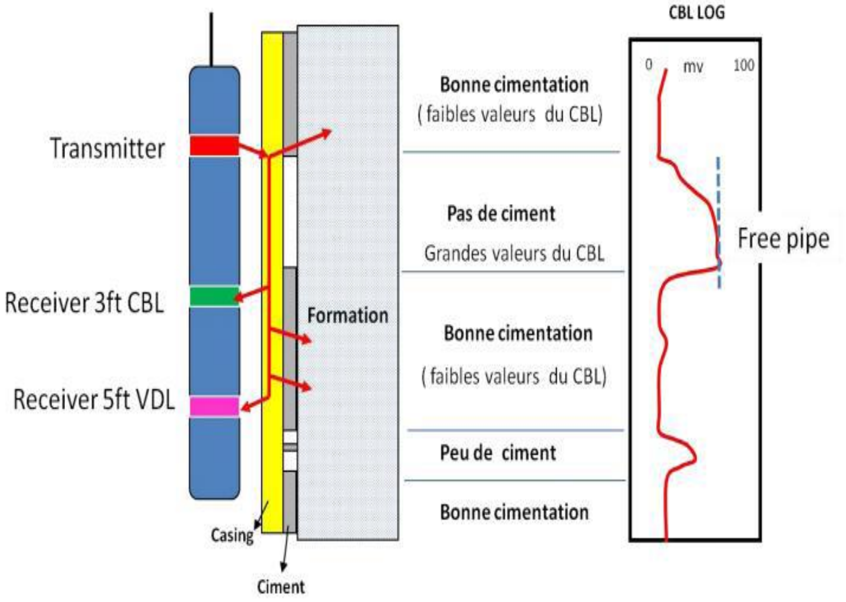


Figure II.5: Wave response translated into log CBL[25].

II.5.1.8. Principle of VDL (Variable Density Log)

Definition

This is a recording of all the sound wave trains received by a receiver located 5ft from the transmitter. It is used to highlight the cement adhesion formation.

Principle

The study of the quality of cementing can be distorted by a number of phenomena.

It has proved useful to record the entire train of sound waves received by a receiver generally located 5ft from the transmitter. Recorded in addition to the CBL, the VDL is used to define the cement/formation bond.

The presentation of this recording is:

In the form of the complete wave train or its positive part only (‘Wave Forme’, ‘Signature Curve’): reading is difficult. In variable density (VDL), only the positive arches being reproduced in a scale of greys that are darker the greater the amplitude.

In formations faster than the casing, the sonic wave crosses the cement-formation interface and arrives at the receiver well before the casing refractions.

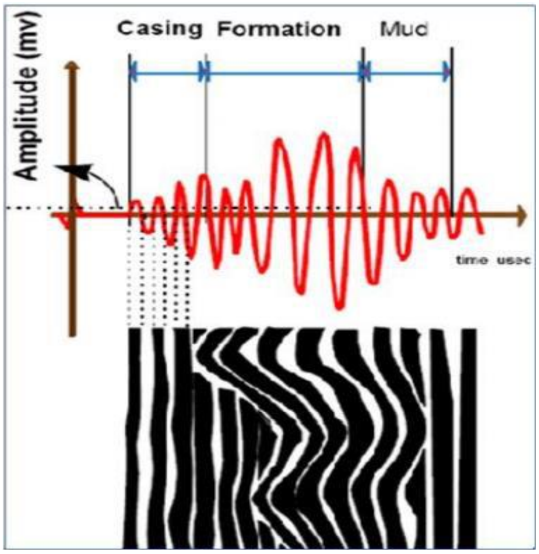


Figure II.6: Classical wave arrival order[25].

II.5.1.9. Interpretation of the VDL (Variable Density Log)

The figure shows the VDL, which indicates the state of the cementing.

In the figure below, more precisely in the lower part of the log (circled part), we can see a weak casing arrival and a strong formation signal, which indicates very good cementing, in other words: good casing/cement/formation, adhesion

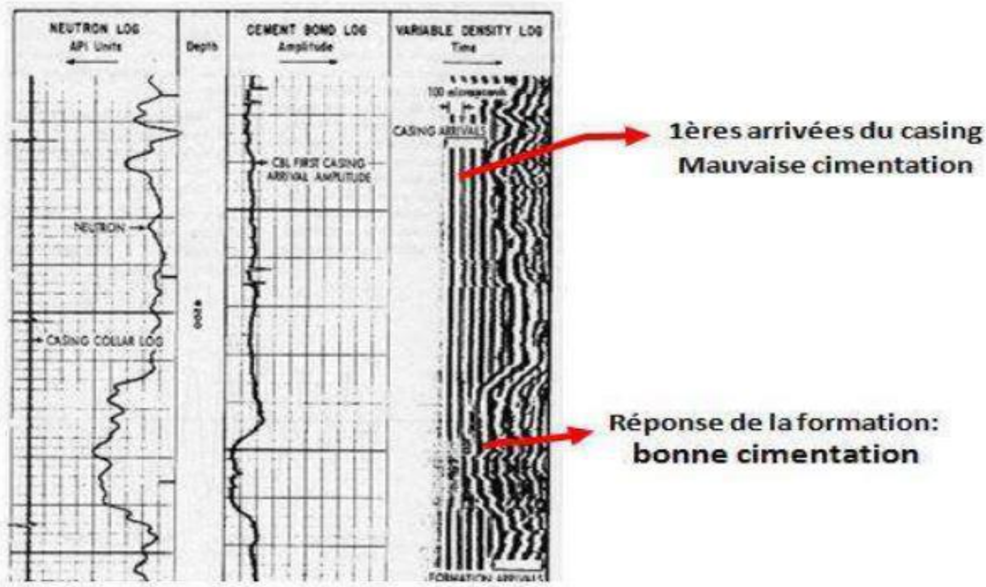
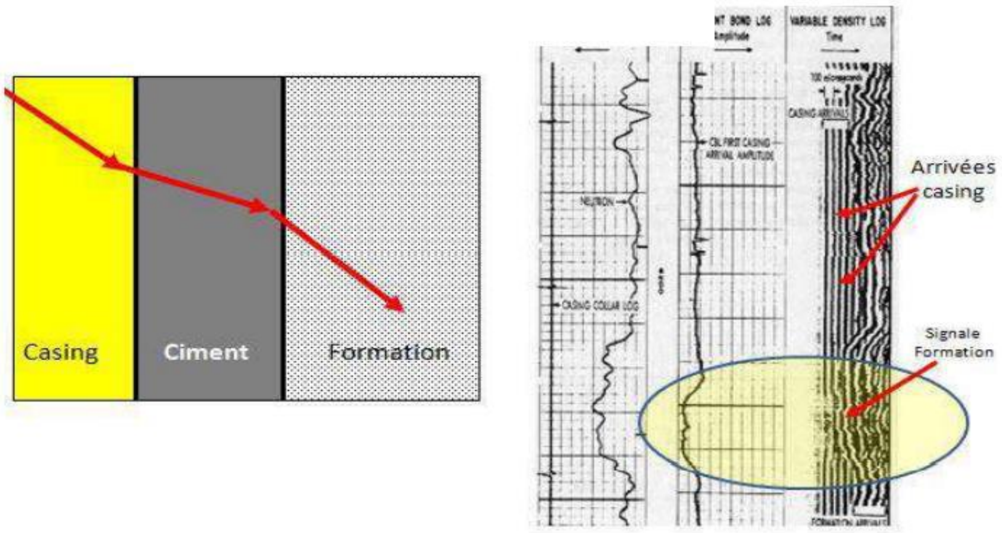


Figure II.7: Log VDL showing the state of cementing[25].



FigureII.8: Channel detection[25].

II.5.1.10. Interpretation of CBL-VDL (Cement Bond Log-Variable Density Log)

A/ Free casing (not cemented)

- The CBL amplitude is high (corresponding to that expected as a function of casing diameter).

- TT approximately equal to that calculated from mud and casing data.

- Casing waves very sharp, straight and well parallel on the VDL.

- Casing joints clean on all logs.

B/ Well cemented casing

- The amplitude of the CBL is low.

- The T.T. is little different from that measured in the free casing.

- In all cases, the VDL shows very weak or even non-existent casing waves and very clear formation waves whose variations correspond to those seen on the sonic recorded in the open hole.

C/ Weakly cemented casing or ‘channeling

- The amplitude of the CBL is average.

- The VDL shows relatively clearly visible casing waves.

- Good cement-casing bond (casing waves are very attenuated), no cement-formation bond (formation waves are not visible).

(Formation waves do not appear and only mud waves arrive after casing waves).

II.5.1.11 CBL-VDL synthesis

- The CBL indicates the quality of the case/cement bond.

- The VDL assesses the quality of the case/cement and cement/formation bonds and the correct filling of the annular space. It is the only tool that can analyse cement/formation contact.

II.5.2.12 Strengths

- Works well in most well fluids, tolerates some casing corrosion.

- VDL provides proof of the cement-formation bond.

II.5.2.13 Weaknesses

- Extremely sensitive to eccentricity.

- No azimuthal measurements.

- Sensitive to wet micro-annulus.

- High CBL amplitude can be ambiguous: micro-annulus, channelling, contaminated cement, light cement.

- Sensitive to rapid formation.

II.5.3. Ultrasonic [USIT Ultra Sonic Image Tool, IBC Isolation Scanner]

II.5.3.1. USIT (Ultrasonic Image Tool)

The ultrasonic imaging tool is designed to provide a high-resolution image of the casing wall and cement distribution. USIT provides four basic measurements:

- The acoustic impedance of the cement behind the casing.

- Casing thickness.

- The internal radius of the casing.

- Estimation of the internal surface conditions of the casing.

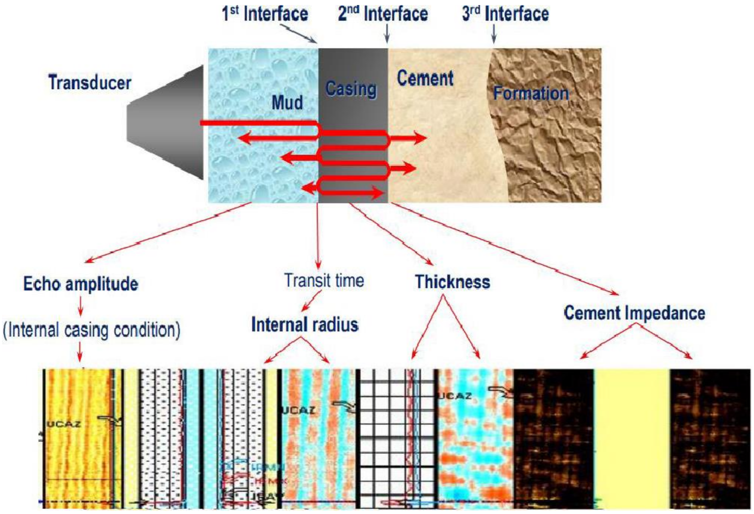


Figure II.9: The principle of Ultrasonics and its measurements[25].

II.6. The phenomenon of gas migration

II.6.1.Definition

Gas migration in oil and gas wells is defined as gases and/or fluids from adjacent formations invading a freshly cemented annulus. During well completions, gas and/or fluids can migrate to zones with lower pressure or even to the surface. Static gel strength (SGS), related to the yield stress of the cement, is a widely accepted measurement used to predict and minimize gas migration. In our thesis ,we look at the mechanisms and some possible solutions to gas migration during oil and gas well cementing. The use of static gel strength (SGS) and experimental measurements for SGS and wellbore pressure reduction are discussed. Rheological properties, including the yield stress and the viscosity of cement slurries, are also briefly discussed. Understanding the rheological properties of cement is complex since its material properties depend on cement type, as well as the shape and size distribution of cement particles. From this brief review, it is evident that in order to reduce free water and settling of the cement particles, to lower fluid loss, and to develop compressive strength in the early stages of cementing, an optimal cement slurry design is needed. The SGS test is a standard method used in estimating the free water in the well and could be a reference for gas migration reduction for oilwell cement slurries[26].

Problems troublesome is topped by its complexity as many various factors influence the process, such as fluid density control, mud removal, cement-slurry properties, cement hydration, and interactions between the cement, casing, and formation. As no other well is the same, reasons that caused the gas migration can differ from one to another well [5]. Extensive research has been done to understand this phenomenon, resulting in various theories that explain the physical processes that can lead gas migration. This theory part concentrates on gas migration after primary cementing and focuses on conditions, types and factors that contribute to gas migration

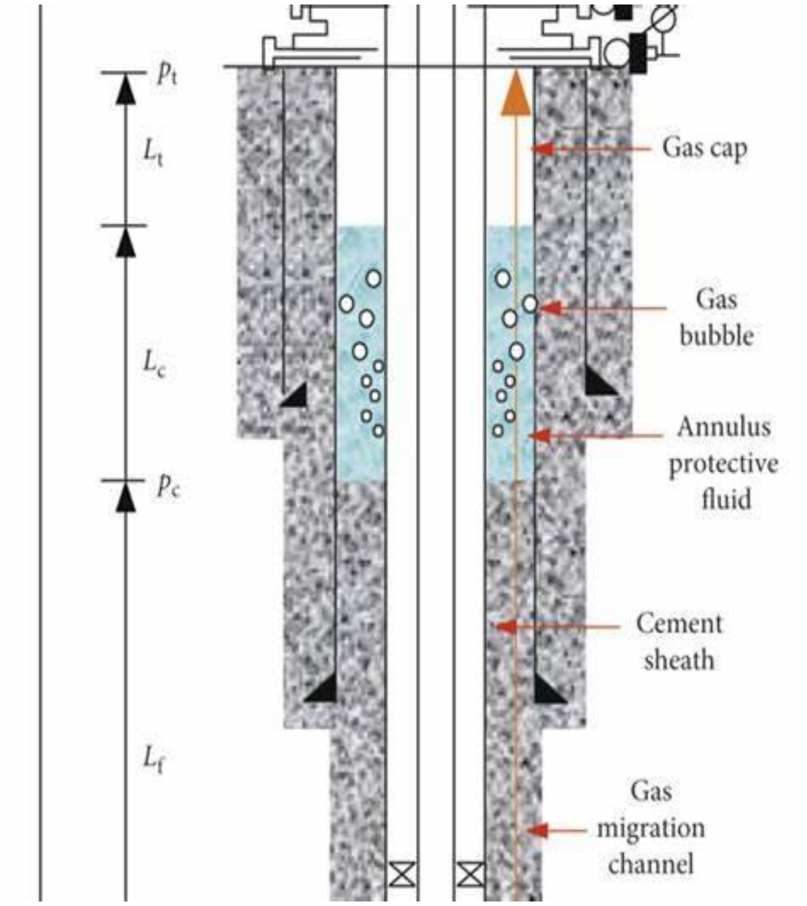


Figure II.10. descriptive schema of channeling problem accurance

II.6.2. Conditions for gas migration:

The most important conditions to occur annular gas migration are:

1. 1.The annulus hydrostatic pressure has a less or an equivalent value compared to the pore pressure
2. Annulus space allows the entrance of gas and
3. A path is available through the annulus in which gas migration occurs. If one of the conditions is eliminated, gas migration will stop[26].

II.6.3. Types of gas migration

as channelling problems can immerge at any time and for various periods of time so it is classified to a three categories according to the period of time that the migration of gas is in place

1. Immediate gas migration.

2. Short-term gas migration.

3. Long-term gas migration.

II.6.3.1 Immediate gas migration:

This type of migration is primarily observed during cement placement, between commence of the cementing job and the final step of cement placement. The best solution to mitigate the challenges is to employ preventive actions

II.6.3.2 Short-term gas migration:

This type of migration which is usually referred to as postplacement migration, is observed between the final step of the primary cementing job (usually highlighted by the plug landing) and the cement setting step. However, the procedure which triggers the migration is assumed to be the annular pressure decay[26].

II.6.3.3 Long-term gas migration:

Long-term gas migration occurs after the cement has set, which may occur within a few hours after the end of the cement job. There is no usual timeframe as migration can occur anytime in a few days, months, or even years [5]. Migration of this type is getting more attention now due to increasing number of Plug and Abandonment operations (P&A) as old wells get to the end of their life cycles. According to industry standards, such as NORSOK and API, one must provide long term integrity (eternal perspective) of well, which includes integrity of cement bonding, impermeability and ability to stop gas migration

Due to increasing amount of wells that have already or will be soon plugged and abandoned industries interest in understanding, predicting and preventing of long-term gas migration has increased [26].

II.6.4.Effective parameters of gas migration

Different parameters implement various roles regarding gas migration issue. It must be regarded that we are not able to control some of these factors through the optimization of slurry phase. The most important factors affected on gas migration are shown in table [26].

Table 1. Factors affecting gas migration[26].

	Annular pressure ≤ pore pressure	Entry space	Migration path
Immediate	Hydrostatic underbalance	Fluid displacement from wellbore	Fluid displacement from wellbore
Short term	Fluid loss	Fluid loss	Slurry permeability
	Gel strength development	Free fluid	Slurry permeability
	Chemical shrinkage of cement	Chemical shrinkage of cement	Filter cake permeability
	Annular bridging	Slurry porosity	Filter cake permeability
	Annular packers	Slurry porosity	Filter cake permeability
Long term	Chemical shrinkage of cement	Chemical shrinkage of cement	Micro annulus
		Mud channel	Mud channel
		Free fluid	Free-fluid channel

		Dehydrated filter cake	Dehydrated filter cake
			Low cement tops
		Bulk shrinkage of cement	Bulk shrinkage of cement
			Cement sheath mechanical failure

II.6.4.1. Fluid loss:

Any reduction in the amount of cement in the hydrostatic head reduces entire cement column, which allows gas to enter the slurry. In order to diminish gas penetration and also cement permeability risks, the API fluid volume in high pressure/high temperature should be less than 50 ml for 30 minutes. It is regarded as one of the most important factors which contribute to gas migration. Fluid loss consequences which may impact it are: **1.** Decrease in hydrostatic column height as a result of slurry-volume reduction. **2.** Increase in slurry gelation characteristics as a result of diminished slurry water content. **3.** Annular bridging**. 4**. Losses in friction-pressure through the compaction stage as a result of slurry volume reduction. API fluid loss rate reduces to lower than 50 mL/30 min, the invasion risks and consequent hazards would remarkably diminish[26].

II.6.4.2. Development of Gel Strength:

Any decrease in the volume of cement slurry caused by fluid loss and hydration phenomena will be offset by the downward movement of the cement slurry due to the slurry. After pumping the cement into the wellbore and allowing being in static form before setting, the development of gel strength commences. Through various tests pertinent to Static Gel Strength (SGS), it was found that the value of 500 lbf/100ft2 would be resistant againstthe fluid invasion for gelled type cement. Therefore, the required time for SGS to reach from 100 lbf/100ft2 to 500 lbf/100ft2 is referred to as the transition time[26].

II.6.4.3. Thixotropic Cements:

Thixotropic cements with high gel strength are resistant to gas migration. Several experiments show that short transition time and temperature have no effect on strong thixotropic cement slurry so it can eliminate fluid channeling and gas migration in cementing process. Mixture of acid-thixotropic cement tested according to API RP 10B2 in order to evaluate gas migration durability, these evaluations indicate more improvement in gel properties compared with thixotropic cement without acid. [26].

II.6.4.4. Cement shrinkage:

This phenomenon comes from cement hydration process, which is also referred to as chemical contraction of cement. Final chemical shrinkage is often split throughout a matrix internal contraction, which is approximately equal to 2%, also a bulk shrinkage ranging from 4% to 6% by cement slurry volume. Various studies and investigations argue the degree of hydrostatic pressure decline as a result of cement shrinkage. Amongst the most novel researches, one was carried out in which reported that the reduction in annular pressure is not affected by chemical shrinkage. AMPS copolymers fair extent be considered as a very effective substitute to design gas tight slurries and styrene butadiene latex effectively reduce permeability, BaroghelBouny et al explained that the cement which has water-cement ratio above 0.40 swells in the first days before shrinkage occurs whereas Horita et.al observed that shrinkage will happen after swelling for water-cement ratio between 0.4 and 0.5. Mounanga et al. indicated that there is a critical point (7%

degree of hydration at 0.4 water-cement ratio) to identify type of cement shrinkage it concluded that chemical shrinkage rate will increase after this point and the autogenous shrinkage before this point same as chemical shrinkage, this is due to calcium hydroxide precipitation [23]. When water-cement ratio is equal to 0.6 swelling occurs because of calcium hydroxide, Aft and AFm large scale crystals [11] this is corroborate Barcelo investigations which show lime as main reason of cement swelling [12], while Pichler et al. concluded that swelling phenomena is just because of tricalcium aluminate [26].

II.6.4.5. Permeability:

Cheung and Beirute were pioneers of proposing a mechanism for gas migration. They carried out their experiments by conducting some laboratory investigations in which the gas primarily invaded the cement pores and ultimately penetrated the entire cement matrix whichgreatly hindered and prevented the hydration process and thus a migration path was established [8]. Afterwards, Parcevaux (1984) highlighted the theory by carrying out a research upon cement slurries and investigating the pore-size distribution while thickening and setting periods. It concluded that at beginning of setting time connected pores started to appear. enlargement of pores occurs and pores communication develops after initial invasion of gas [18]. All-Yami at 2009 designed a new cement formulation with high density which can prevent gas migration by permeability reduction. Experiment results show that Hematite and Manganese Tetroxide with equal concentration significantly reduce fluid loss through the cement blocks. Also utilizing latex (in gas block additive form) more than 3.5 gallon per sack improves the results[26].

II.6.4.6. Mud removal:

Mud removal is very important in cementing job for obtaining proper zonal isolation. used a new designed fiber to pre-flush cementing fluids and concluded that nonaqueous removal significantly improve from the well when fiber was used through cementing operations[4]. Chun researched on Nano Emulsion to remove filter cake and non-aqueous drilling fluids. Results of this study indicated that technology of Nano Emulsion able to decrease interfacial tension between oil and water below 0.001 mN/m. which can significantly reduce mud removal problem. It can be use acid with Nano Emulsion simultaneously to eliminate calcium carbonate and filter cake. Advantage of these natural source, easy handling, nontoxic and bio degradable emulsions are free of toluene and benzene. Also Juan used seven surfactants with different formulations of maximum concentration of 10 percent in volume of spacer which achieved to same results. Recently smart unconventional biomaterials used to oil based drilling fluid removal. It is determining bonding strength between casing and set cement to verifying proper cleaning efficiency of mud contaminations [26].

II.6.4.7. Casing/ Formation Interface (micro annulus):

The phenomenon of gas migration may even occur through micro annulus, which is expressed as infinitesimal gaps that might be created between the casing and liner and also around the cement sheath. It also can be formed between cement sheath and formation post setting. Pressure and temperature variations during or after cementing operations can expand or contract the steel casing both in length and diameter values can intense micro-annulus and will cause deformation. The contraction of cement after the primary setting is approximately a few tenths of a percent and it does not seem toestablish a remarkable continuous annulus. Latest 270 000 operating wells data review show that, 6% of wells were recognized to contain leaks, 0.5% of them having gas migration and 5.5% having surface casing vent flow in micro annulus. HPT logging coupled with SNL logging assist accurately identifying gas migration in micro annulus and source of fluid leakage. An experimental investigation conducted on micro-annuli cell coupled with pressure and strain gauges to evaluating leakage rate in order to improve micro-annulus interpretation, the results show that in linear elasticity regime, test cell radial deformation is proportional to micro-annulus pressure and maximum pressure gradient located in micro-annulus outer part. Size of micro-annulus correlated to rate of leakage by utilizing a model coupling radial deformation to pressure inside the micro-annulus, this modeling and prediction are compared with experimental results [26].

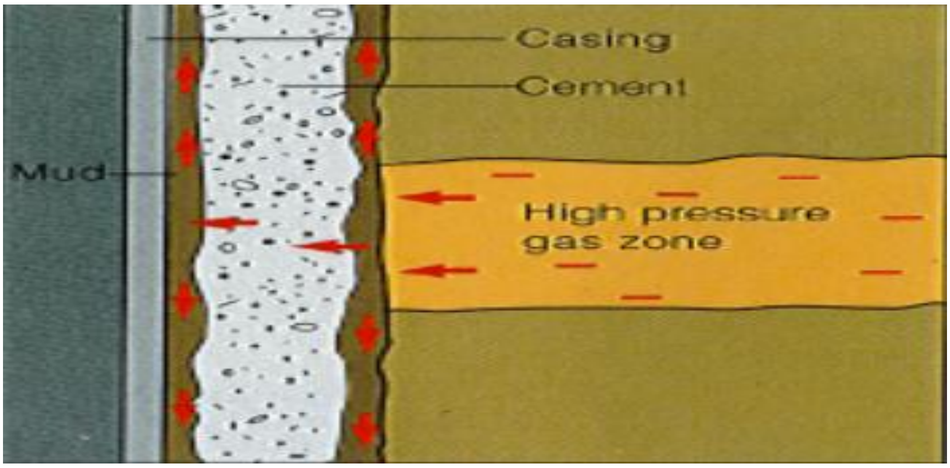
II.6.4.8. Cement sheath Mechanical failure:

In case that compressional and/or tensile stresses violate the maximum possible values designated to prevent the formation of micro cracks in cement or local near casing crushing (shear failure), sufficient space for gas entry or gas migration path will be created. Tectonic stresses, subsidence and formation creep can the key factor which cause cement loading. Shadravan studied on cement fatigue cycle by conducting several experiment on different type of cement blocks. In these experiments, temperature and pore pressure are constant at 330F and 15,000 psi. Experiment results and calculations indicated that primary failure in cement blocks in all cases was radial failure which is implemented in high pressure and temperature conditions. Skorpa et.al designed a setup to evaluate cement sheath integrity in presence of mud contaminations their results show that in cases which have mudfilm, radial cracks not to develop and propagate. It can be used low concentration (less than 5 wt%) gypsum in order to adsorbing energy and reducing mechanical failure [26].

II.6.5. Main channeling passages

There are basically three main passages for the gas to migrate through,

1. Through the voids of mud cake which occurs as a result of improper design of spacer and thus poor mud displacement



FigureII.11. gas displacement through mud voids,

Through microannulus between cement-formation and cement casing. This is due to contraction-expansion mechanism during cement setting

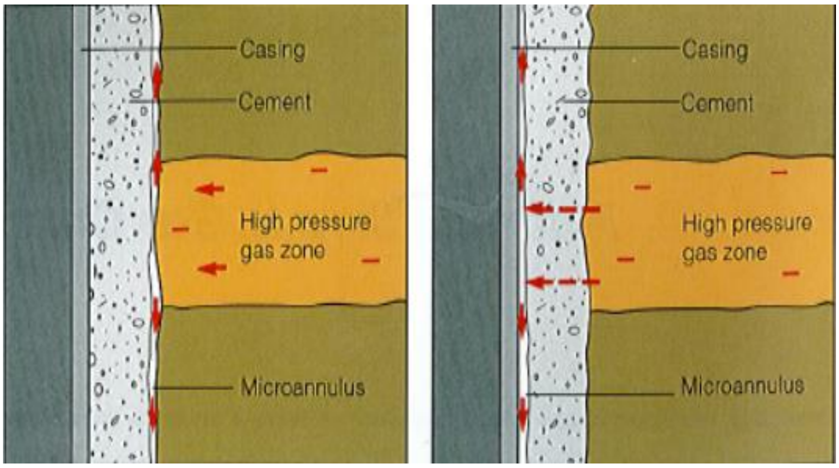


Figure II.12. gas displacement through microannulus

Through "matrix gas channeling", which is through the cement itself this time.This happens when the cement naturally creates microvoids through which the gas can migrate

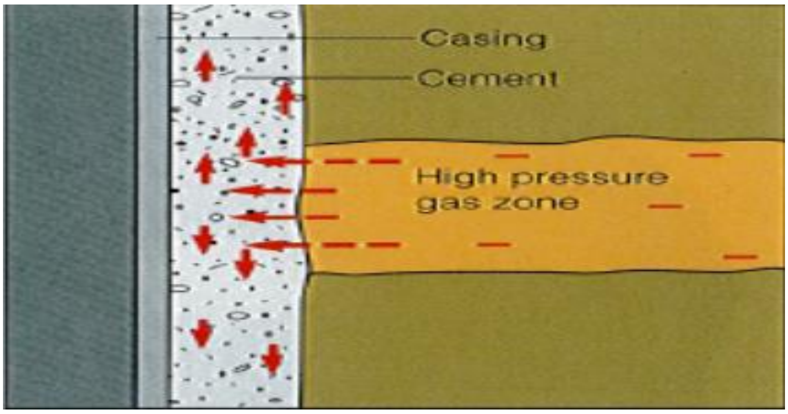


Figure II.13. gas displacement through matrix gas channeling

Adding 2.5-6% by weight of anchorage clay to the cement at a temperature of 93.5° Celsius to overcome the shrinkage problem and the void resulted by that which leads to gas migration. Adding 4-8% by weight of a class of synthetic rubber powder eliminates the migration of gas through the cement itself, it seals the microvoids occurring within the cement during setting. Ironate sponge has also shown good results according to the same research, ironate sponge addition to the slurry delivers better bond to the casing due to higher magnetic field of ironate sponge under higher temperatures of deeper formation

II.6.6. Strategies and solutions to prevent and combat the migration of gas

Thousands of research and millions of dollars spent on understanding the mechanics of fluid (specially gas) migration and developing solutions, it leads to a wide range of different strategies that describe different aspects of gas migration phenomena. Experimental investigation and case studies to provide practical advice, technical solution development [3], application of different cement additives in cement slurry and prediction technique for cement quality are number of strategies are studied by researchers. For example Use of nanoparticles additives of cement slurry, especially Nano silica in some condition has mitigated gas migration through modification in cement setting profile, gel strength development, hydration process and cement microstructure. Another effective additive for this purpose which produced by Halliburton are D-series additives, include D-193, D-700, D600, D-500 and D-400 which used for low- and medium-temperature, high temperature, medium temperature, low temperature and cold environments respectively. Also an innovative additive for fluid loss prevention and weighting the cement slurry is UNIFLAC. This fluid-loss additive is a cost-effective and universal solution for fluid-loss control for all cementing applications. The additive is a custom-made third generation solid polymer that can be pared solved in the mix water or dry blended with the cement. Its robust properties make slurry design very simple and produce predictable results in the field from the surface casing to the liners . All the approaches and strategies utilized to minimize the gas migration risks primarily rely on targeting one or multiple gas migration conditions, including the control of annular pressure decline, reduction of gas entry space, and ultimately minimizing the migration path. As a result, techniques and approaches to mitigate the mentioned challenges are typically categorized in three different classifications regarding the target conditions during the timeframe of different types of gas migration[26].

II.6.6.1. Low Permeability cement slurries

This strategy primarily highlights declining the cement matrix permeability while liquid-to-solid transition period and mainly focuses on the third condition. Normally, low permeability is met by blending certain additives with the slurry of cement. CMC and some other additives added to G class cement in one of south Iranian oil field which show proper reduction in cement permeability. In order to prevent CO2 corrosive effect on set cement an acid-base calcium cement prepared for the first time in china. After 7 days of exposure to an solution with 700 psi and 212F CO2 the yield is equal to 0.63% while class G cement under similar conditions has yield equal to 16.54% of carbonation rate. Micro silica exhibit much more rigorous bonding properties, and thus smoothly increases the cement strength and less strength retrogression. It must be denoted that similar gas migration prevention characteristics are introduced for Gas Con additive[26].

Table 2. Technique and approaches to prevent gas migration[26].

	Annular pressure ≤ pore pressure	Entry space	Migration path
Immediate	Fluid density	**Inapplicable**	**Inapplicable**
Short term	Right-angle-set cement	Low porosity cement	Packers
	Sandwich squeeze	Low porosity cement	Sandwich squeeze
	Compressible cement	Compressible cement	Low permeability cement
	Fluid density	Compressible cement	surfactant
	Thixotropic cement	Low fluid loss cement	Thixotropic cement
	Low fluid loss cement	Low fluid loss cement	Thixotropic cement
	Back pressure	Zero free water cement	Low permeability filtercake
	Annular pressure pulses	Zero free water cement	Low permeability filtercake

Long term	**Inapplicable**	**Inapplicable**	Packers
			Compressible cement
			Expensive cement
			Flexible cement Mud removal

II.6.6.2. Right Angle Set Cements:

Cements slurries of Right Angle Set (RAS) type are explained as systems which do not exhibit continuous gelation tendency through the placement of slurry which is typically followed by rapid slurry viscosity at the final time of designed pumping schedule. Gel properties of cement with RAS cannot be expanded exponentially and quickly while quickly forms a low permeability matrix that prevents gas infiltration. The design of the RAS slurry is difficult for temperature ranges lower than 250 Fahrenheit since rapid gel development process is mainly dependent upon temperature parameter. Prabhakar experimentally tested sulfur aluminate (CSA) and gypsum cement to evaluate RAS and gel strength properties of new formulation cement slurry, results show in high content CSA cement slurry transition time for gel decreases whereas gel strength development increased. Proper set cement properties can be reached only by using moderately compacted micro silica which has about 300kg/m3 bulk density. Popular and ease handling micro silica do not provide effective performance to prevent gas migration. Ramirez designed a new Sorel technology cement slurry without utilizing Portland cement which play an important role in cementing operation Expandable Cements: Small distances between cement and formation can lead to gas migration, expandable cement helps to eliminate these distances and prevent gas migration. However, expandable cement cannot remove large channels. The main components of expandable cement include: calcium alumni ferrite-type, sulphur aluminate-type, aluminate-type, and silicate-type. Expanding and hardening of silica expandable cement is slow, however aluminate expandable type is fast. This approach highlights the third condition of gas migration by preventing the formation of micro annulus in long term considerations [26].

II.6.6.3. Foam cement:

Foam cements are made by mixing base cement with one or more foaming agents and adding a gaseous phase (generally nitrogen) to the cement slurry. The purpose of utilizing foam cement is to provide high strength but also low weight cement slurry. Density of this type of cement depends on the density of the components of the cement mixture [8]. Preparation and designing of foam cements is not possible with the addition of just a few additives and requires sophisticated technology. The results of field experiments have shown that foam cement can be used effectively to eliminate the problem of zone isolation. The mechanism of preventing gas migration by foam cement does not exactly cover the specific time frame of gas migration but experience has shown that it can be useful at all three migration times . The primary advantages of foam cementing rather conventional mitigations that might be practical to diminish migration problems are: enhanced toughness, impact resistance eliminating loss circulation and influx controlling of water and gas. Well-dispersed nitrogen bubbles contribute to compensate the adverse impacts of hydration chemical shrinkage. Regarding the conventional design, bulk shrinkage is typically a significant value whereas it is a reduced for foam cement systems [26].

II.6.6.4. Self-healing cements:

One of the recent achievements in cementing operations is self-healing cement (SHC) concept which mainly targets the long term gas migration condition. A hydraulic barrier fast and automatically forms by swelling during exposure to formation fluids. Slurry design and required self-healing substances to optimize it with a regard to target hydrocarbon compositions are the challenges in this strategy. Rheology control agent such as friction reducer, working time controlling agent (retarders) and fluid loss control agents are the most common component to designate self-healing cement[26].

II.6.6.5. Applied Annulus Pressure:

Pressure of pumping fluid that exerted on annulus surface can effectively prevent gas migration. The pressure should be applied immediately after the wiper plug is inserted and at least until the cementing is operational. Surfactants: Surfactants added to the cement slurry and enter the migrating gas and provide a stable foam. This foam withstands the migration of gas from the slurry [26]. The surfactant slows the movement of the gas by converting the gas into an immobile fluid and viscous foam. The addition of surfactant also reduces the slurry surface tension, thereby preventing the bubble from shrinking and moving. The combination of these two mechanisms together with the appropriate slurry design greatly reduces the risk of gas migration after cementation [26].

II.6.5. Conclusion

Effective parameters on gas migration are: fluid loss, gel strength development, cement shrinkage, permeability of cement sheath, mud removal, migration pathway, cement sheath mechanical failure and using thixotropic cement. Application of low permeable cement, right angel set cement, expandable cement, foam cement, self-healing cement, annular space pressure control and surfactant are strategies and solution to prevent gas migration. In order to cope with the gas it must be ensured that the two main conditions do not occur simultaneously: hydrostatic pressure in the annular space should be less than or equal to the pore pressure and there must be a path to gas migration or must be created. Investigation of these two conditions requires a good understanding of the initial hydration mechanism of the cement. At beginning of cementation chemical shrinkage occurs, followed by swelling and autogenously shrinkage, and their intensity depends on the type and amount of the cement additives, the degree of hydration, the water-cement ratio and the fineness of cement. There are three main mechanisms that control the cement deformation during hydration: chemical shrinkage, structural swelling due does large crystals, and self-desiccation shrinkage. They are in concurrence and the structural swelling is dominant at early time and at high w/c ratios. In other words, the autogenously deformation of cement depends upon hydration degree and w/c ratio. There is different type of pathway to migration based on well geometry

1. Cement-casing interface,

2. Formation-cement interface,

3. Channel through the damaged layer and

4. Chanel throughout the time of slurry placement.

CHAPTRE III

PRACRICAL ANALYSE OF CHANELLING PROBLEM

TMSK-1

III.1 ISOBLOK overview

III.1.1 Introduction to ISOBLOK

The ISOBLOK gas migration control system is designed for medium and high temperature cement application. it relies on a remarkable synergy between latex particules and liquid polymers to provide excellent fluid loss and gas migration control.

The resultant slurry has an adjustable viscosity suitable for effective mud removal.it can be used over wide temperature and density ranges and for deferent applications the additive also controls gas migration by importing the cement bond to formations and casing.

The ability of the cement slurry to stop gas migration is directly related to additive concentrations which is determined based on bottom hole circulating temperature (BHCT) and the solid volume friction. The ISOBLOK system can be used at BHCTs from 38^{o} C to 177^{o} C and slurries with density ranges from 960 to 2760 Kg/ m^3[27].

III.1.2Application

- Control of annular gas channelling in medium to high temperature primery and remedial cementing
- Cementing expendable tubular
- Highly deviated and horizontal well cementing

III.2 flex STONE overview

III.2.1. Introducing Flex STONE

Flex STONE is advanced flexible cement technology extends the lifetime of wells that undergo fluctuation in pressure and temperature, reducing the incidence of costly workover and remedial intervention by virtue of superior mechanical properties

The technology improves production isolation by ensuring effective hydraulic sealing across low fracture gradients and improves long-term isolation and casing protection in corrosive environments. It also delivers a robust and long-term seal and barrier in high temperature plug and abandonment scenarios [28].

III.2.2. Application

- Wells with large variations in mud weight during drilling, potential micro annulus development, or planned postplacement pressure and temperature variations.
- Gas and oil wells or injector wells.
- Fracture stimulation candidates.
- Plug and abandonment candidates

III.2.3. How it works

Flex STONE technology uses the optimized particle-packing concept from the field proven CemCRETE concrete-based cementing technology.

Long-term hydraulic isolation throughout a well's life cycle requires more than just a focus on compressive strength. Changes in downhole conditions can lead to mechanical damage of set cement behind the casing, either because of direct mechanical failure of the system or the creation of micro annuli. Fluctuations in wellbore pressure and temperature from operations such as pressure or drawdown tests, stimulation treatments, or formation loading can all adversely affect the cement sheath. The combination of lower Young's modulus and higher tensile strength provides better resistance to failure caused by changing stresses [28].

III.3. Practical study of TMSK-1 well

In order to evaluate the operation, we used the experimental results of BH-14 well phase 9 5/8" to analyses this problem of gas migration.

III.3.1. WELL DATA

he following Table III.4 summarizes the description of the well

Table III. 1: well DATA[29].

Entry	Description
Well Name	TIMOSKALINE-1 (TMSK-1)
Well Type	Vertical EXPLORATION
Vertical Permit/Block	339b
Spud date (Estimated)	May 2023
Drilling days (Estimated)	90 days without rig move
Total time for the well	132 days
Operator	SONATRACH-Drilling Division
Drilling Contractor	ENTP
Rig Name	TP 180
Well TD	3500 m MD / TVDRT
Water Well	/
Targets	Ordovician: (DMK/GEG/GOS/QH) Dev.inf Cambrian will be well TD
Surface Coordinates	
Latitude	26° 37' 10.0081"N

Longitude	1° 39' 16.0086" E
UTM	X= 366 043 m Y = 2 944 753 m

III.3. Well schematic

➢ **Phase 26”: Realization of The Section: 350 m**

- Drilling from the surface up to the coast 350 m
- KCl-polymer mud 1,05-1,08
- Casing: 18 5/8" J55-K55

➢ **Phase 16”: Realization of The Section: 1400 m**

- 18 5/8" casing shoe drill with PDC bit
- KCL-polymer mud with d— 1.15 -1.30 sg
- Drilling from 350 m to 1400 m
- Drop for a 13 3/8’’ column. (N80)
- Single stage cementation

➢ **Phase 12 ¼”: Realization of The Section: 2146m**

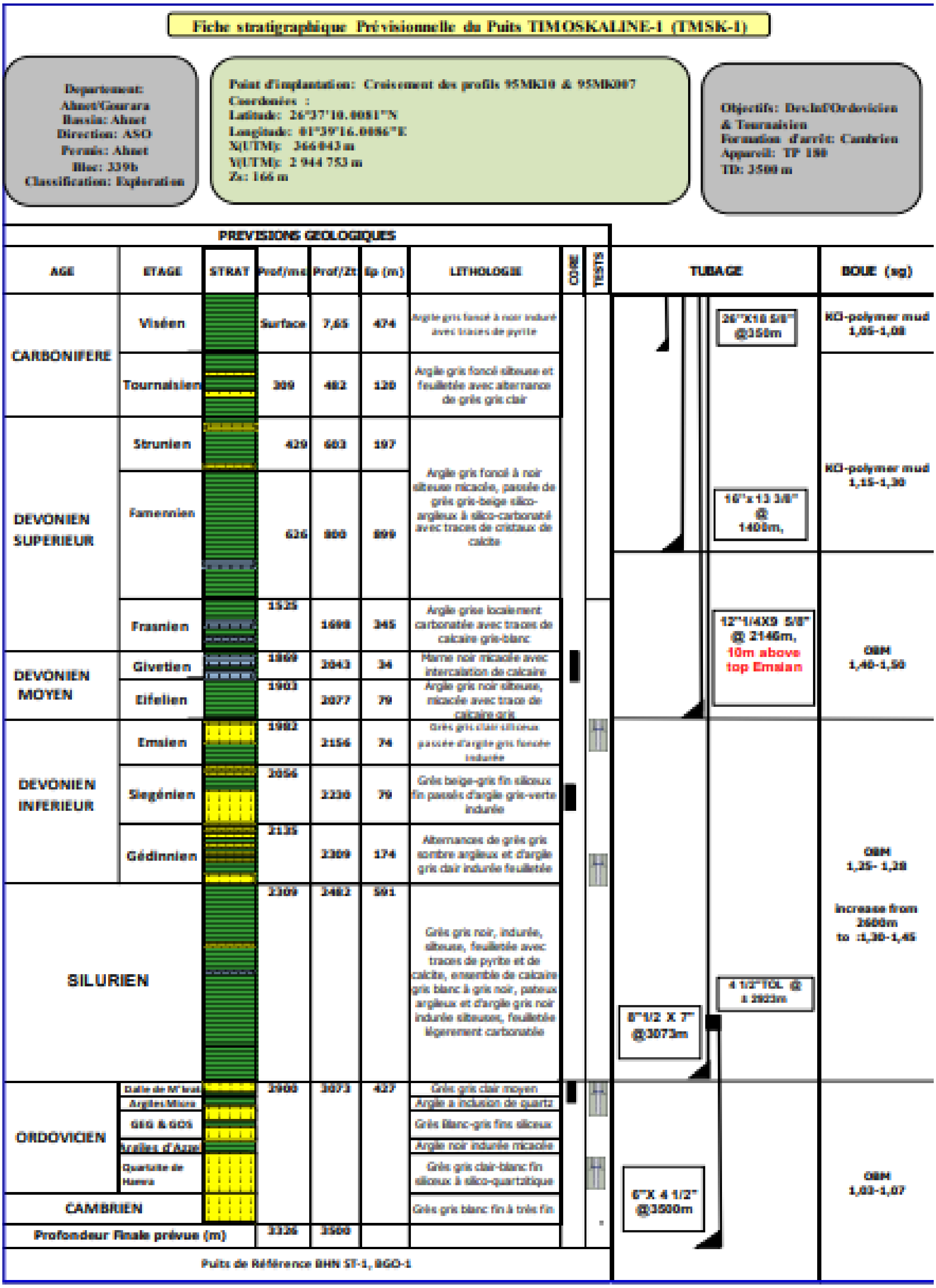
- 13 3/8’’ casing shoe drill with PDC bit
- OBM 1,40-1,50
- Drilling from 790 m to 1779 m
- Drop for a 9 5/8’’ column. (P110)
- Single stage cementation

➢ **Phase 8 ½’’: Realization of The Section: 3073 m**

- 9 5/8’’ casing shoe drill with PDC bit
- 1,25- 1,28 increase from 2600m to :1,30-1,45
- Drilling from 1779 m to 2093 m
- Drop for a 7’’ column. (P110)
- Single stage cementation

➢ **Phase 6’’: Realization of The Section: 3500 m**

- 7’’ casing shoe drill with PDC bit
- OBM 1,03-1,07
- Drilling from 2093 m to 2170 m
- Drop liner 4 ½’ (TOP LINER 2923 m



Fiche stratigraphique Prévisionnelle du Puits TIMOSKALINE-1 (TMSK-1)

Departement: Ahnet/Gourara
Bassin: Ahnet
Direction: ASO
Permis: Ahnet
Bloc: 339b
Classification: Exploration

Point d'implantation: Croisement des profils 95MK10 & 95MK007
Coordonées :
Latitude: 26°37'10.0081"N
Longitude: 01°39'16.0086"E
X(UTM): 366043 m
Y(UTM): 2 944 753 m
Zs: 166 m

Objectifs: Dev.Inf/Ordovicien & Tournaisien
Formation d'arrêt: Cambrien
Appareil: TP 180
TD: 3500 m

PREVISIONS GEOLOGIQUES

AGE	ETAGE	STRAT	Prof/msl	Prof/Zt	Ep (m)	LITHOLOGIE	CORE	TESTS
CARBONIFERE	Viséen		Surface	7,65	474	Argile gris foncé à noir induré avec traces de pyrite		
	Tournaisien		309	482	120	Argile gris foncé silteuse et feuilletée avec alternance de grès gris clair		
DEVONIEN SUPERIEUR	Strunien		429	603	197	Argile gris foncé à noir silteuse micacée, passée de grès gris-beige silico-argileux à silico-carbonaté avec traces de cristaux de calcite		
	Famennien		626	800	899			
	Frasnien		1525	1698	345	Argile grise localement carbonatée avec traces de calcaire gris-blanc		
DEVONIEN MOYEN	Givetien		1869	2043	34	Marne noir micacée avec intercalation de calcaire		
	Eifelien		1903	2077	79	Argile gris noir silteuse, micacée avec trace de calcaire gris		
DEVONIEN INFERIEUR	Emsien		1982	2156	74	Grès gris clair siliceux passée d'argile gris foncée indurée		
	Siegénien		2056	2230	79	Grès beige-gris fin siliceux fin passés d'argile gris-verte indurée		
	Gédinnien		2135	2309	174	Alternances de grès gris sombre argileux et d'argile gris clair indurée feuilletée		
SILURIEN			2309	2482	591	Grès gris noir, indurée, silteuse, feuilletée avec traces de pyrite et de calcite, ensemble de calcaire gris blanc à gris noir, pateux argileux et d'argile gris noir indurée silteuses, feuilletée légèrement carbonatée		
ORDOVICIEN	Dalle de M'krat		2900	3073	427	Grès gris clair moyen		
	Argiles Micro					Argile a inclusion de quartz		
	GEG & GOS					Grès Blanc-gris fins siliceux		
	Argiles d'Azzel					Argile noir indurée micacée		
	Quartzite de Hamra					Grès gris clair-blanc fin siliceux à silico-quartzitique		
CAMBRIEN						Grès gris blanc fin à très fin		
Profondeur Finale prévue (m)			3326	3500				

Puits de Référence BHN ST-1, BGO-1

TUBAGE

26"X18 5/8" @350m
16"x 13 3/8" @ 1400m,
12"1/4X9 5/8" @ 2146m, 10m above top Emsian
4 1/2"TOL @ ± 2923m
8"1/2 X 7" @3073m
6"X 4 1/2" @3500m

BOUE (sg)

KCl-polymer mud 1,05-1,08
KCl-polymer mud 1,15-1,30
OBM 1,40-1,50
OBM 1,25- 1,28
Increase from 2600m to :1,30-1,45
OBM 1,03-1,07

Figure III.1: well schematic[29].

III.3.4. Cement program

Table III. 2: cement program[29].

Casing	Shoe Depth (m)	Estimated BHST ºC	Cement Type	Volume	
18"5/8	350	38-40	Lead - 1.58sg light from 200 to surface Tail - 1.90sg to 200m above shoe	Lead - 100% OH excess Tail - 50% OH excess	
13"3/8	1400	63@1054m	Lead - 1.60sg light to200m inside 18"5/8 with gas block Tail - 1.90sg to 200m above shoe with gas block	Lead - caliper + 15% Tail - caliper + 10%	
9"5/8	2146	85@1748m	Lead - 1.60sg light 200m inside 13"3/8 with gas block Tail - 1.90sg to 200m above shoe with gas block Lead	Lead - caliper + 15% Tail - caliper + 10%	
7"	3073	125@2831	Lead - 1.60sg light 200m inside 9"5/8,with gas block Tail - 1.90sg to 600m above shoe (in face to Sulurien formation),with gas block	Caliper + 10%	
4"1/2 Liner	3500	134@3131m	single stage - 1.90sg to top of liner	Caliper + 10%	

III.3.5. Well risks

Table III. 3: well risks[29].

Identified Risk/Hazard	Mitigation	Contingency
Managing losses in Inter Conti, Famennian	-Have adequate supply of drilling water. -Increased sweep frequency. -Maintain effective management of Water supply. -Maintain optimum flow rate. -Optimize drilling practice for bottom hole cleaning. i.e. Y.P.	-Ensure water pits full &Line up to rig tanks. -Cure losses with LCM
Bit balling problems top hole drilling	-Maintain optimum flow rate. -Cent. Jets should be bigger than 12/32 - Control dilution rate.	- Use fresh water & caustic pills

Difficulties to run 18 5/8" casing	- Wipe the hole as required. - Make sure the hole is clean before running the casing. - Place optimized Hi-Vis prior to POOH with BHA.	- Ream each Kelly drilled twice during connection. - Perform a check/wiper trip with stiff assembly, in case the casing did not go in

Tight holes, over Pulls	- Perform periodic check trips - Work string to break tight spots - Pump-out hole at low flow rate - Back ream if required. -Ream every connection.	- Circulate with L-H pills. - Check shale inhibition in mud system.
Wellbore Instability through Famennian & Frasnian	- Ensure mud weight is sufficient to hold FAMENNIAN and FRASNIAN shales back without inducing losses - Maintain Fluid loss to less than 5ml. - Maintain KCL range (3-6 %) - Maintain concentration of Baracarb & baratrol to seal any micro fracture. - Minimize exposure time (DP connection time).	-In case of stuck & failed to release plug back & side track.
Unable to get 13 3/8" casing to the planned TD	- Ensure POOH on last BHA run is Smooth. - Circulate hole clean prior to POOH the BHA. -Place optimized Hi-Vis pill.	- Consider additional wiper trip, depending on Frasnian open.
High torque & Bouncing -12 ¼'' Hole drilling	-Use under gauge STABS - Possible use of Roller Reamers in place of stabilizers in upper part of 12 ¼" hole - Use shock sub to minimize vibration - Optimize mud parameters.	- Additional bit round trip. - Consider torque reducer in mud if possible.
Overpull & tight hole	-Optimize hole cleaning, Hi-Vis & reaming - Observe hole drag & overpull while	-Stuck pipe procedures in place

	connections. -Increase mud weight	
Shallow Fault at top of Silurian	-Expected to cut fault planned gains or losses may happen - Check for fast break while drilling. - Flow check	-Pump LCM.

III.3.6. 12 1/4” HOLE SECTION X 9 5/8”

CASING Mud system: OBM mud @ 1.40 - 1.50 SG MW. The 12 1/4” section will be drilled as a vertical hole with a packed hole assembly through the bottom Famennian/Frasnian, Givetian/Eifelian and should be stopped ± 10 m above the Emsian. The 9 5/8” casing will then be run to isolate the Upper and Medium Devonian formations from the drilling of 8 ½” hole, and will permit a safe MW adjustment through the Lower Devonian series. The 9 5/8” shoe is critical; it must be set close to the Emsian formation (10-15 m above Emsian for minimum Upper Devionian shales exposure to avoid hole instability) without penetrating the Emsian sandstones. The main considerations for this hole section are: - Caving and shales instability Frasnian shales . - High gas background towards the base of the Frasnian and Givetian formations. - Potential losses while drilling throughout the Frasnian/Givetian limestones

- Correct location of the 9 5/8” casing shoe (Geologist to advise). The 12 ¼” section will firstly drill the Famennian/Frasnian formation which consists of dark brown to dark grey mudstones with siltstones interbedding with thin sandstones and Dolomitic-limestones layers which can be fractured. The Frasnian mudstones are subject to borehole instability which can be aggravated with DP shocks against borewalls. The Givetian/Couvinian sequence is also an alternance of mudstone and siltstones interbedding with thin fractured limestones/sandstones layers. Those formations exhibit a low compressive strength and good ROPs are expected, especially with PDC bit. Hole packing-off is likely to occur while drilling the bottom Famennian/Frasnian formation (overpressure shales). Increasing the mud weight to hold back the formation may be the last solution, but a better precaution should be applied first by monitoring hole cleaning by periodically circulating high viscosity pills and spotting the same prior to making trips and running casing. In addition, engineering a high enough yield point to ensure proper hole cleaning will also minimize mechanical sticking problems. -Wiper trips could be necessary in Frasnian (Overpull have been notice while passing through those sections). - Risk of losses while drilling through the Frasnian/Givetian limestone makes us to recommend having sufficient LCM material/Cement on site. - While drilling this 12 ¼” section, the wellbore trajectory will be checked with Totco survey. Note on the survey frequency: the survey frequency will be adapted on observed BU rate: in case of a low BU rate the survey frequency will be extended, on the opposite if high BU rate is noticed survey can be taken on shorter intervals (base to advice). 9 5/8” casing shoe location: The thickness of the Eifelian formation is expected to be in a range of ± 79 m. Therefore to correctly locate the 9 5/8” shoe, the Eifelian formation will be penetrated by ± 69m maximum. In this way we will limit the Medium Devonian shales exposure without penetrating into the Emsian formation. The 9 5/8” casing shoe will be cemented in one stage using two cement slurries with the cement top @ ± 250 m above the 13 3/8” casing shoe. − A surface casing fill-up system will be used while running the casing. − The 3-4 last joints will be run with circulation to be able to set the shoe close to bottom as required. − The casing tally needs to accommodate a minimum rat hole. − Two cement slurries, Isoblok or flexstone tail slurry @ 1.90 SG with additives with a coverage of at least ± 250 m in 9 5/8” - 13 3/8” casing annulus. Note: depending of gas shows in the Frasnian/Givetian formation, recipe may vary. test must be recalculated). − The csg slips will be set with tension equivalent of the weight of the non-cementing part of the csg plus 10%. − The casing will be cut accordingly to the Sonatrach wellhead procedure. • The section C 13 5/8” x 3M 11” x 5M will be nipple-up as per wellhead procedure, and pressure test to 3150 psi.

III.4. The analysis and interpretation of the cementing operation in TMSK-1 well

III.4.1. pressures in well cementing operation:

This diagram (Figure III.3) represents the pump pressure and the head pressure of the cementing, as a function of time during the cementing operation

III.4.2. Cementing job of the 13 3/8 section

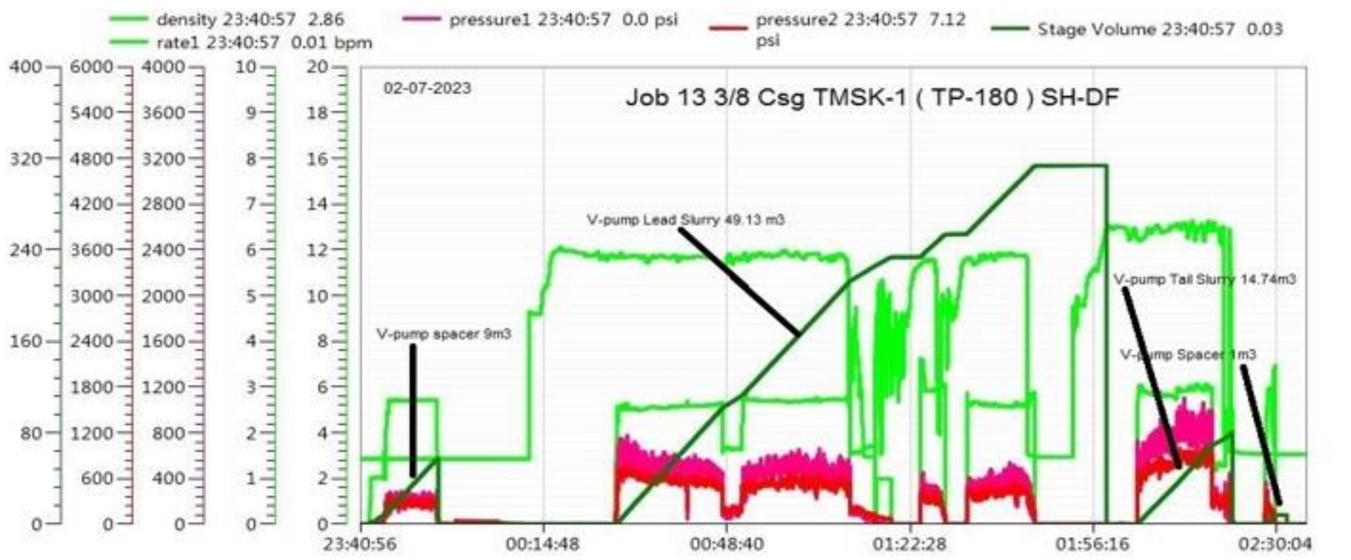


Figure III.2: the diagram of pump pressure and cement head pressure[30].

III.4.3. Interpretation

We can notice that pumping the spacer and the cement according to the following cementing program:

- From 0 min to 10 min pump spacer ahead v=9 m^3, d=1.30 sg with pump rate 800l/min.
- drop bottom plug.
- From 49 min to 1 h.10 min pump 49.13 m^3 of lead slurry d=1.60 sg Flex stone gastight rate 500 l/min.
- From 22 min to 1 h.32 min pump 14.74 m^3 of tail slurry d=1.90 sg Flex stone gastight rate 500l/min.
- Drop top plug.
- From 1 min to 1 h 43 min pump spacer behind 1 m^3, d=1.40 sg with pump rate 800l/min.
- From 22 min to 2 h. 5 min displacement of cement 60.83 m^3 of KCL mud d=1.20sg.

- From 6 min to 2 h.58 min switch to cops unit to bump plug

. • bump plug 3000 psi.

- bleed of no return 10 min.

III.4.4. the result CBL-VDL of casing 13 3/8’’

the 13.375’’ casingwas run from surface to 1401 m. this casing was cemented with laid slurry LT-10 flex 1.6 g/cc and tail slurry LQ-13 flex.Where top cement expected at 150 m .

and isolation scanner with combination with CBL-VDL were run on 12 july 2023 over the interval of 150 m to 1370 m in order to evaluate the hydraulic isolation across this casing and indentify top of cement.

During logging the well was full of 1.4 g/cc ,OBM. Good data quality was obtained from the tools the interpretations of the log can be summeriwed as follow

- **Over the interval 15 m- 200 m**

  SLG map shows liquid matiail behind 13.375 casing (free pipe).top of cement indentified at 200 m . TIE (third interface echo) shows that the 13.375 casing is eccentred at severel levels

- **Over the interval 200m- 353 m**

  SLG map shows presence of cement with patchy dry micro-annulus

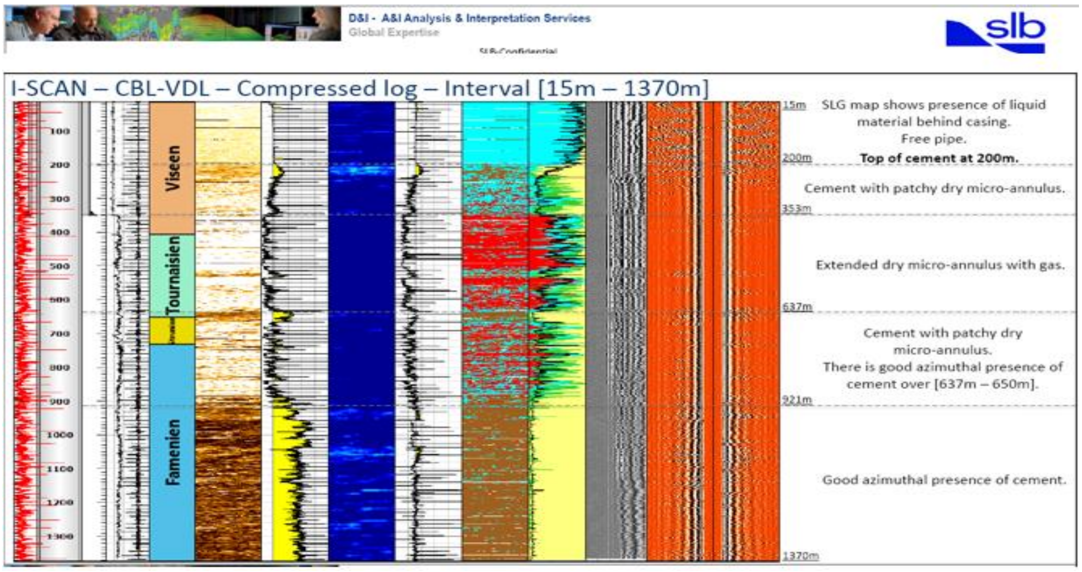
- **Over the interval 353 m- 637 m**

  SLG map shows extended dry micro-annulus with gas

- **Over the interval 637 m- 921 m**

SLG map shows presence of cement with patchy dry micro-annulus . there is good azimuthal pesence of cement over 637 m and 650 m .

- **Over the interval 921m- 1370** m SLG map shows good azimuthal presence of cement behind casing .



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I-SCAN – CBL-VDL – Compressed log – Interval [15m – 1370m]

15m SLG map shows presence of liquid material behind casing. Free pipe. **Top of cement at 200m.**

200m Cement with patchy dry micro-annulus.

353m Extended dry micro-annulus with gas.

637m Cement with patchy dry micro-annulus. There is good azimuthal presence of cement over [637m – 650m].

921m Good azimuthal presence of cement.

1370m

Figure III.3: the result CBL-VDL of casing 13 3/8’’[30].

III.4.5.Corrective actions to channiling problem in TMSK-1

In the light of the technical exchanges, the action plan proposed by the OPR is as follows.

1- Install a cement plug to insulate Open Hole from (150m). The cement plug will be placed below the perforations (Top at 400m).
2- 2- Make the perforations with the Halliburton surgijet tool under the 18"5/8 casing shoe in order to achieve a bridge block the gas.
3- The perforation points on the interval (360 m – 400 m)
4- Injectivity test with RTTS (the Exploration Operations Department has stressed that the chances of success are low (presence of micro-annulus).
5- If injectivity, placement of a cement plug of injectivity squeeze Pmax

N1: Formation fracturing pressure will be communicated by OPE. (Missing DATA).

N2: The cement plug formulation will be fixed by the cementing cell.

6- If no injectivity, move to another puncture point.
7- Observation of the annular pressure and bubbling at the cellar level.
8- If the operation of squeezing and eliminating gas bubbles is successful, it is necessary to cover the perforations with cement during the cementation of the CSG 9 5/8 (to do the hydraulic calculation of the csg 9 5/8 cementation to see the fusibility to cover the Perforations by cement during cementation (CSG 9 5/8).

III.4.6.CEMENT COVERAGE AND RESULT OF WELL CEMENRT RESTURATION RESULT

After squeezing operation with flex-tone cement from the result was as it follows

- the cement is in good condition, there are no communication with the mud and the cement.
- The channelling was eliminated

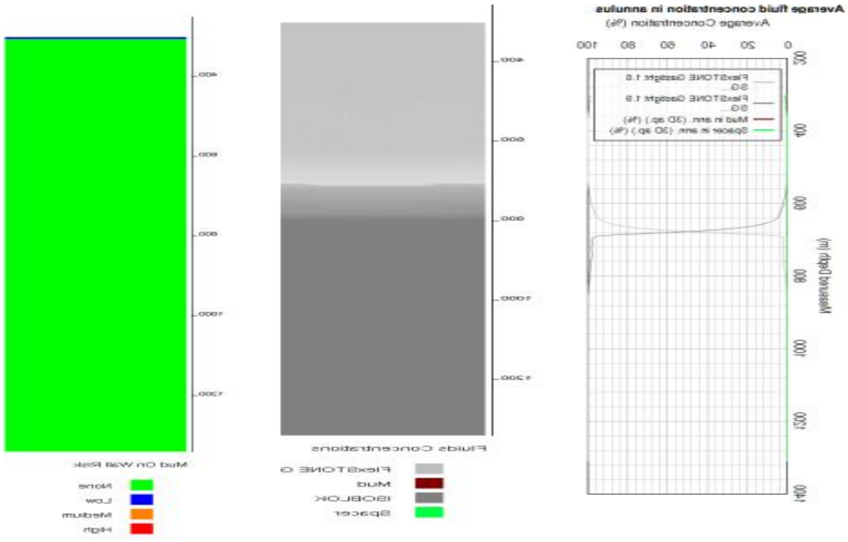

Figure III.4. : mud removal and cement coverage[30].

General Conclusion

During our study of the gas channelling that appears in cementing operation and leads to reservoir damage and effects production in AHNET region he results that we found after the analyzes of the problem show that the gas channelling in the TMSK-1 well was:

- during cement hydration due to hydrostatic pressure drop.
- Contamination of cement with mud (changes cement characteristics).
- Bad elimination of mud and cake.

there are several techniques and technologies to eliminate the above problem. Our contribution focuses on the latest, most cost-effective techniques for blocking migrating gases.

Our solution to this problem focuses on the "Schlumberger" product that is widely used in the market for cases so similar to the TMSK-1 well and cases in the same conditions. This product is known in the market by "Flex stone". The chemical construction of Flex stone is a company secret, this product has shown performances on cement quality against gas migration; casing corrosion; high temperature in the studied case of TMSK-1 well and other wells such as BH-14;GF26 GF18 . but despite of the remarkable result of Flex stone in AHANET region specially and other Adrar regions it is not affirmative that this product results are total. In some cases, the use of flex stone could not totally eliminate gas channelling and the well could not be recovered.

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