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Kasdi Merbah Ouargla University
Faculty of Hydrocarbons, Renewable Energies and Earth and Universe
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Presented by :

- Messaour Sohaib
- Yousfi Mohammed Elmabrouk
- Khenfer Messaoud

-THEME-

**Post and Cementing of 7" Liner with Hydraulic
Liner Hanger in BKNS-3 Well**

Thesis defended on : 10/06/2026 **before the Examination Committee :**

President :	MESSAOUDI Abdeljabbar	UKM Ouargla
Examiner :	ABIDI Saad Elfakeur	UKM Ouargla
Supervisor :	TOUMI Nabil	UKM Ouargla

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THANKS

First of all, we thank our God who gave us the strength and power to complete this modest work.

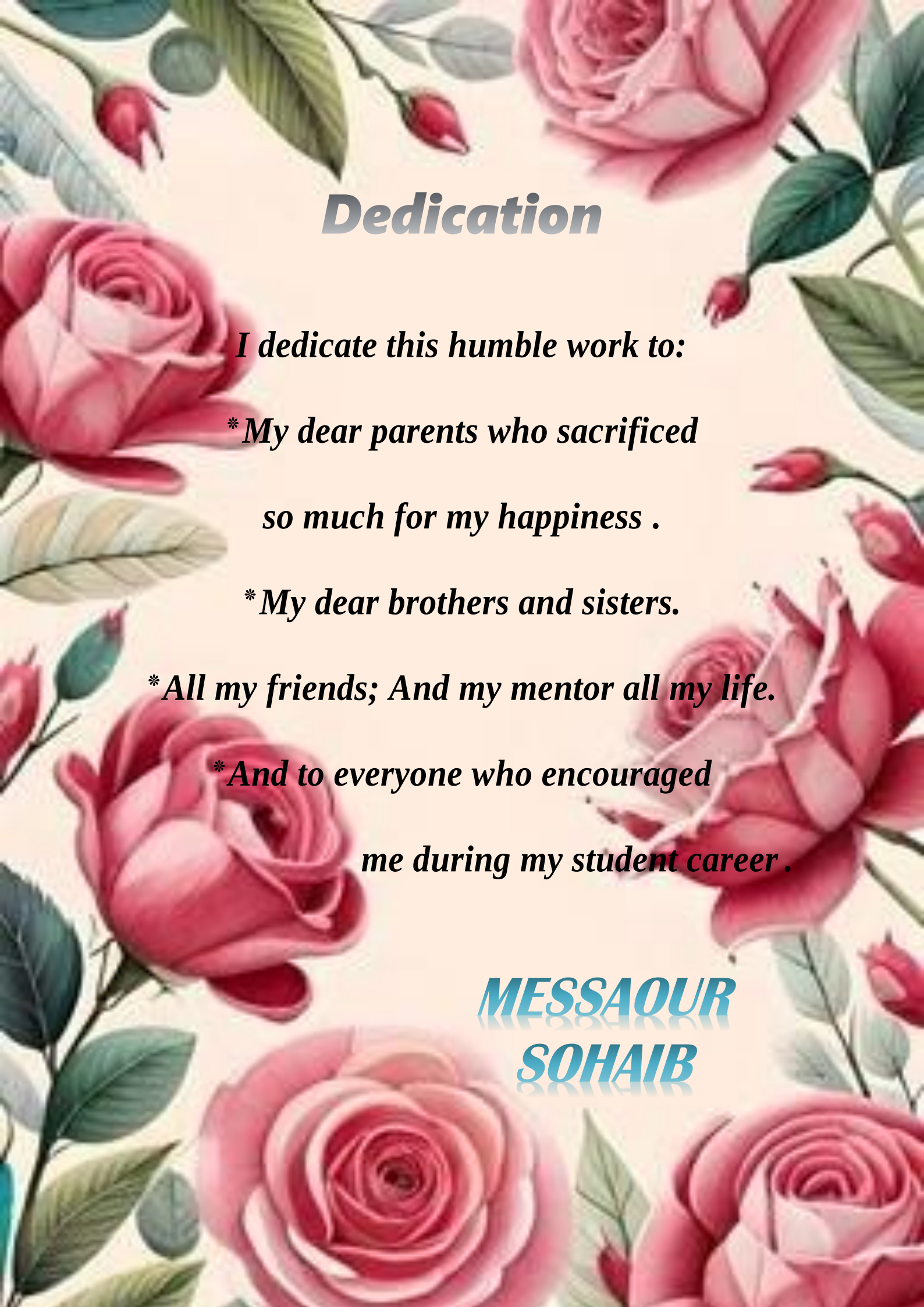
All our sincere thanks to our promoter:

Mr. Toumi Nabil

who guided us to carry out this work, for his follow-up, his wise advice and his availability and to those who welcomed us into the professional environment, Also a special thank you to all the teachers of the FORAGE department and to all the teachers of the faculty of Hydrocarbons for the efforts they provided to all the students.

We would like to take this opportunity to also thank all those who collaborated directly or indirectly in the production of this dissertation.



The background of the entire page is a lush arrangement of pink roses and green leaves. The roses are in various stages of bloom, with some fully open and others as buds. The leaves are dark green with visible veins. The overall tone is soft and romantic.

Dedication

I dedicate this humble work to:

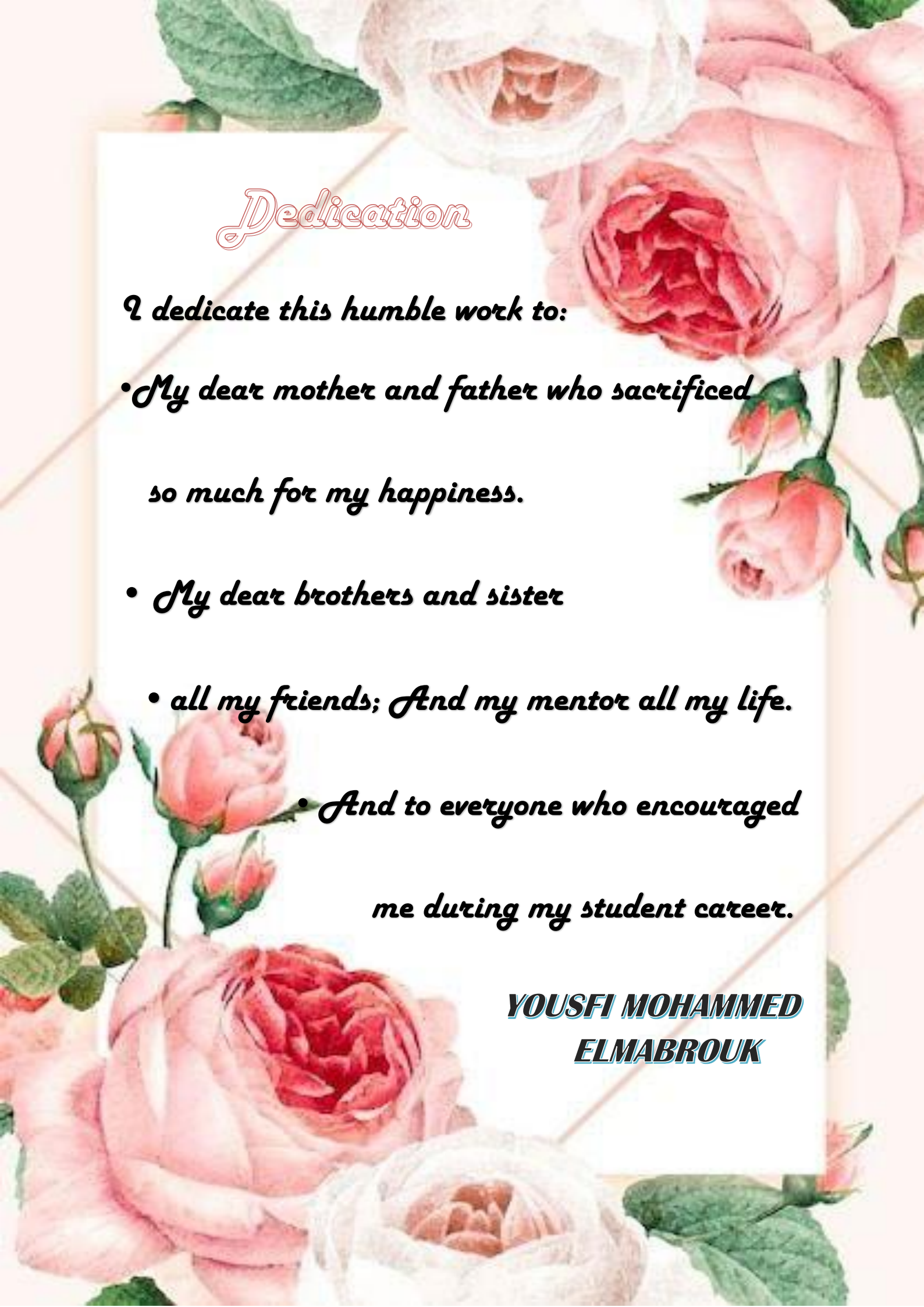
****My dear parents who sacrificed
so much for my happiness .***

****My dear brothers and sisters.***

****All my friends; And my mentor all my life.***

****And to everyone who encouraged
me during my student career .***

***MESSAOUR
SOHAIB***

The background of the entire page is a soft-focus image of several pink roses with green leaves. The roses are in various stages of bloom, with some showing deep red centers. The overall tone is romantic and elegant.

Dedication

I dedicate this humble work to:

- *My dear mother and father who sacrificed so much for my happiness.*
- *My dear brothers and sister*
- *all my friends; And my mentor all my life.*
- *And to everyone who encouraged me during my student career.*

***YOUSFI MOHAMMED
ELMABROUK***

The background of the entire image is a soft-focus photograph of several pink flowers, likely cherry blossoms, with delicate petals and green stems. The flowers are arranged in a way that they appear to be framing the central text area.

Dedication

I dedicate this humble work to:

- ***My dearest parents who sacrificed so much for my happiness;***
- ***My wife encouraged me to complete my studies;***
- ***All my friends and teachers throughout my life;***
- ***And to all those who encouraged me during my student years.***

KHENFER MESSAOUD

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Nomenclature

Element	Chemical formula
Tricalcium silicate	$3\text{CaO} \cdot \text{SiO}_2$
Dicalcium silicate	$2\text{CaO} \cdot \text{SiO}_2$
Tricalcium aluminate	$3\text{CaO} \cdot \text{Al}_2\text{O}_3$
Tetracalcium alumino-ferrite	$4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$
Magnesia	MgO
Lime	CaO
Silica	SiO_2
Alumina	Al_2O_3
Hematite	Fe_2O_3
Sulfur oxide	SO_3
Potassium oxide	K_2O
Water	H_2O
Calcium sulfate (Gypsum)	CaSO_4
Sodium oxide	Na_2O

List of abbreviations and units

chortcuts	Full name
API	American Petroleum Institute
DV	diverter valve
CBL	Cement Bound Log
VDL	Variable Density Log
TT	Transit Time
MD	Measured Depth
TVD	Trou Vertical Depth
TD	Trou Depth
N	Northing
E	Easting
MSL	Mean Sea Level
GLE	Ground Level
RT	Rotary Table
LTI	lost time incident
HSE	Health Safety Environment
Q	flow
m	metre
Feet	unit of length
ft	feet
" or in	inch
Psi	unit of pressure
KHz	kilo hertz
Km	kilometre
bar	unit of pressure
°	degree

Summary

This study presents the running and cementing of a 7-inch liner using a hydraulic liner hanger in well **BKNS-3** located in the Berkine Basin. The work highlights the importance of casing and cementing operations in ensuring well integrity, zonal isolation, and safe hydrocarbon production.

The study includes the geological and technical characteristics of the well, as well as the theoretical concepts related to liners, cementing equipment, and cement slurry properties. The practical part focuses on the liner running and cementing procedures, including the main operational calculations and field operations.

The results confirm the success of the cementing operation and the effectiveness of the hydraulic liner hanger system in improving well performance and operational safety.

Résumé

Cette étude présente la descente et la cimentation d'un liner de 7 pouces à l'aide d'un liner hanger hydraulique dans le puits **BKNS-3** situé dans le bassin de Berkine. Le travail met en évidence l'importance des opérations de tubage et de cimentation pour assurer l'intégrité du puits, l'isolation zonale et la sécurité de la production.

L'étude comprend les caractéristiques géologiques et techniques du puits ainsi que les notions théoriques relatives aux liners, aux équipements de cimentation et aux propriétés du laitier. La partie pratique est consacrée aux opérations de descente et de cimentation du liner avec les principaux calculs opérationnels.

Les résultats obtenus confirment la réussite de l'opération de cimentation et l'efficacité du système de suspension hydraulique dans l'amélioration des performances du puits et de la sécurité des opérations.

المخلص

تتناول هذه الدراسة عملية إنزال وتثبيت لاينر بقطر 7 بوصات باستعمال نظام تعليق هيدروليكي في البئر **BKNS-3** بحوض بركين. وتركز الدراسة على أهمية عمليات التغليف والإسمنت في ضمان سلامة البئر وتحقيق العزل الطبقي والإنتاج الآمن للمحروقات.

تشمل الدراسة الخصائص الجيولوجية والتقنية للبئر، إضافة إلى الجوانب النظرية المتعلقة باللاينر ومعدات الإسمنت وخصائص الملاط الإسمنتي. كما يتناول الجانب التطبيقي مراحل إنزال وتثبيت اللاينر مع أهم الحسابات والعمليات الميدانية. وأظهرت النتائج نجاح عملية التثبيت وفعالية نظام التعليق الهيدروليكي في تحسين أداء البئر وسلامة العمليات.

The drilling of oil wells is considered one of the most delicate, complex, and costly engineering operations, as its primary objective is to make the hydrocarbon reservoir accessible and exploitable under optimal technical and economic conditions. This requires the integration of several engineering disciplines and techniques in order to reduce well construction costs, achieve the set objectives safely, and properly prepare the well for the completion phase prior to production. This process includes metallic and mechanical construction aspects through the design and development of various drilling equipment and tools, while benefiting from previous experiences to improve performance and enhance operational efficiency.

Since oil well drilling is divided into several successive phases to ensure well stability and integrity, it is necessary to protect the walls of the drilled hole using steel pipes of different lengths and diameters known as casing strings. These casings prevent formation collapse, isolate geological layers from one another, and ensure proper pressure control.

Among the techniques adopted to reduce costs and improve drilling efficiency is the liner technique (suspended or partial casing), which represents a more economical alternative compared to running a full casing string. Although this technique has been used for a long time and has become more common and easier to manage, it remains a sensitive operation that requires careful planning and preparation, particularly with regard to running and cementing operations. For this reason, continuous research is being conducted to improve running and cementing procedures, as well as to optimize liner hanger design, in order to minimize technical complications and carry out the operation at the lowest possible cost while maintaining safety and quality standards.

Within this framework, this work follows the implementation of a drilling program for an oil well, namely well **BKNS-3**, with a focus on running and cementing a 7-inch liner. It also discusses the liner hanger system as a technical innovation within liner technology. The study concludes with the monitoring and evaluation of the cementing operation, which represents a decisive step in determining the success of the operation and ensuring proper zonal isolation and achievement of the well objectives.

Chapter I

Geology constitutes a fundamental element in understanding the behavior of the well during drilling operations. It allows the identification of the sequence of formations encountered, their lithological characteristics, as well as the pressure and temperature conditions that directly influence the selection of drilling parameters and technical programs.

II: Geological Context of the Berkine Basin

The basin is bounded by:

- Tunisia and Libya to the east
- Hassi Messaoud to the west
- Illizi Basin to the south
- Northern Saharan structures to the north **[1]**



III: Basin History

Exploration activities in the Berkine Basin began in the late 1950s, with the discovery of gas and condensate in 1958 in the Hamra quartzites (Ordovician) and in Triassic reservoirs. Approximately 150 wells were drilled, resulting in the discovery of a significant number of oil and gas fields. [1]

IV: Berkine Basin Petroleum System

IV.1: Source Rock

In the Berkine Basin, there are two main source rock intervals: Silurian shales and Upper Devonian :

- a) **Silurian** : The Silurian shale is present over almost the entire basin, except on the western and northern margins where it was eroded during the Hercynian phase.
- b) **Upper Devonian** : The source rocks are subdivided into two zones:
 - The lower zone (Frasnian), with a thickness ranging from 150 to 300 m.
 - The upper zone (Frasnian–Famennian), with a thickness varying from 50 to 500 m.
- c) **Upper Ordovician** : Source rocks are located within clayey and micro-conglomeratic formations.
- d) **Carboniferous** : Source rocks are present in clay-rich intervals. [2]

IV.2: Reservoir Rock

The main reservoirs in the basin are those of the Triassic, Carboniferous, Lower Devonian, Ordovician, and Cambrian :

- TAGS (Upper Triassic Clayey Sandstone)
- Carbonate Triassic
- Intermediate Triassic
- TAGI (Lower Triassic Clayey Sandstone)
- El Hamra Quartzite [2]

IV.3: Seal Rock

The sealing of Triassic reservoirs is ensured by clays of the carbonate–intermediate Triassic and by evaporites of the Triassic–Liassic. Fault offsets provide lateral sealing in most traps.

In the Carboniferous and Devonian, the seals are represented by intraformational shales

On basin margins, poor-quality basal TAGI layers locally act as vertical seals associated with the carbonate Triassic.

The sealing of Ordovician and Cambrian reservoirs is ensured respectively by Silurian shales and intra-Ordovician clays. In the Cambrian, the seal is provided by the El Gassi shales.

Laterally, vertical fault throws associated with structural axes ensure lateral closure. [2]

V: Well Overview

BKN Sud-3 (BKNS-3) is located in the block 404d, it is planned as vertical development well in order to extract oil from the TAGI reservoir, evaluate the extension of the Siegenian reservoir (gas level), ensure sustainable development of the field and maximize oil and gas production. [3]

V.1: General Location

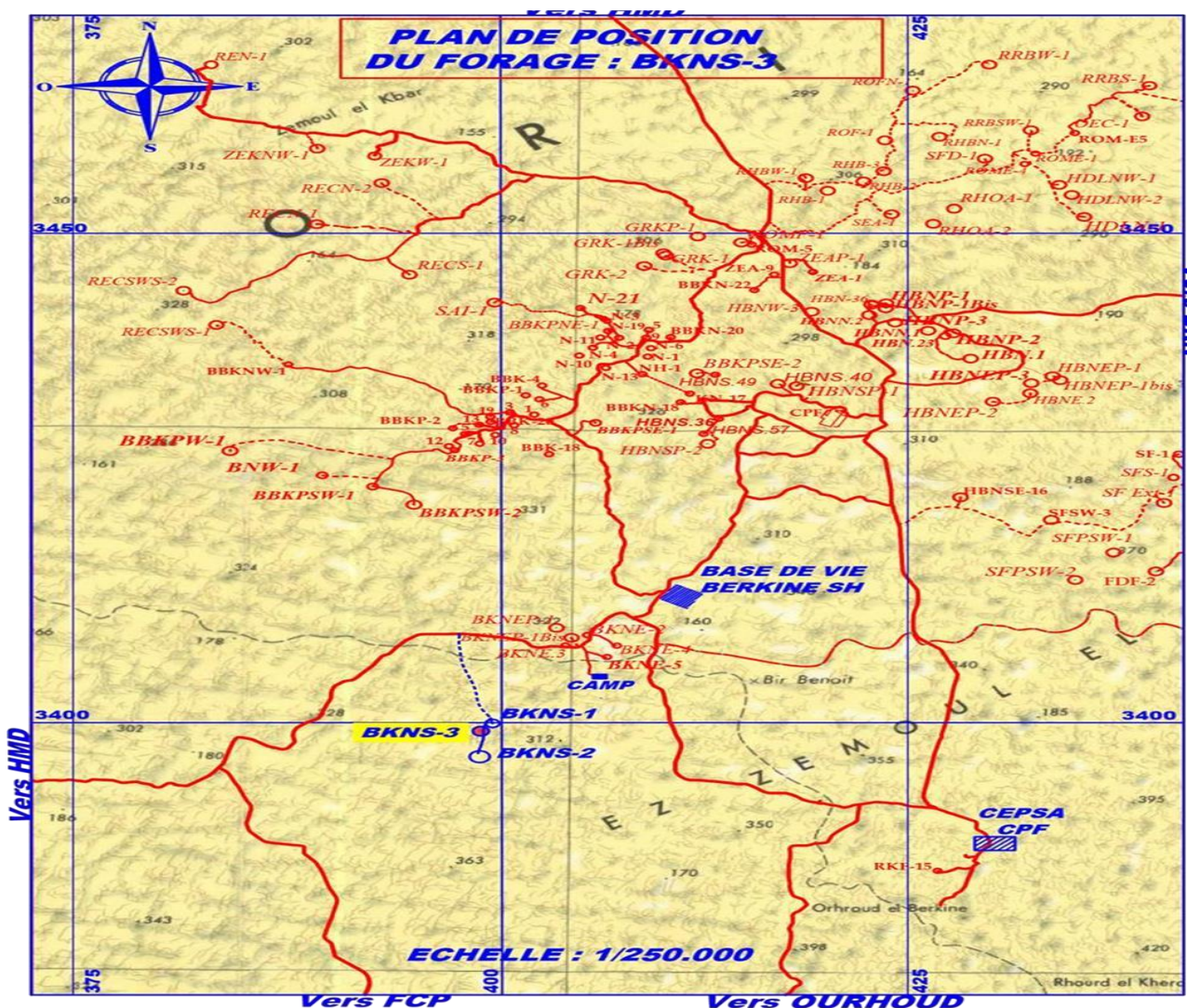
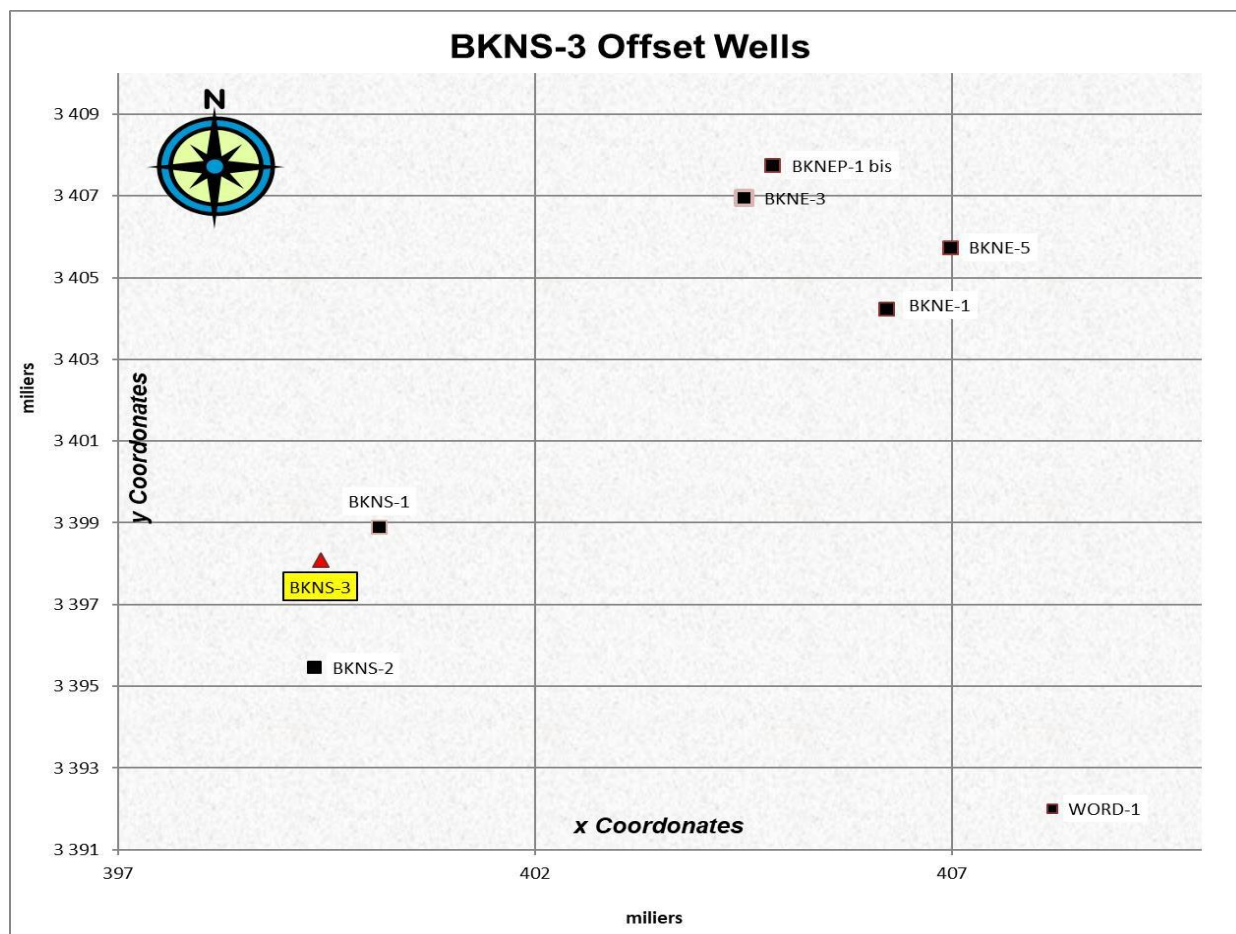


Figure 2: Geographical location of well BKNS-3 [3]

V.2: Offset Wells**Figure 3: BKNS-3 Offset Wells Location Map [3]****Table 1 : Distance between wells adjacent to the well BKNS-3 [3]**

WELL	X coor	Ycoor	Distance (Km)
BKNS-3	399423,82	3398093,72	-
BKNS-1	400126,99	3398898,96	1,07
BKNS-2	399350,00	3395470,00	2,62
WORD-1	408203,43	3392013,39	10,68
BKNE-1	406210,00	3404239,00	9,16
BKNE-3	404502,08	3406946,10	10,21
BKNE-5	406976,99	3405741,27	10,75
BKNEP-1 bis	404850,02	3407749,90	11,08

V.3: Well Data**Table 2 : Well information BKNS-3 [3]**

Well Name	Berkine Sud-3 (BKNS-3)
Bloc	404d
Basin	Berkine sud
Périmètre	Bir Berkine Sud
Coordinates UTM (F32)	X= 399423.818 m - Y= 3398093.720 m
Coordinates Geographies	M: 7°56'58.76709" E - L: 30°42'49.72692" N
Gird coordinates	Zs= 212.144m Zt= 220.97m
Profile	Vertical
Well type	Devlopment
Primary Objective	Trias Argileux gréseux inferieur
Secondary Objective	Siegenien C
Well Total Depth (RKB)	4508m
Formation at TD	Siegenien C Inf
Target Days	66 days to TD 101 total days
Drilling rig	ADES-802

V.4: Geological Objectives of BKNS-3 Well

The BKNS-3 well is a vertical development well with the following main objectives:

- Exploitation of the **TAGI (Triassic Argillaceous Sandstone – Lower)** reservoir, which represents the primary oil target.
- Evaluation of the extension of the **Siegenian C** reservoir, known to contain gas and condensate.
- Contribution to the sustainable development and optimization of field production.

The total depth of the well is **4508 m**, with a secondary objective located in the Devonian formations. [3]

V.5: Lithostratigraphic Description of BKNS-3 Well

The lithostratigraphic column of BKNS-3 shows a succession of formations ranging from the Tertiary to the Lower Devonian. Each formation presents specific characteristics that influence drilling operations. [3]

V.5.1: Surface Formations (Tertiary and Senonian)

The surface formations mainly consist of:

- Mio-Pliocene
- Senonian carbonates
- Senonian anhydrite
- Senonian salt formations

These formations are generally unconsolidated or composed of evaporitic rocks (anhydrite and salt). They often present wellbore stability issues and require early casing installation. [3]

V.5.2: Cretaceous Formations

This sequence includes:

- Turonian
- Cenomanian
- Albian
- Aptian
- Barremian

These formations consist of alternating limestones, clays, and marls. Their mechanical properties vary and may affect the rate of penetration (ROP) and wellbore stability. [3]

V.5.3: Jurassic Formations

The Jurassic formations encountered include:

- Neocomian
- Malm
- Argillaceous Dogger
- Lagoonal Dogger

These formations are lithologically heterogeneous, alternating between clay and carbonate layers. They may cause drilling problems such as differential sticking and circulation losses. [3]

V.5.4: Lias Formations

The Lias includes several important levels:

- Anhydritic Lias
- Saliferous Lias
- Horizons Lias S1, S2, and S3

The presence of salt layers is critical during drilling due to their plastic behavior, which can cause wellbore shrinkage (creep) and difficulties in maintaining hole diameter. [3]

V.5.5: Triassic Formations (Main Reservoir)

The Triassic is one of the most important petroleum-bearing intervals and includes:

- Triassic carbonates
- **TAGI (Triassic Argillaceous Sandstone – Lower)** at 3379 m

The TAGI reservoir represents the main oil-bearing formation of the BKNS-3 well, characterized by good porosity and permeability. [3]

V.5.6: Devonian Formations

The Devonian sequence includes:

- Tournaisian
- Strunian
- Fammenian
- Frasnian
- Givetian / Eifelian
- Emsian
- **Siegenian C (upper and lower)**

The **Siegenian C** reservoir (4361–4457 m) represents the secondary target and mainly contains gas with condensate. [3]

V.6: Architecture

The architecture of the well can be summarized in the following figure :

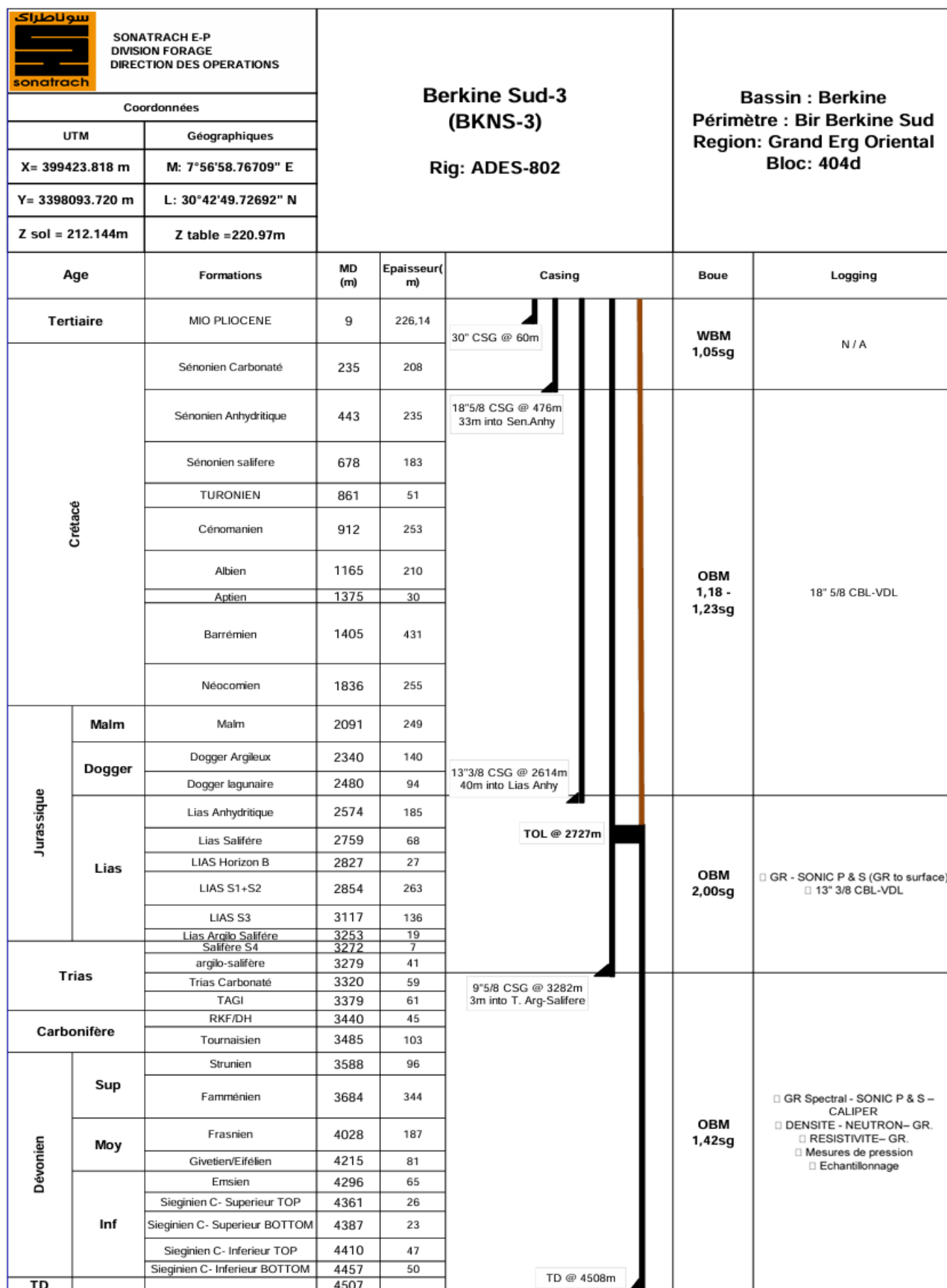


Figure 4 : Well Architecture of BKNS-3 Well [3]

V.7: Offset Pore Pressure and Temperature Gradient

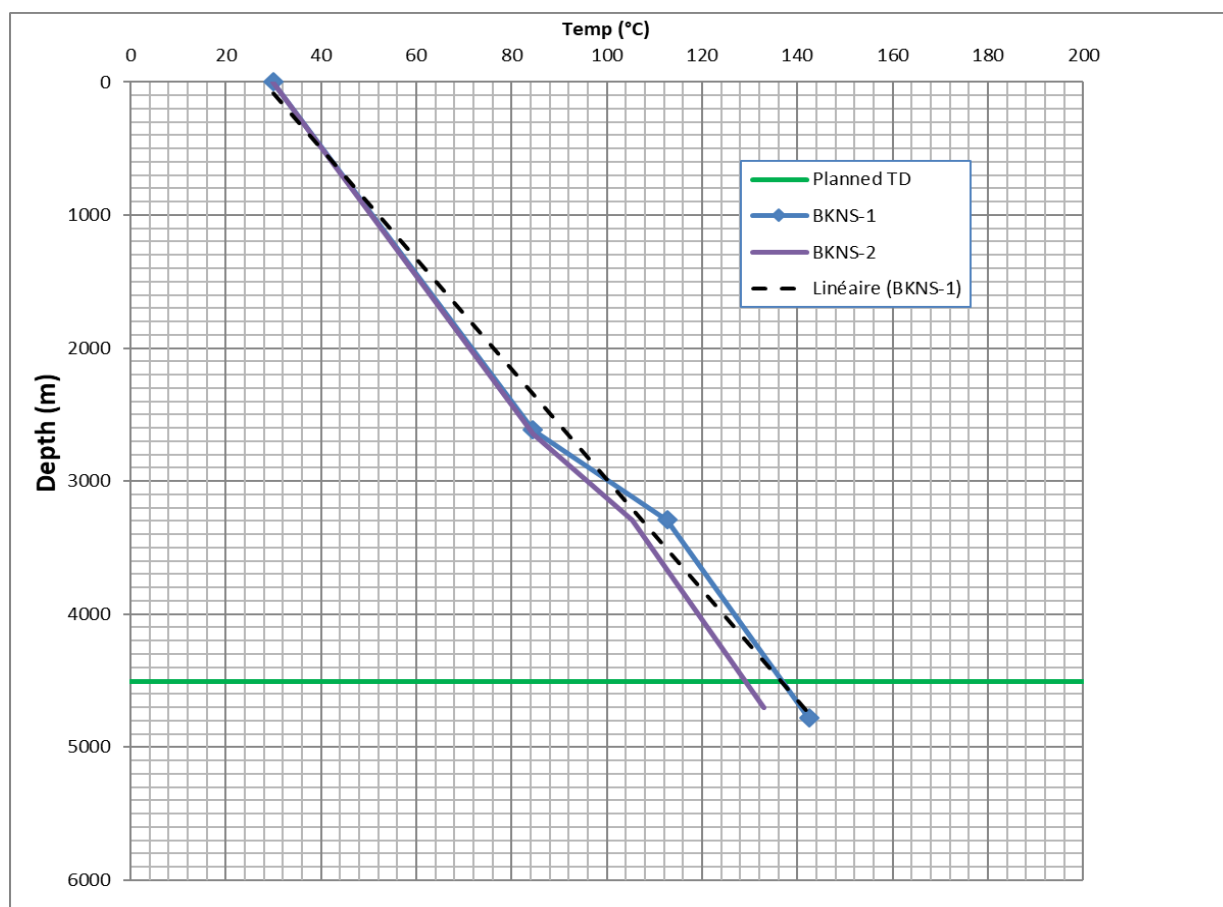
According to the RDI, Static pressures are mentioned on the below table:

Table 3 : Reservoir Pressure and Temperature Data [3]

Réservoir	TAGI	Siégénien C
Nature du fluide	Huile	Gaz à condensât
Pression réservoir (Bar)	356.52	568,52
Température de réservoir (°C)	103	135,7

Table 4 : Reservoir Pressure, Depth and Equivalent Mud Weight (EMW) [3]

Reservoir	Pressure & Depth	EMW
TAGI	5171 Psi [3379m]	EMW=1,08sg
Siegénien-C	8245 Psi; [4361m]	EMW=1,33sg

**Figure 5 : Pore Pressure and Temperature Gradient Profile for BKNS-3 Well [3]**

The Max temperature expected in **BKNS-3** is 136 °C.

These values indicate a **High Pressure / High Temperature (HP/HT)** environment, requiring careful selection of drilling fluids and equipment.

VI. Conclusion

The geological study of the BKNS-3 well reveals a complex succession of sedimentary formations spanning multiple geological eras. This lithological diversity directly impacts drilling operations in terms of wellbore stability, pressure management, and equipment selection.

The presence of key reservoirs such as TAGI (oil) and Siegenian C (gas) highlights the economic importance of the well. Therefore, a thorough understanding of the geological context is essential to ensure successful drilling operations and optimize hydrocarbon production.

Chapter II

I: Casing

I.1: Introduction

Since oil well drilling is carried out in several successive phases, it is essential to ensure the stability and safety of the well during the entire drilling operation. To achieve this objective, the walls of the drilled hole must be protected and reinforced by installing steel pipes of different diameters and lengths, known as **casing**. These casing strings are placed at different depths in the well and cemented in place to isolate geological formations, prevent the collapse of the borehole walls, and control the pressure of formation fluids. This process plays a crucial role in maintaining well integrity and ensuring safe and efficient drilling operations. [4]

I.2: Definition of Casing

Once drilled, the well is covered with pipes, called casing, to prevent the walls from collapsing and to allow drilling to continue without problems. The selection of casing, both in terms of diameter and strength, depends on several factors, the main ones being (Nguyen, 1993):

- the planned depth.
- the expected pressures.
- the type of anticipated effluent: oil or gas.
- the risk of corrosion. [4]

I.3: Role of Casing

The installation of casing aims to securely support the drilled hole in order to:

- isolate it from the formations and fluids encountered.
- enable it to withstand the pressures that may be met during drilling of the next phase.
- provide mechanical support to the wellhead components.

These main functions are only effective when the casing is properly cemented. [4]

I.4: Types of Casing

An oil well is divided into several drilling phases, with a specific type of support (casing) corresponding to each phase. [4]

I.4.1: Conductor Pipe (Guide Pipe)

This is a very light string of pipes, anchored into the ground to a depth of several meters.

Its purpose is to channel the drilling mud at the start of drilling and to support unconsolidated surface formations. (Slimani., et al, 2004). [4]

I.4.2: Surface Casing

This is the first actual string of casing pipes to be run and cemented. Its purpose is to support the surface formations, which are often prone to collapse, isolate surface freshwater to prevent contamination by drilling mud, and serve as an anchor for blowout preventers and the wellhead.

To achieve these functions, the surface casing is cemented to the surface to provide good mechanical stability for the overall well structure. The main goal for this casing is to ensure strength and complete tightness at all levels, (Nguyen, 1993). [4]

I.4.3: Intermediate Casing

Of variable depth depending on the difficulties encountered, it allows to:

- avoid continuing drilling in an open hole presenting risks (collapses).
- isolate formations containing fluids under high or low pressures,
- prevent the rupture of the formations around the surface casing shoe in case of a blowout.

The depth and the number of intermediate casings depend, among other factors, on the pressures encountered in the next phase. (Slimani et al., 2004). [4]

I.4.4: Production Casing

This casing is essential to ensure complete protection of the producing formation and the installation of production equipment. If the well is productive, a flow tubing will be run inside this casing.

It is thanks to this production casing that the tubings and well equipment are protected; this allows the tubing to be removed from the well at any time for replacement or inspection of any other production equipment. (Nguyen, 1993). [4]

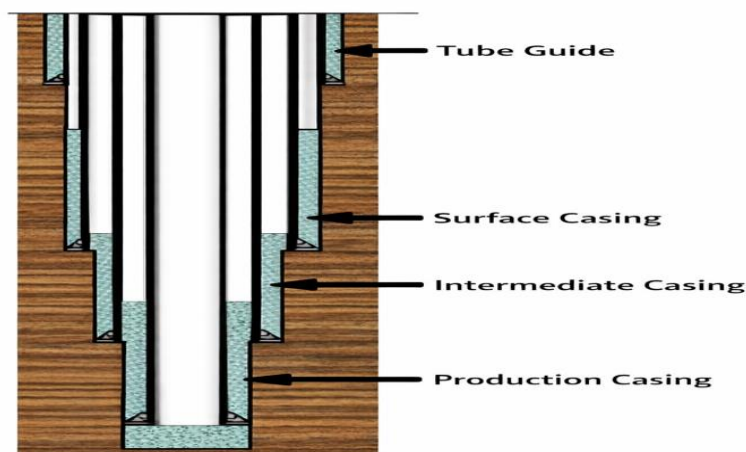


Figure 6 : Different types of casing columns [4]

I.4.5: Liner (Suspended Casing)

All the previous casing strings cover the wellbore from the bottom to the surface and are suspended inside the previous casing string. In contrast, these lost casing strings are attached to the lower part of the previous casing string using a mechanical system called a **liner hanger** and are cemented with an overlap. This is necessary to ensure proper sealing between the two casing strings.

Liners offer advantages such as saving pipe material, reducing weight, and providing flexibility. However, there are disadvantages, including the high complexity of suspension and cementing operations. Additionally, the previous casing string must be properly sized to withstand the same burst pressure as the liner (Nguyen, 1993). [4]

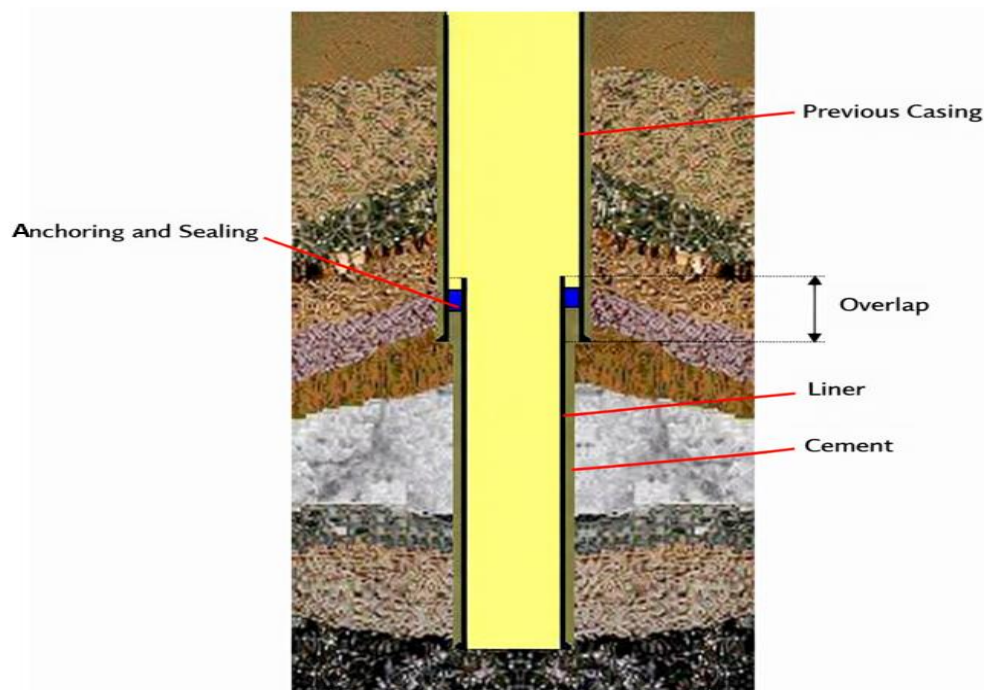


Figure 7: Loop column (liner) [4]

I.5: Casing Characteristics

I.5.1: Manufacturing

The pipes are manufactured in different steel grades and wall thicknesses depending on the stresses they will be subjected to during running and throughout the life of the well. The steel grades used are as follows: H40, J55, K55, C75, L80, N80, C90, T95, P110, Q125 .

The letter indicates the chemical composition of the steel, and the numbers represent the minimum yield strength in thousands of psi. Some grades are not standardized by the API in certain dimensions .

Pipes can be manufactured by:

- Seamless drawing.
- Longitudinal electric welding without additional metal.
- Overlap welding. [5]

a) Color Identification

The color and number of bands are as follows:

- **H40:** no marking or black
- **N80:** one red band
- **C95:** one brown band
- **J55:** one green band
- **K55:** two green bands
- **C75:** one blue band

The bands are marked at a distance from the female coupling not exceeding 0.60 m. [5]

b) Description of the Most Commonly Used Casing Grades

Table 5: Casing Grades [5]

Grede	Description
H40	Lower grade, maximum yield strength 80,000 psi; suitable for H ₂ S wells.
J55	Good for H ₂ S wells.
K55	Same collapse and burst resistance as J55 but with higher tensile strength; resistant to H ₂ S at any temperature.
L80	Generally the most used in the industry; suitable for H ₂ S wells
N80	Alloy steel; not suitable for H ₂ S at all temperatures
C90	Used in high-temperature wells containing H ₂ S
T95	Alloy steel designed to improve upon C95, which does not resist H ₂ S at low temperatures.
P110	Designed to address problems encountered in deep wells.
Q125	Often used for deep high-pressure wells, especially for high collapse pressures; can be used in H ₂ S environments at temperatures around 107 °C or higher.

c) Casing Lengths (Ranges)

The API has specified three casing ranges, which are:

Table 6: Casing Lengths [5]

Range	Length (ft)	Length (m)
1	16-25	4,8 - 7,5
2	25-34	7,5 - 10,2
3	Over 34	Over 10.2

I.5.2: Diameter

The nominal diameter of a pipe corresponds to its outer diameter expressed in inches. The allowable tolerance is $\pm 0.75\%$.

The clearance between the pipe body and the hole generally ranges from 1½" for smaller sizes to 4½" for larger sizes. [5]

I.5.3: Wall Thickness

For the same steel grade, the wall thickness may vary depending on the forces to which the pipe will be subjected. The maximum tolerance allowed by the API for pipe wall thickness is 12.5%.

The largest tool dimension that can be run inside a pipe is equal to the mandrel diameter, which is smaller than the pipe's inner diameter. [5]

I.5.4: Weight

The nominal weight, expressed in lb/ft, is provided for identification purposes. Each wall thickness for a given pipe size corresponds to a nominal weight, which cannot be used for calculations as it does not account for the weight of couplings. [5]

I.5.5: Thread Types

In general, casing and couplings are characterized by their thread type. The API specifies four properties of a thread:

- **Thread height** : the vertical distance from the base to the crest of the thread relative to the thread axis
- **Pitch** : the distance between two successive thread crests
- **Taper** : the change in thread diameter expressed in in/ft
- **Form** : threads can be round or square

There are two main types of threads: API and non-API

I.5.5.1: API Threads

The API has standardized three types of threads:

a. Round Thread: Characterized by 8 threads per inch with a V-groove. Its taper is $\frac{3}{4}$ in/ft for all casing diameters.

b. Buttress Thread: This is a square thread with 5 threads per inch. Its taper is $\frac{3}{4}$ in/ft for casings with diameters over $7\frac{5}{8}$ inches, and 1 in/ft for casings with diameters over 16 inches.

c. Extreme-line Thread: This is a trapezoidal thread profile that ensures good metal-to-metal sealing. It is the most suitable for high-pressure and high-temperature wells. It is characterized by :

- 6 threads per inch and a taper of $1\frac{1}{2}$ in/ft for diameters from 5 to $7\frac{5}{8}$ inches
- 5 threads per inch and a taper of $1\frac{1}{4}$ in/ft for diameters from $8\frac{5}{8}$ to $10\frac{3}{4}$ inches

The first two are used for coupling with a sleeve, while the third is used for integral joint connections.

The round thread can be short or long (tensile resistant; only used in steel grades above H40 and for pipe sizes equal to or smaller than $9\frac{5}{8}$ inches). Round threads generally provide tensile strength lower than the pipe's minimum yield strength (except for some thin pipes in lower grades and smaller sizes).

Buttress and extreme-line threads provide joint strength equal to or greater than the pipe's minimum yield strength.

Advantages of integral joints compared to sleeve joints include:

- Better sealing,
- Smaller outer diameter (easier to run in the well),
- Better tensile strength than round-thread joints. [5]

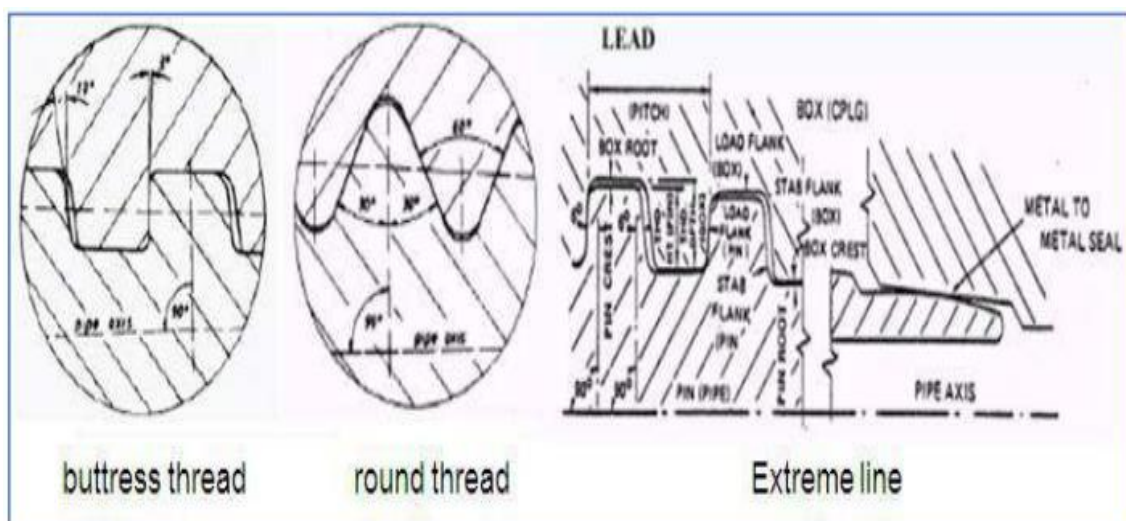


Figure 8 :Different types of API threads. [5]

I.5.5.2: Non-API Threads:

These threads can be made on API-standard tubing. The most important are: VAM and NEW VAM.

The seal is achieved by metal-to-metal contact (each tube end resting on a tapered shoulder machined inside the sleeve), and the connection is made with a buttress-type thread (6 threads per inch for 4½" tubing instead of the usual 5).

This joint can have:

- standard sleeve.
- special-dimension sleeve with a smaller outside diameter.

The VAM joint has tensile strength comparable to that of the API buttress-threaded joint, but it has the advantage of providing a better seal, even under high pressures. [5]

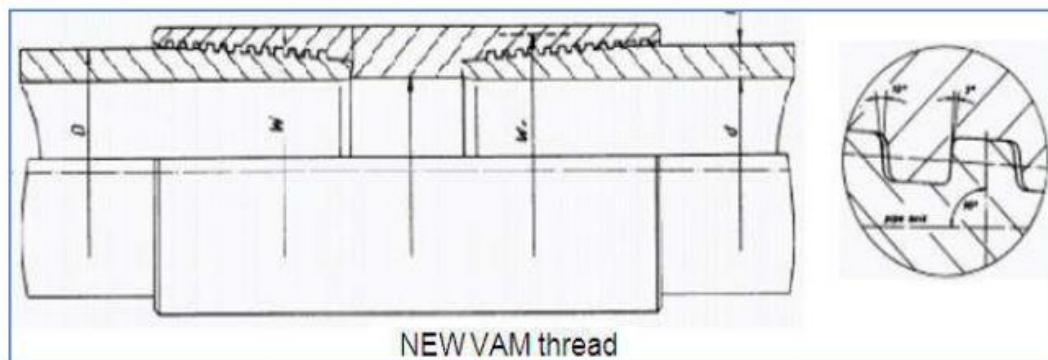


Figure 9: NEW VAM Thread [5]

I.6: Casing Stresses

1. Crushing Stresses: These are due to the hydrostatic pressure exerted by the fluid present in the annular space between the casing and the borehole; this pressure is counterbalanced by the pressure inside the wellbore .

During drilling, casing, and grouting operations, the wellbore may empty either partially or completely, and the internal pressure decreases or even disappears.

Crushing stresses due to the hydrostatic pressure of the annular space increase with depth.

API has defined a safety factor for crushing equal to 1.125, taking into account tensile stress, assuming the casing is empty and the annular space is full of drilling mud (casing completely empty) or the casing is full of drilling mud and the annular space is full of cement (end of grouting and before cement setting). Use the higher value.

2. Burst stresses: These originate from the internal pressure due to the fluids that may be produced by the well (water, gas, or oil) and their pressure. This internal pressure is

Counterbalanced by the hydrostatic pressure of the fluid present in the annular space between the casing and the borehole.

Hydrostatic pressure increases with depth; therefore, burst stresses are higher at the top of the well casing.

The API has defined a burst safety factor of 1.10, assuming the annular space is filled with water and the inside of the casing is filled with gas (in its early stages).

3. Tensile stresses: Each tube lowered into the well is subjected to a tensile stress due to the weight of all the tubes below it.

This stress can be reduced by floating the well casing (partial filling during descent). For safety reasons, the API has defined a safety factor for traction of 1.75, assuming the casing is in the mud. This factor must not fall below 1.30 during the well's lifetime. [6]

I.7: Casing Centering

Centering a casing is a crucial factor for achieving good cementation. For this purpose, centering devices are used, placed:

- at the areas to be cemented.
- at the doglegs.
- on either side of the shafts.
- in areas at risk of blockage or losses.

There are three types of centering devices: flexible centering devices used in vertical and moderately deviated wells, rigid centering devices used in horizontal wells, and rotary centering devices used in rotational cementation applications such as liner columns.

It is preferable to use spiral-shaped centering devices, which promote turbulence during slag injection. [6]



Figure 10 : The different types of centering devices [6]

II: liner**II.1: Introduction**

The casing and cementing operation represents a major portion of the total drilling cost. Therefore, researchers and drilling specialists are trying to minimize drilling costs by focusing their research on this operation. This has led to the invention of a reduced casing, known as a lost casing or liner, whose main purpose is to optimize casing costs. [7]

II.2: Definition

A liner is a lost casing that does not extend to the wellhead, but rather to a limited height inside the previous casing. It is cemented with an overlap in the last casing, extending from the placement depth to a certain distance inside the previous casing. This overlap is necessary to properly seal the lost casing within the previous casing and ensure a good seal between the two. This seal is crucial to prevent effluent from passing behind the lost casing during production.

II.3: Advantages and Disadvantages of Liners**II.3.1: Advantages of Liners**

The main advantages of a liner are:

- Reduced cost due to fewer casings
- Reduced lifting capacity during liner descent
- The possibility of using a mixed drill string (5" top and 3.5" bottom, for example) after liner descent, which reduces lifting capacity
- Reduced wellhead capacity
- Reduced drill string preparation time before descent
- The liner is more flexible than a full drill string
- Circulation losses are avoided because annular head losses are reduced at the drill string
- Possibility of completion within the existing casing if the completion equipment cannot pass through the liner. [7]

II.3.2: Disadvantages of the liner

The main disadvantages are:

- Suspending the liner within the casing is more difficult than suspending a full column in the wellhead
- Few columns are exposed to the effluent, and if they weaken, it is mandatory to complete the liner with a full column, which necessitates reworking the well

- The descent time is very long in the case of a liner that includes hydraulically activated equipment. [7]

II.4: Liner Use

The liner can be used to cover part of the overburden like a normal casing to allow drilling to continue (drilling liner), or to cover the reservoir and bring it into production (production liner). It can also be used to cover a damaged section of casing (scab liner). This liner can be cemented or insulated at the top and bottom with packers .

It is even possible to use a first liner and then connect a second one to it via a tie-back. [7]

II.4.1: Drilling Liner

Also called an intermediate liner, this liner is a section of casing anchored to the previous, already cemented casing. It is used to isolate problem areas below the technical stack, such as:

- Loss zones
- Abnormally high pressure zones [6]

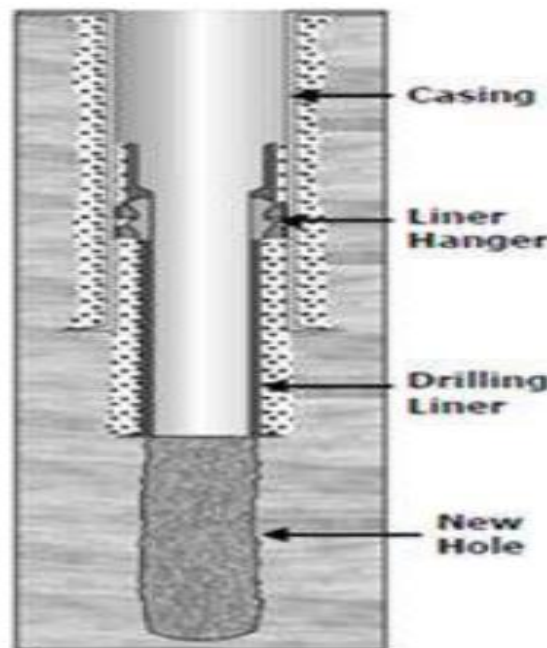


Figure 11:Drilling Liner [6]

II.4.2: Production Liner

This is a casing section used in the final phase (production phase). It is suspended either from the drilling liner or the technical stack. It will be cemented and subsequently perforated or left open-hole (in the case of a slotted liner). [6]

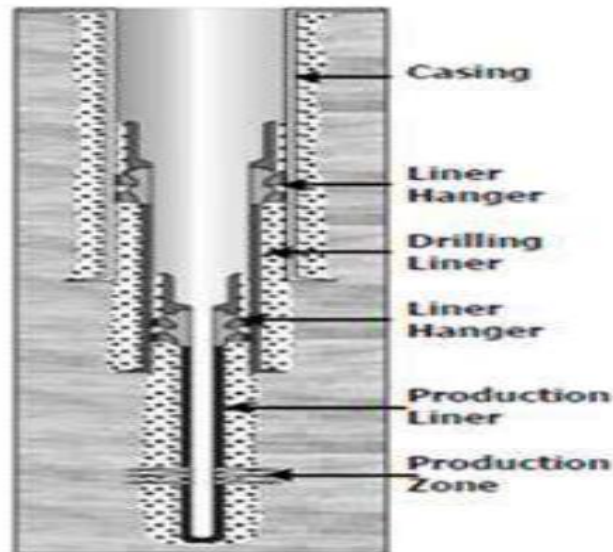


Figure 12: Production Liner [6]

II.4.3: Stub Liners

A stub liner is a casing column of the same diameter as the liner, connected to the latter by a sealing gasket to create a continuous column from the bottom to the surface. This is used for the following reasons:

- The casing column above the liner is weakening or damaged (by corrosion, etc.)
- Poor sealing at the top of the liner
- The need for high strength, for example, due to abnormally high pressures. [6]

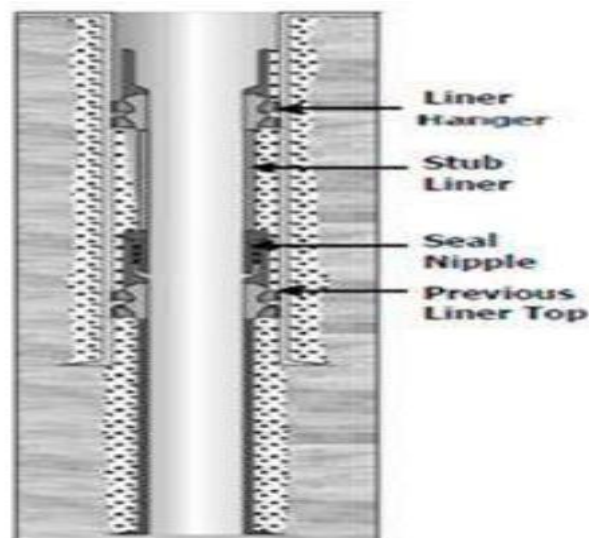


Figure 13: Stub Liners [6]

II.4.4: Scab Liners

This is used to repair a deteriorated section of casing. This liner can be cemented or sealed at the top and bottom with packers. It is used under the same conditions as the stub liner. [6]

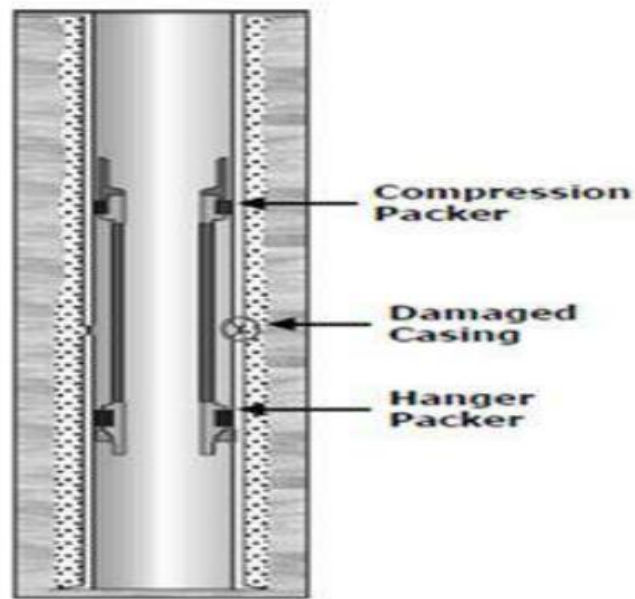


Figure 14 : Scab Liners [6]

II.4.5: Tie-back liner

A tie-back liner is a section of tubing that extends from the top of an existing liner to the surface. It may or may not be cemented . [7]

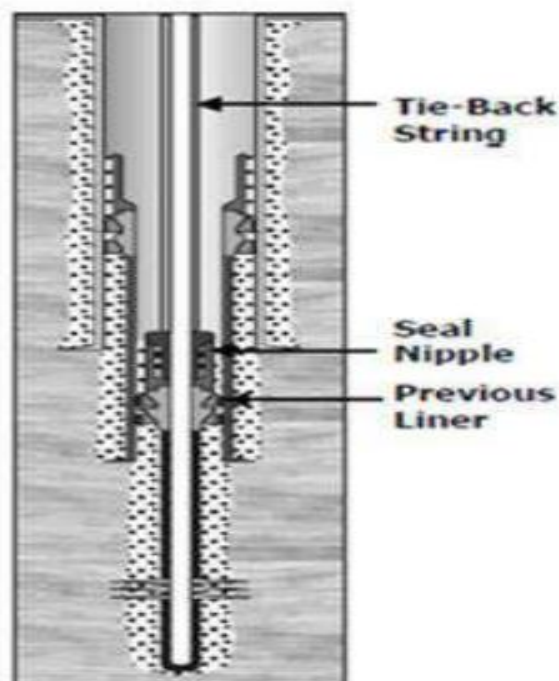


Figure 15 : Tie-back liner [6]

II.5: Components of a conventional liner

There are several types of liner compositions, but generally, a liner must include two types of components: handling and installation components, and cementing accessories. [7]

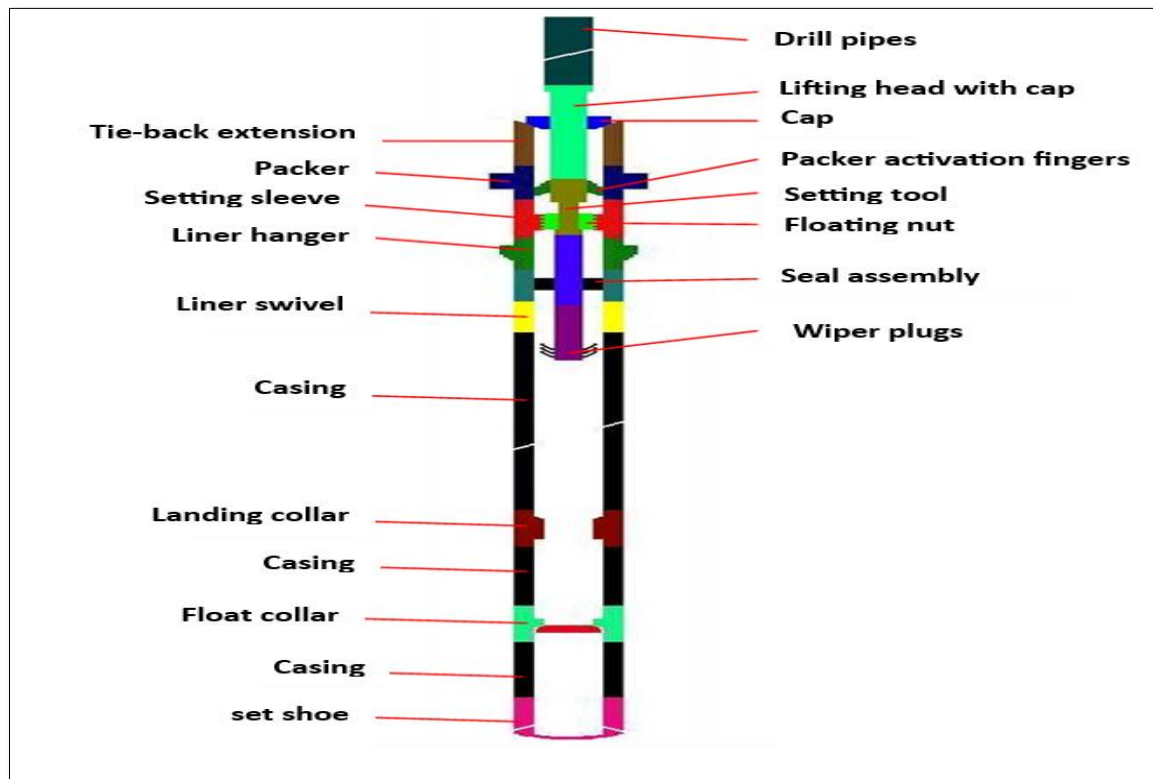


Figure 16: Liner Composition [7]

II.5.1: Installation Components

II.5.1.1: Setting String

The drilling string used for lowering the liner is generally composed of rods. In cases where the well is significantly deviated, heavy rods can be used. The use of a sliding sleeve is prohibited. The rods must be calibrated before the operation. [7]

II.5.1.2: Setting Sleeve (or Setting Collar)

Screwed to the liner head, this device connects the liner to the drill strings via the installation tool for lowering and anchoring. Therefore, it must be able to support the entire weight of the liner before anchoring. It also serves as a support point to allow the packer to inflate by adding weight with the rods. [7]

Two types are distinguished:

- **Mechanical setting sleeve**

The connection between this sleeve and the setting tool is ensured by a left-hand ACME female square thread, with 4 to 6 threads per inch, or by a system with a J-slot.

- **Hydraulic setting sleeve**

The connection includes a collar in the setting tool, which fits into a groove in the setting sleeve. This collar is released from the groove by increasing pressure, thus freeing the setting tool. [7]

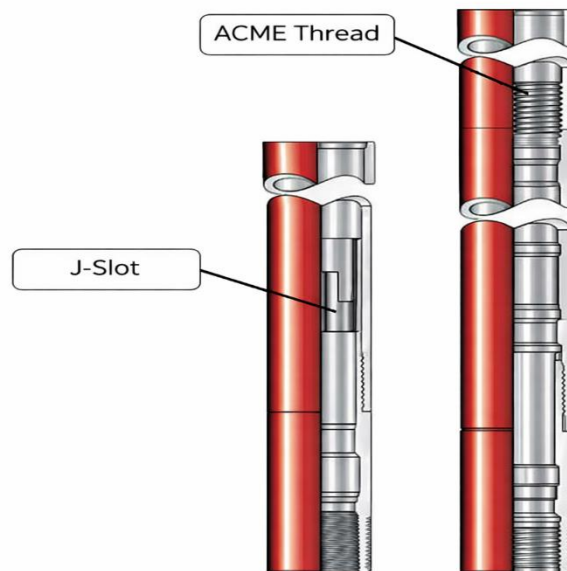


Figure 17: setting sleeve [8]

II.5.1.3: Setting Tool

This tool connects the setting sleeve to the drill string for lowering the lost casing. It also performs the following functions:

- Supporting the weight of the liner during lowering
- Ensuring a watertight seal between the liner and the drill string:

This function is necessary to force mud or cement to pass through the liner and exit via the shoe into the annular space between the liner and the borehole, preventing it from passing between the liner and the setting tool. It is also necessary to allow the activation of the various tools in the case of a hydraulic liner.

- Incorporating the liner grouting plug(s) at its end.

The setting tool is unscrewed before the liner is cemented, removed to ensure it is unscrewed, and then placed without being screwed onto the approximately 10-ton setting sleeve to ensure a watertight seal during cementing. It is reinstalled after the liner is cemented. [7]

There are two types:

A/ Mechanical Setting Tool

The mechanical setting tool has a floating nut with a male ACME thread, generally left-handed, with 4 to 6 threads per inch, requiring 8 to 15 right-hand turns to unscrew. This nut is screwed onto a thread of the same type on the setting sleeve.

A ball stop facilitates unscrewing by setting the drill string on the setting sleeve, thus keeping the floating nut free. Water passages used to balance pressures and allow filling above the seal are machined either on the mandrel or along the entire thread of the nut.

In its upper part, the setting tool contains a cover that prevents cuttings from falling

between the setting tool and the liner. [9]

The disadvantage of this system is that it may unscrew during the running of the liner.

B/ Hydraulic Setting Tool

This system consists of a collar made of fingers that engage in a groove of the setting sleeve. To release the setting tool, pressure is increased, which pushes a sleeve upward, thereby moving the fingers forming the collar. These fingers move under an external sleeve attached to the body and retract, thus releasing the setting tool from the setting sleeve.

The setting tool also has another mechanical backup activation system in case the first pressure-activated mode fails. This is done by rotating the liner one-quarter ($\frac{1}{4}$) turn to the left, which moves the finger-carrier sleeve upward.

This setting tool can support heavy liners and can also rotate them, thanks to the fingers that engage in slots machined at the top of the setting sleeve. [9]

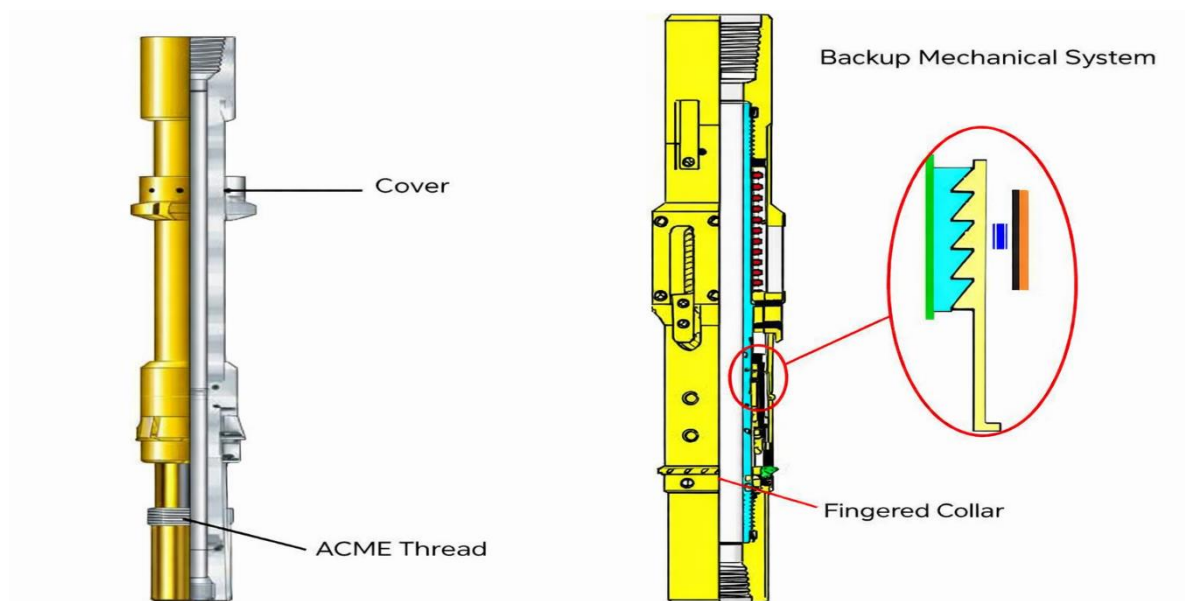


Figure 18:Mechanical and Hydraulic Setting Tool [9]

II.5.1.4: Sealing System:

The setting tool is always equipped with a sealing system in its lower part, which can be categorized as follows:

A/ Swab Cups (Setting Cups)

It is a tube that supports cups directed downward, placed at the end of the setting tool, allowing fluid to pass from top to bottom while preventing flow in the opposite direction.

The use of this system is limited by depth because the cups have pressure and temperature

limitations. [9]

B/ Cementing Pack-off

It is a pack-off bushing placed below the setting sleeve. This system maintains sealing between the drill pipes and the liner even after the liner is released. It can:

- Either be attached to the setting tool.
- Or be attached to the liner, sealing around the stinger of the setting tool. In this case, it will be drilled out during the liner inspection. [9]

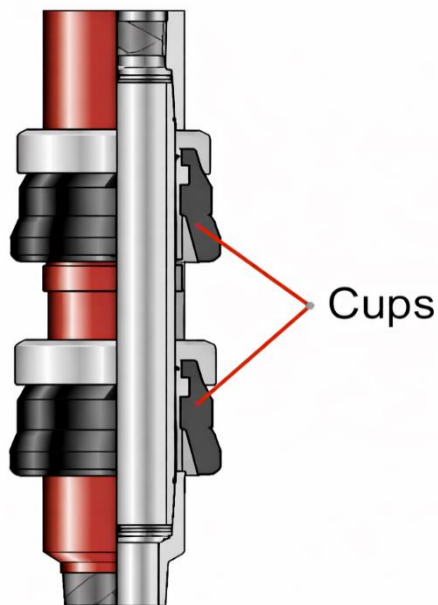


Figure 20 : Swab cups [8]

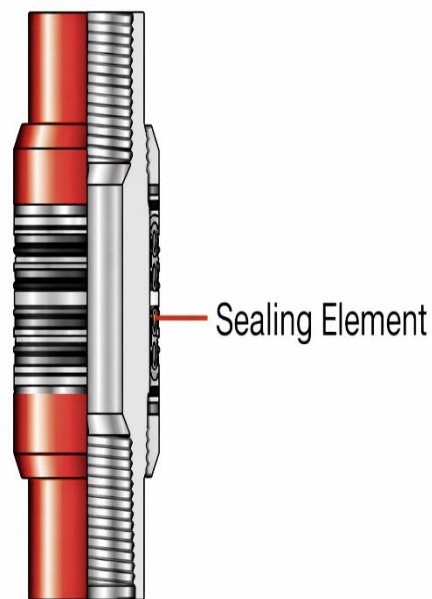


Figure 19 : Cementing pack-off [8]

II.5.2: Suspension Device (Liner Hanger):

This device, placed at the top of the liner, ensures its suspension inside the previous casing and is designed to support the weight of the liner. It includes slips that are kept in a retracted position during running. The anchoring of the hanger consists of sliding these slips over a tapered surface, which pushes them outward and presses them against the walls of the previous casing. This anchoring may be mechanical or hydraulic depending on the manufacturer. [9]

Different Types of Liner Hangers:

The choice of the anchoring system depends on the type of liner and the well conditions. If a liner weighing more than 8 tons is run in a vertical or moderately deviated well with insufficient friction, it is preferable to use a mechanical system. In all other cases, the hydraulic system is preferred. [9]

1. Mechanical Hanger:

This hanger is anchored by rotation and translation. It includes a slip cage in which a **J-slot** groove is machined and is equipped with friction springs that press against the casing. The body contains a key (lug) that moves within this groove. [9]

A/ Operating Principle:

To anchor this hanger, it is sufficient to pull upward to slide the hanger body and therefore the key upward while the cage remains stationary due to the friction springs pressing against the casing. Once the key is released, it is necessary to rotate a quarter turn (approximately three turns at the surface, according to the rule of thumb: one turn per 1000 meters) to the right (or to the left depending on the type) and quickly apply a weight of between five and ten tons. The key follows the J-slot path, and the hanger body moves down enough to allow the tapered surfaces of the body to slide under the liner slips and press them against the casing. [8]

B/ Conditions of Use:

It is used in the following cases:

- when the liner weighs more than **10 tons**;
- in **vertical or slightly deviated wells (15°–20°)** where friction and torque are not significant. [9]

2. Hydraulic Hanger:

This type of suspension is anchored by increasing the pressure inside the liner and does not require any movement of the drill string. It consists of a slip sleeve that presses against the casing.

A/ Operating Principle:

Once the ball is dropped, the pressure is increased until the shear pins holding the slip sleeve are sheared. The sleeve then moves upward, allowing the anchoring slips to engage with the tapered surfaces and press against the casing.

The shearing of the pins is observed at the surface by a pressure surge. At that moment, it is sufficient to quickly apply weight to help the slips slide between the casing and the cone.

B/ Conditions of Use:

It is used in the following cases:

- in **deviated wells** with significant friction;

- in **offshore drilling**;
- to **anchor a liner inside another liner**. [9]

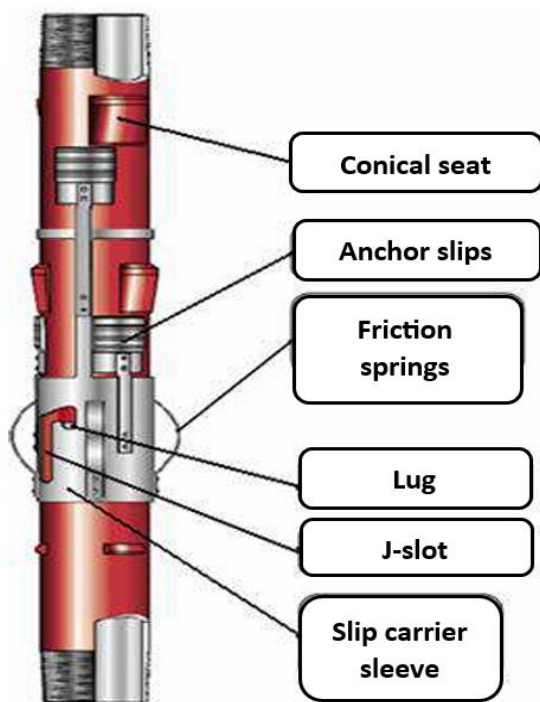


Figure 22 : Mechanical liner hanger [9]

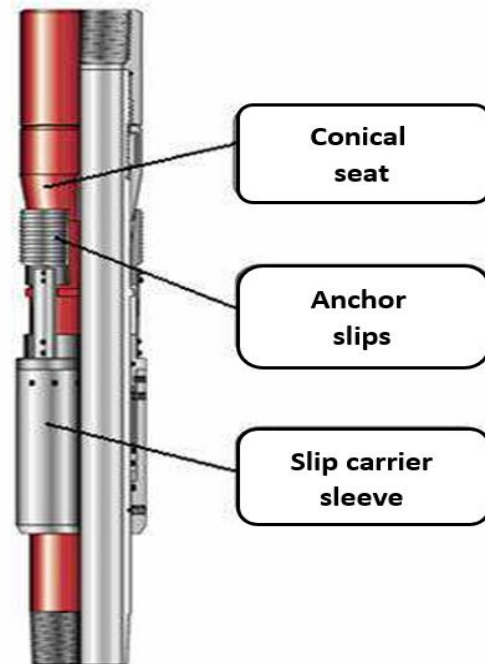


Figure 21 : Hydraulic liner hanger [9]

Note: In some cases, rotary liner hangers are used, which allow the liner to rotate during circulation and cementing. This improves the displacement of the mud by the cement slurry, especially when the wellbore is caved or oval-shaped, or when the liner is poorly centralized.

They should be used whenever possible, provided that the torque required to rotate the liner is less than the makeup torque of the connections. [9]

II.5.3: The Liner Top Packer

The **liner top packer** may or may not be integral with the setting sleeve. It is used to reinforce the seal behind the liner, above the cement, preventing overpressure during reverse circulation after cementing, which can cause lost circulation, and subsequently preventing reservoir fluid from flowing upward. Its use is optional. [9]

Operating Principle:

This packer is made of very soft metal, sometimes lead, covered with a layer of rubber. To inflate it, sufficient weight is applied with the rods to permanently deform it. To avoid the risk of premature setting, the packer is locked either by shear pins or by a special locking device (some types inflate by rotation).

The packer can be an independent piece placed above the hanger, or combined with it to form a **liner hanger-packer**.

However, the packer presents a restoration problem if the cementing is poor. Therefore, if reverse circulation losses are not an issue, it is preferable to inflate it only after verifying the cementing quality.

In addition, being oversized, it increases pressure losses, which may cause lost circulation during running, circulating, and cementing.

In some cases, liners are not equipped with a packer, and if sealing needs to be reinforced later, cement restoration is performed or a **scab-liner** equipped with packers is run. [9]

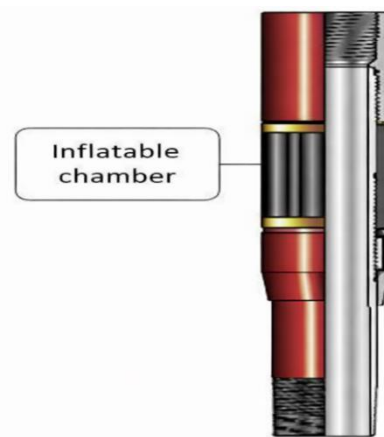


Figure 23: Liner Top Packer [9]

II.5.4: Polish Bore Receptacle (PBR):

It is threaded directly onto the setting sleeve and can have a length of up to 6 meters. It receives the tie-back of an additional casing string.

The inside of this extension is smooth, and its top is beveled to allow the passage of tools. After cementing the liner, this extension is cleaned using a special mill or a sub-jet. The PBR and tie-back together form a very tight and strong sliding joint, allowing very easy connection to the liner. The setting sleeve and the PBR extension can be manufactured as a single piece. [7]

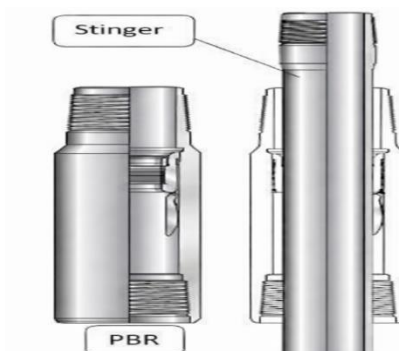


Figure 24: PBR [7]

II.5.5: The Rotating Joint (Liner Swivel)

This device is used only in the case of a mechanical hanger and is threaded below it. It allows rotation of the drill string and suspension during the setting of the slips of the suspension device, even if the lower part of the column is stuck in the formation. It must be located in the annular space between the casing and the liner, and above the shoe of the previous casing, to allow proper cementing. [8]

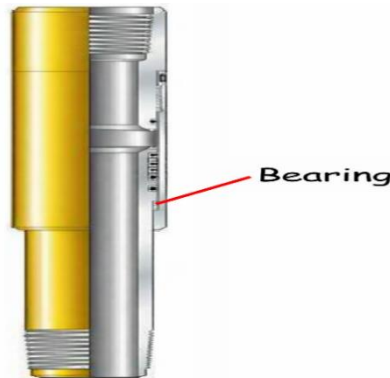


Figure 25: Liner Swivel [7]

II.5.6: Liner Accessories

Like a normal casing, a liner can have centralizers and scratchers. For highly deviated and horizontal wells, rigid spiral blade centralizers are used. They have the advantage of maintaining sufficient annular space between the liner and the lower part of the hole, which facilitates the movement of mud by the cement slurry.

These centralizers, made from a low-friction alloy, are placed on the body of the pipe between two **stop collars**. The accessory program depends on the well profile. The design of the centralizer blades and stop collars is intended to minimize friction during the running and rotation of the liner.

The spiral shape of the blades creates turbulence during the placement of the cement slurry.

The outer diameter of the centralizers is equal to the hole diameter minus $\frac{1}{4}$ ". [7]

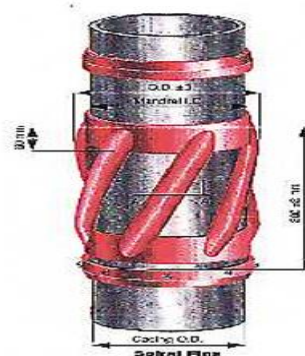


Figure 26: Rigid Centralizer with Stop Collar [7]

II.5.7: Hydraulically Operated Valve (Pac Valve)

It is a valve used for stage cementing operations and screened liners. This equipment acts as a bypass between the inside of the casing and the annulus in order to circulate and displace cement into the annulus at the selected depth.

This PAC valve contains lateral ports covered by two internal sleeves positioned one above the other and fixed to the body by shear pins, whose number determines the operating pressure.

For stage cementing operations (whether for a liner or conventional casing), the activation of the PAC valve is achieved by applying pressure on the displacement plug of the first stage, which lands on the lower sleeve and shears the shear pins, thereby releasing the sleeve. Locking is achieved through the movement of the second sleeve displaced by the final displacement plug.

For screened liner cementing operations (with ECP packer), the PAC valve is associated with a ball seat. Once the ball lands on the seat, pressure surges are obtained.

The operating pressure of the two sleeves is adjusted by varying the number of shear pins. The number of shear pins holding the lower sleeve is lower than that of the upper sleeve. [7]

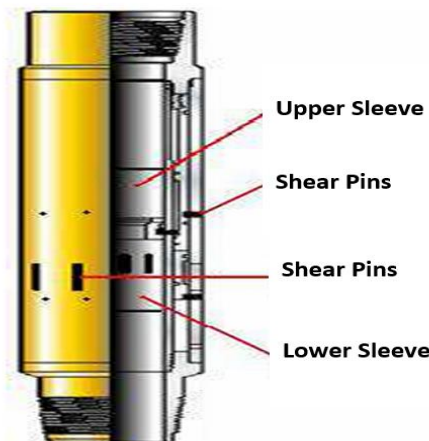


Figure 27: Pac Valve [7]

II.5.8: Cementing Accessories

II.5.8.1: The Shoe (Set Shoe)

Like casing shoes, it can be a channel, ball, valve, or automatic fill-up shoe, but it cannot be converted by dropping a ball.

In general, the shoe has one or two check valves that prevent the return of cement slurry at the end of the displacement. This return is usually blocked by two valves, which can be placed either both in the shoe, or one in the shoe and the other in another coupling (**float collar**)

located one pipe above the shoe, or both placed in the float collar if the shoe does not include them.

It is recommended to use shoes equipped with side ports to allow circulation even if the liner is set at the bottom.

The shoe can be equipped with fins that prevent the liner from rotating during the unthreading of the setting tool, if there is no hanger. [7]

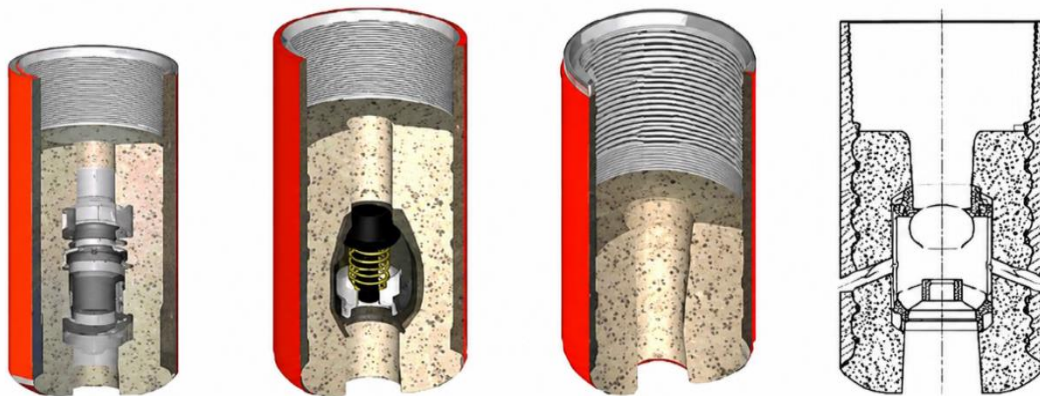


Figure 28 : Different Types of The Shoe (Set Shoe) [7]

II.5.8.2: The Landing Collar

Positioned one, two, or three joints above the shoe, it is used to hold the cementing plugs and indicate the end of the displacement.

It can be a check valve, a flapper valve, an automatic fill-up type, or have a seat for an ejectable ball.

When two cementing plugs are used, the landing collar must include a bypass system that allows the cement to pass. The collar with a ball seat is used when the hanger anchoring is hydraulic.

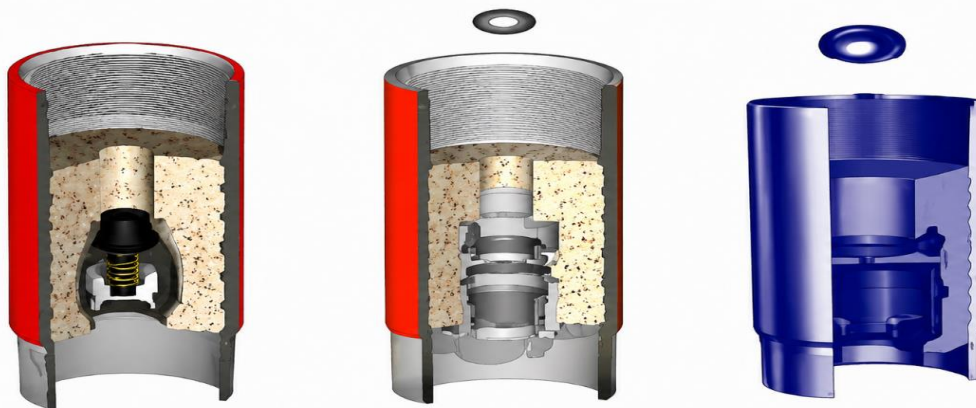


Figure 29 : Types of Landing Collars [7]

II.5.8.3: Cementing Plugs

1) Liner Wiper Plug

It is run to the end of the setting tool, below the sealing devices.

It has cups that serve to wipe the inside of the liner and a central hole that allows the passage of mud and the injection of cement slurry.

It is disconnected from the cannula of the setting tool or its special sleeve in the liner by shearing pins when the pump-down plug, at the end of cement slurry injection, anchors into it. This shearing is indicated by a pressure jolt.

This plug ensures separation between the cement slurry and the mud; at the end of the displacement, it seats on the landing collar and remains attached to it thanks to a retention system (**latch**). [7]

2) Pump-Down Plug:

Depending on the setting assembly, it can have 3 to 5 rubber fins of different outer diameters, designed to wipe the inside of the rods and the setting tool.

It is released from the cementing head at the end of the cement slurry injection. It scrapes the inside of the assembly and the setting tool and, at the end of its travel, anchors into the wiper plug at the end of the setting tool. By increasing the displacement pressure, the wiper plug is released, and both plugs move simultaneously through the liner until they reach the landing collar, where they lock and seal via a locking system.

In some liner cementing operations, a tail plug and a top plug are used (i.e., two pump-down plug / wiper plug sets).

Sometimes, in slim-hole liners where the difference between the liner inner diameter and the rods is small, only pump-down plugs are used, which scrape both the inside of the rods and the liner.

In the case of using two sets of plugs or in slim-hole liners, the top pump-down plug cannot be pierced by pressure to allow cement passage due to its small diameter. For this, the landing collar provides a bypass for the cement.

For safety, the pump-down plug is equipped with a disc that bursts if the landing collar bypass is not functional.

In some cases, the wiper plug contains a ball seat at its lower part to activate certain hydraulically operated equipment at the top of the liner. [7]

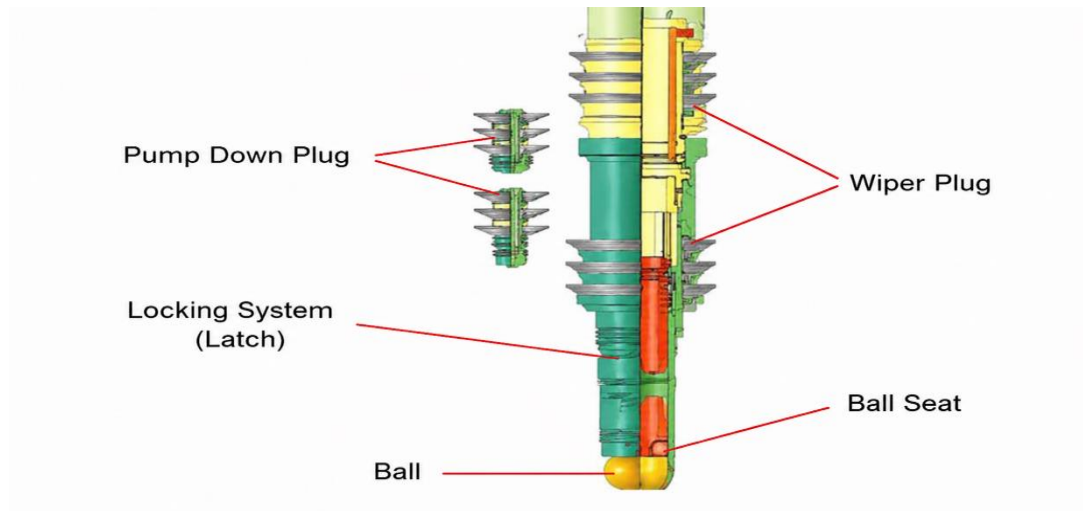


Figure 30 : Wiper Plug and Ball Seat Assembly [7]

II.5.8.4: Cementing Head

It is threaded onto the drill string; it contains the plug that must be pumped through the drill string before displacement (**pump-down plug**) and, if required, a pressure ball in the case of a hydraulic suspension device.

The cementing head is equipped with an optional indicator sub (**flag sub**) that signals the actual release of the plug pumped through the drill string.

It is also fitted with a swivel that keeps it stationary while the drill string rotates. [7]

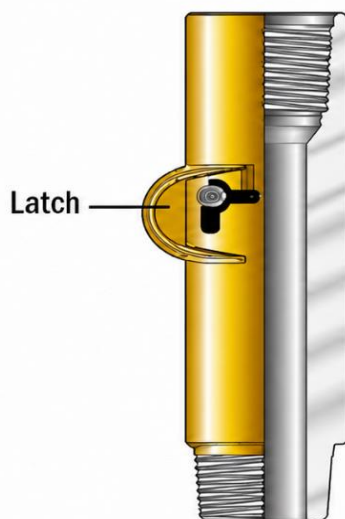


Figure 32 : Flag Sub (Indicator) [7]

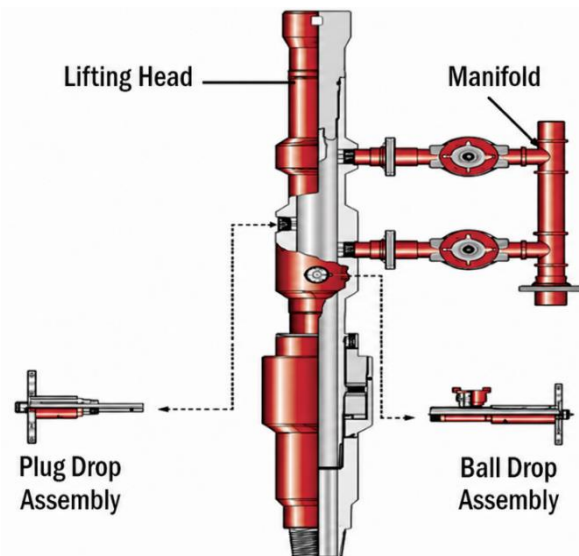


Figure 31 : Cementing Head [7]

Chapter III

I: Cements and slags**I.1: Definition of cement**

Cements are hydraulic binders, that is to say that in contact with water, their mineralogical constituents hydrate, forming a paste or slag which hardens and becomes a material endowed with mechanical properties capable of binding other materials.

The properties of the slag and hard material depend on the nature of the hydrates formed. They are also strongly influenced by pressure and temperature, which is the case in well bores. It is therefore essential to take this phenomenon into account. [10]

I.2: The constituents of cement**I.2.1: Clinker**

According to Bogue (1952), clinker is the main constituent of Portland cement. Clinker is the result of firing at 1450°C a mixture of 80% limestone and 20% clay (the raw material). At high temperatures, limestone loses carbon dioxide, subsequently lime, silica and alumina recombine to form:

- Tricalcium silicate $3\text{CaO} \cdot \text{SiO}_2$ (C3S) (50-70% of the clinker).
- Dicalcium silicate $2\text{CaO} \cdot \text{SiO}_2$ (C2S) (10-30% of the clinker).
- Tricalcium aluminate $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ (C3A) (2-15% of clinker).
- Tetracalcium aluminoferrite (Tetracalcium ferro-aluminate) $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$ (C4AF) (5-15% of the clinker).

The clinker still contains in small quantities, in the form of solid solution or taken in complex combinations, alkalis (Na_2O , K_2O), magnesia (MgO), various traces of metals.

The alkaline and magnesia content must remain low, as these materials can adversely influence the stability of the hardened cement. With the help of the microscope, we can distinguish the mineralogical structure of the clinker into three phases, to which the researchers gave the following names:

A = alite (crystallized phase), appears in the form of fairly large polygonal crystals (dark angular grains) of around 50 μ .

B = belite (vitreous phase), is found in impure form in clinker (slightly rounded and striped grains).

C = Celsite (slightly dark and light vitreous phase), is found in clinker in impure form and vitreous phase. [11]

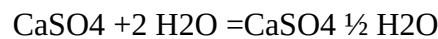
I.2.2: Calcium sulfate Gypsum (CaSO₄)

Gypsum is a white rock, matt in appearance, finely crystalline, soft (scratchable with a fingernail) and with a density of 2.3. Some yellow traces of sulfur may appear, it is mainly made up of hydrated calcium sulfate (CaSO₄, 2(H₂O)), gypsum is very pure (often 98%) and does not require purification during its exploitation.

Calcium sulfate (gypsum: CaSO₄.2H₂O) is a setting regulator added in small quantities to the other constituents of cement during its manufacture, 3 to 5% of the mass of the cement.

The SO₃ content must not exceed 3.5% in the cement; for each type of clinker, there is an optimal percentage of gypsum which gives both the best resistance and minimal shrinkage.

During grinding, under the effect of the temperature reached during grinding and storage, the gypsum will dehydrate into plaster, possibly into anhydrite and modify the rheological behavior of the cement. [11]

**I.2.3: Fly ash**

They are very fine powder products, coming from the dust removal of combustion gases from thermal power stations. We distinguish :

- Siliceous fly ash (V) which has pozzolanic properties.
- Calcium fly ash (W) which has hydraulic and sometimes pozzolanic.[11]

The average chemical composition of the ashes is produced in table (7) Following:

Table 7: Average chemical composition of ashes. [11]

Element	Percentage
SiO ₂	50
Al ₂ O ₃	30
Fe ₂ O ₃	8
CaO	2
Na ₂ O	5

I.2.4: Pozzolans (P)

They can be of volcanic (volcano ash), animal or plant origin. Certain materials such as clay and shales can, after heating and grinding, develop similar properties. [11]

I.2.5: Silica fume

Silica fumes are a by-product of the silicon and its alloys industry.

They are made up of spherical particles of very small diameter (of the order of $0.1\mu\text{m}$). To enter the composition of a cement as a main constituent, they must be present for at least 85% (by mass), the silica fumes used in the cement industry must meet the following conditions: (see table 8) [11]

Table 8: Silica fumes. [11]

Amorphous silica	$\text{SiO}_2 \geq 85$ by mass
Fire loss	$\leq 4\%$ by mass
Mass area	$\geq 15 \text{ m}^2/\text{g}$

I.2.6: Calcined shales

They are produced in a kiln at 800°C , they contain clinker phases, small quantities of free lime (CaO) and calcium sulfates, as well as oxides. In larger quantities, they have strong pozzolanic hydraulic properties.

The calcined shale, finally crushed, must have a compressive strength of at least 25MPa at 28 days, their expansion must be less than 10mm using a mixture of 30% by mass of crushed calcined shale and 70% by mass of cement reference. [11]

I.2.7: Fillers

These are “secondary constituents” of cements, so they can never exceed 5% by mass in the composition of the cement, they are mineral, natural or artificial materials which act through their particle size on the physical properties of the binders (handleability, power water retention). [11]

I.3: The classes of petroleum cement

There are various categories of cement, defined by standards set by the American petroleum institute API, these categories are determined according to the depth and bottom temperature of the cement.

well, this classification makes it possible to resolve practically all the problems posed by cementing in boreholes:

- **Class A:** used from the surface up to 6000 feet (1829 m), when no pressures. special characteristic is requested. Ordinary type.

- **Class B:** used from the surface to 6000 feet (1829 m), when conditions require moderate or high sulfate resistance.
- **Class C:** used from the surface up to 6000 feet (1829 m), when conditions require high initial strength. Available in regular type and moderate or high sulfate resistance type.
- **Class D:** used from 6000 to 10000 feet (1829 to 3048 m) in moderately high temperature and pressure conditions. Available in both types, moderate and high sulfate resistance.
- **Class E:** used from 10,000 to 14,000 feet (3048 to 4268 m), in high temperature and pressure conditions. Available in both types, moderate and high sulfate resistance.
- **Class F:** used from 10,000 to 16,000 feet (3,048 to 4,877 m), in very high temperature and pressure conditions. Available in both types, moderate and high sulfate resistance.
- **Class G:** used as a base cement to cement from the surface up to 8000 feet such as or, with accelerators or set retarders to cover a wide range of depths and temperatures. Available in both types, moderate and high sulfate resistance.
- **Class H:** used under the same conditions as class G cement, but designed for higher slag densities. Available in type, medium sulfate resistance.
- **Class J:** used from 12,000 to 16,000 feet (3,660 to 4,880 m) for extremely high temperatures and pressures .[12]

I.4: Petroleum cement additives

We can simply define cement slag by the mixture between the cement and the mixing water, the latter must meet certain requirements and for this we must add additives. [11]

I.4.1: Definition of additives

Additives are chemical products that we mix with the cement either dry in the cement or with mixing water in order to obtain a slag with particular properties. These additives can be classified into seven main families. [11]

I.4.2: Types of additives

- **Accelerators:** These additives are intended to accelerate the hardening of cement. Accelerators make it possible to accelerate the setting of the cement, to increase the initial strength and to be able to reform more quickly.
- **Retarders:** Retarders are used to allow the pumpability time of the cement to be adjusted to the desired value because in a large number of cases the cement sets too quickly to leave time for the operation to put it in place.
- **Dispersants:** These products, as their name indicates, will disperse the grains of cement in

suspension in water, thus causing fluidification of the cement slurry. Their mode of action is similar to that of the retarders, because they coat the cement grains with a thin charged film electrically.

- **Lightening:** These are light inert materials mixed with cement whose effect is on the one hand to reduce the density of slurry, on the other hand to reduce costs. On the other hand, most of lightening have an effect on the setting time and the compressive strength of the cement. It will be often necessary to compensate with appropriate additives.

- **Heavy :** The role of the weighting agents is

- Increase slurry yield without reducing mixing water.
- Control high background pressures.

Among the main weighting agents include: barite, iron oxides.

- **Filtration control agents:** They prevent the loss of water from the slurry by filtration in permeable formations, which risk trigger either an untimely intake or a lack of intake due to the absence of water necessary for the hydrolysis and crystallization of cement components.

- **Special Agents**

There are two types of special agents:

- Anti-foamers: They prevent excess foam produced when mixing, which risks interfering with the proper functioning of the pumps.
- Gelling agents: They modify the thixotropic characteristics of certain slurries. [11]

1.5: Types of cement slurries

1.5.1: Ordinary slurry

The basic slurries used for cementing have characteristics such as chemical composition, particle size; once mixed with the mixing water, we obtain slurries with a density normally between 1.78 and 1.98. They were also called ordinary slurries because petroleum cement is very stable at these densities. [12]

1.5.2: Low-fat slurry products

The densities of regular slurries can sometimes have disadvantages. In fact, certain formations do not support cement columns of such weight. It is therefore sometimes necessary to lighten the cement slurry to reduce hydrostatic pressures in the area of fragile layers and thus avoid fracturing. In the use of lightweight cements we generally distinguish: cement plugs intended to plug losses and cementing casings covering fragile areas. [12]

I.5.3: Dense or heavy slags

A so-called ordinary slag has a density of between 1.78 and 1.98. This limit can be pushed up to 2.15, and to obtain higher slag densities, it is necessary to incorporate weighting products. High densities are used when significant hydrostatic pressure is required for well control. [12]

I.5.4: Slags for high temperatures

Portland cement can be used up to around 80°C; beyond this temperature, so-called delayed cements are used, in order to achieve sufficient pumpability time to install the slag in the well. Special additives will be added to have the desired compromise. [12]

I.5.5: Dairy products for cold regions

The drilling temperature to be cemented drops below 10°C, conventional cements do not give satisfactory results. However, if the temperature remains above the freezing point of the aqueous phase, there is an increasingly pronounced slowdown in setting with a very slow development of compressive strength. For a lower temperature, the aqueous phase freezes, the cement no longer hydrates and setting does not occur. Two remedies can be applied: either raise the temperature to accelerate setting, or use cement systems that can set at low temperatures.

I.5.6: Thixotropic slags

Thixotropic cements are cement slags which have particular rheological properties and which are associated with interesting mechanical properties.

These cements are highly thixotropic, that is to say that a gel forms quickly in the absence of agitation or flow, this gel being however destroyed if agitation is resumed. These cements are expansive, which ensures a better connection between the casing and consolidated formations. The mechanical strength of these cements is suitable although it develops more slowly than for a conventional slag. [12]

I.6: Formulation of cement slag

We can simply define cement slag by the mixture between the cement and the mixing water, the latter; is a mixture of water and additives which each have a specific function in the cement slag matrix. To formulate a slag it is absolutely necessary to know how to predict and simulate the real conditions of the well such as: the static temperature at the bottom of the hole to calculate the circulation temperature, the bottom temperature in circulation, the principle is to circulate mud to cooling the well, this modifies the setting time and therefore the pumpability time, in a favorable direction, as well as the nature of the formations crossed and the pressure

of the pores and fracturing.

From these data, we can validate the characteristics of the slag on a laboratory scale:

- The density of the slag imposed by the limitations of the hydrostatic pressure of certain formations encountered.
- Filtration characteristic.
- Rheological parameters of slag.
- Setting time for development of compressive strength. [12]

II: General information on cementation

II.1: Cementation of oil wells

The cementing of a casing in a borehole is a capital operation which aims to close the space between the casing and the drilled hole with a cement slurry having characteristics suitable for the bottom conditions of the well such as:

- The temperature which is proportional to depth
- Pressure
- Aggressive elements, sulfates, chlorines and hydrocarbonates. [12]

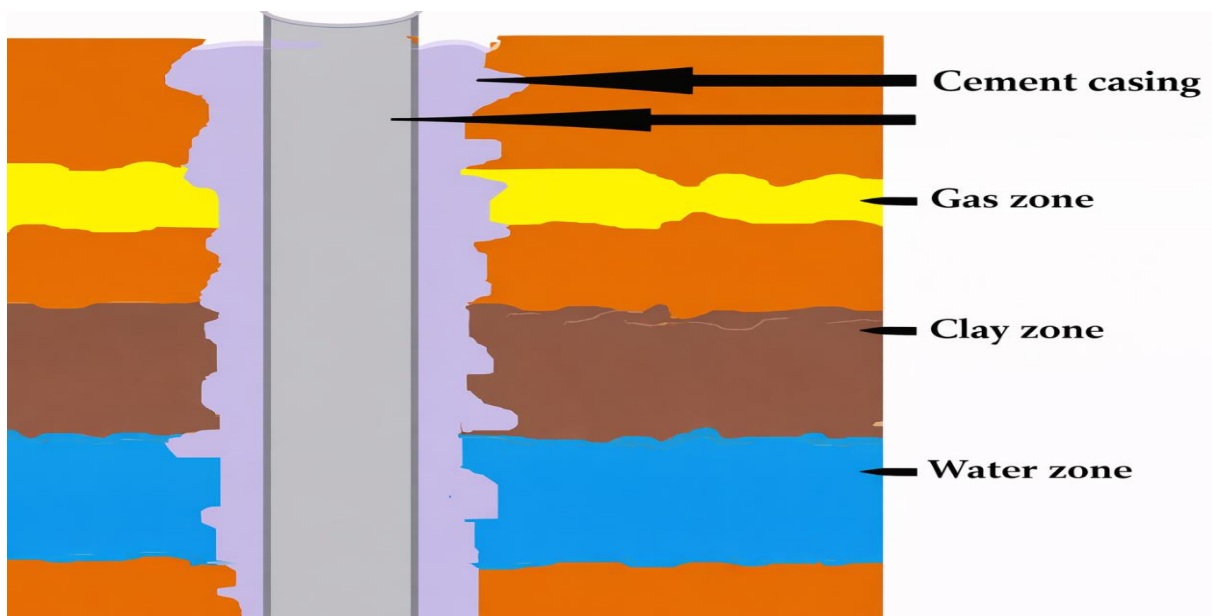


Figure 33 : Cement arrangement [12]

II.2: Purposes of cementing:

- close the layers at high pressure to eliminate the risk of blowout
- isolate the different formations to prevent contact of different fluids
- support the casing string
- protect the casing against corrosive fluids

- prevent the sinking of the well walls
- avoid pollution of groundwater [10]

II.3: Different types of cementing

II.3.1: Stinger cementing

Stinger cementing is used in large diameter surface columns.

Example: 18^{5/8} column in a 24" or 26" hole, with the aim of:

- reduce excess cement
- avoid contamination
- reduce the duration of cementation

To carry out stinger cementing, we use a tool called a Stinger screwed to the end of a set of rods.

The depth of the well rarely exceeds 500 m. The casing string is fitted with a special shoe to receive the stinger.

The rod packing is lowered inside the casing to the shoe. The stinger is anchored in the special shoe.

We then carry out the following operations:

- Circulation inside the stems. The mud return is normally done through the Hole-Casing annular space
- Injection of a washer plug inside the rods.
- Pump the volume of slag inside the rods.
- Throw the flush plug inside the rods.
- Hunt with mud
- When the plug reaches the level of the shoe, there is a sudden pressure.
- Undock the stinger
- Circulation inside the stems. The return of mud must be done through the tubing. This circulation is done to check the tightness of the hoof.
- Reassemble the filling and wait for the cement to set. [10]

II.3.2: Primary cementation

The cement slurry thus injected flows through the shoe and then rises into the ring finger. The retaining ring, as its name indicates, serves as a shoulder for the lower and upper scraper plugs which frame the volume of slag in the casing.

A burst of pressure bursts the lower plug to allow the slag to circulate in the annular

finger. It is the slag that directly pushes the mud into place and washes both the walls of the hole and the exterior of the casing as it flows. When all the slag is injected. The upper plug is released and is moved by circulation of the drilling mud.

This operation is called hunting. The flush volume is the volume of mud between the ring and the cementing head. At the end of the flush, you should notice a rise in pressure which means the upper cap stops. [10]

II.3.3: Cementing under pressure: (squeeze or squigging)

It is the installation of a cement slag under pressure at a given point of the well. The aim of the operation is to remedy a waterproofing defect or to create a new waterproofing (perforation of a depleted layer). This operation consists of applying pressure to a permeable formation so that the slag gradually dehydrates and forms a cake of cement which sets and seals the sealing defects or areas with losses.

The injection of slag is generally carried out following the "hesitation squeeze" method, which consists of injecting in volumes of a few hundred liters interspersed with pumping stops of a few minutes, gradually increasing the pressure until reaching the pressure of squeeze. [10]

II.3.4: Cement plugs

Cement plugs have many applications, either during drilling or after the production of a well. Among these applications we can cite:

- clogging of loss areas.
- isolation of problem areas.
- abandonment plug.
- deviation.
- anchoring a packer in an open hole.

These applications are very varied and the properties sought in these applications are also very diverse. The composition, placement and final properties of the cement must therefore be adapted to the problem to be solved. [10]

II.3.5: Staged cementing

Double-stage cementing is used:

- if the formations are fragile (risk of loss of circulation or low pressure zones).
- if the heights of the annuli to be cemented are significant (contamination of the slag).
- if two different types of slag must be put in place.

The column is equipped with a differential valve or diverter valve (DV) at the desired

dimension, the primary cementing is carried out in a conventional manner, however using a plug passed through the narrowing provided by the DV. After the burst of pressure we drop the bomb. The opening pressure shears pins and moves the liner. We can then inject the slag, but we do not use head plugs. At the end of the injection, we release the tail plug which we chase to the DV. This will close the DV by moving a second folder. [10]

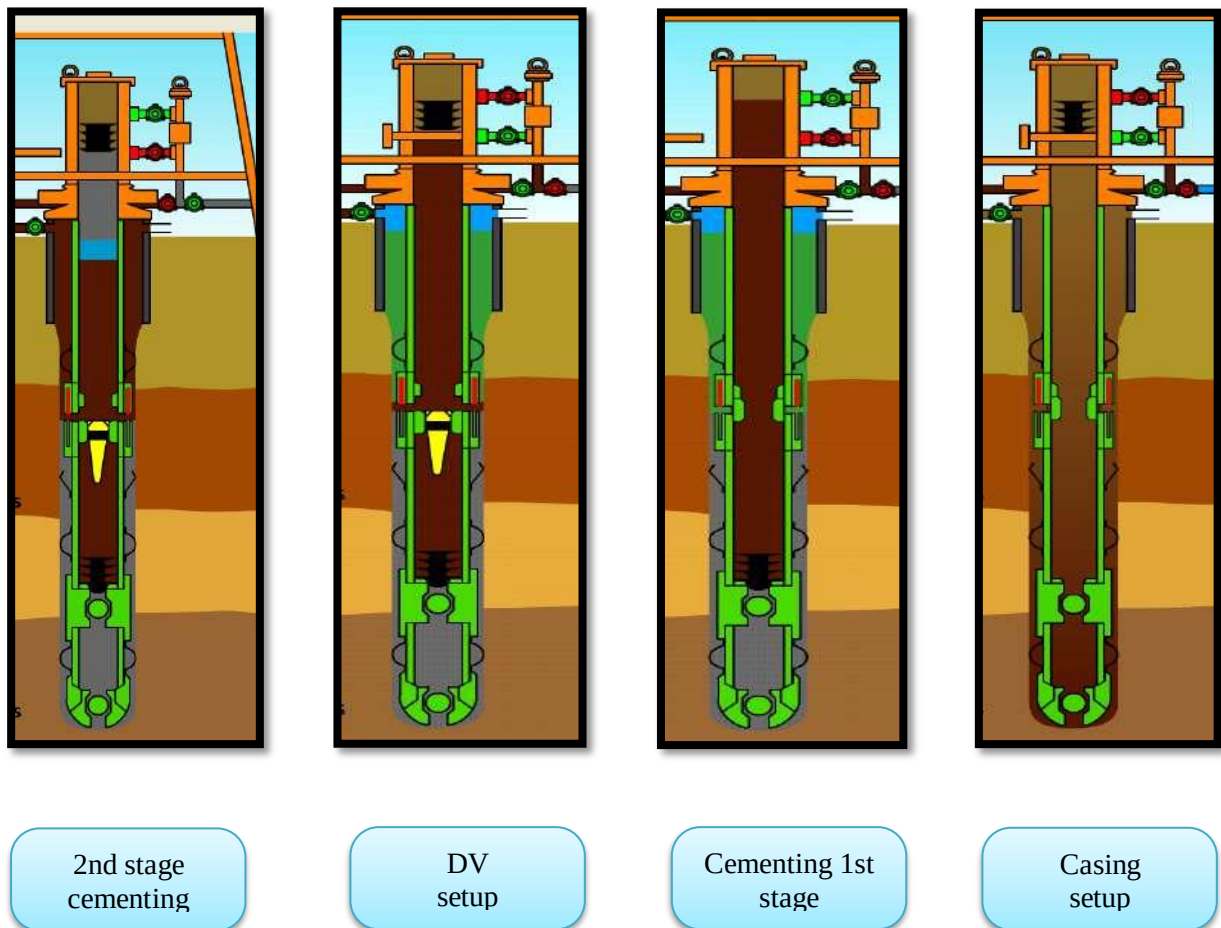


Figure 34: progress of staged cementing [10]

III: Preparation of cementation:

This involves determining:

- top cement,
- the density of fluids (slag and spacer),
- the travel regime,
- the volumes of the different fluids. [13]

III.1: The cement top

The cemented length must be at least 200 m and the top cement must be located 150 m

above the highest productive level. Depending on the height required to cement, several solutions will be possible:

- use of several types of slag,
- use of a DV.

The cementing of the air gap of the previous casing is only necessary for the question of definitive abandonment of the well. Cementing of the air gap could be considered Later:

- if the fracturing gradient is too low,
- if the length to be cemented > 1500 m,
- if the quantity of cement available is too low,
- if we encounter logistical or time problems... [13]

III.2: Fluid density

The hierarchy of mud, spacer, slag densities must be provided as follows: In vertical or slightly deviated wells:

Cement/sludge density difference as high as possible

- spacer density = mud density + 10 points
- slag density = mud density + 40 points

In horizontal or very deviated wells:

Cement/mud density difference as low as possible. [13]

III.3: the travel regime

Probably the most difficult parameter to determine because it depends on:

- the calibration of the well and the geometry of the well,
- fluid rheology,
- the resistance of the fragile point,
- pumping means of the cementing operator.

Tables of reasoning combined with calculation software facilitate the choice, which will necessarily belong either to the turbulent regime, or to the laminar regime, or to the sublaminal regime.

In a simplified manner, good mud/spacer/slag movement is generally obtained:

- for diameters > 12"¼
 - by a sublaminal regime or,
 - by effective laminar.
- for diameters ≤ 12"¼

- by an effective laminar regime if the well is caved or,
- by a turbulent regime if the well is calibrated (a well calibrated hole is a necessary but not sufficient condition for turbulent movement).

The classic rules of rheology now well known in relation to well conditions make it possible to state the following elements for each displacement regime. [13]

III.3.1: The sublaminal regime

This placement is used when the flush flow rate depends on the slag manufacturing flow rate or the diameter of the annular space (large diameter casing cementing).

Conditions:

- Reynolds number $Re < 100$
- annular speed < 25 m/min
- rheology $YV_{mud} < YV_{spacer} < YV_{lag}$

The sublaminal regime is only possible with a Binghamian slag. The calculation of the flush flow rate will take into account the smallest diameter of the overhang and the "U" tube effect. [13]

III.3.2: The effective laminar regime

The laminar regime can be applied to all fluids.

For Power fluids, it corresponds to speeds of 0 to 75 m/min. and for Binghamian fluids at speeds of 25 to 75 m/min.

The laminar regime which does not have a flat front of movement like the turbulent or the sublaminal is, a priori, the least satisfactory for the movement of the mud.

The current excellent knowledge of rheology by the operator and cementing companies has made it possible to overcome this problem by respecting certain calculation criteria.

- pump fluidized sludge at the head of the spacer.
- **The minimum flow** rate for placing the slag depends on the cleaning force on the wall.
- **The maximum flow** rate is limited by the fracturing gradient.

It is necessary that throughout the movement of the slag, the equivalent density in cementing must always be:

- lower than the pressure gradient
- higher than the pore pressure. [13]

III.3.3: The turbulent regime

The Turbulent diet can also be applied to all fluids. It is practiced at annular speeds > 100

m/min. to ensure a good safety margin in relation to the critical speed. The turbulent regime is all the more easily obtained as the rheological model of the slag is in Power.

Implementation in Turbulent is possible provided that we have:

- an acceptable equivalent density,
- a well calibrated in the area to be cemented,
- low viscosity of the three fluids,
- sufficient pumping capacity.

The flushing flow rate is calculated based on the maximum diameter to be cemented.

Terms:

- Reynolds number $Re > 3000$
- annular speed $V_{EA} > 110 \text{ m/min}$ [13]

Choice between Laminar regime / Turbulent regime

The optimization of the density difference and pressure losses is the same. The preceding rules apply equally to both types of plans.

Experience shows that when the installation is carried out in true turbulent mode, the result is better.

This is due to the better action of the turbulent regime on wall tension and channeling.

- **Wall tension**

Due to the significant pressure losses in turbulent conditions, the tension on the wall is very high, which allows good cleaning of the wall.

In the same way, the effective laminar regime will be better than the sublaminal regime.

- **Channeling**

The perfect move does not exist, there are always, in a real implementation, areas of uncertainty.

Poor movement in Laminar creates a film of mud against the wall or residual pockets of mud. Thus the entire height may be poorly cemented.

A bad move in Turbulent causes a “polluted” top followed by a well-cemented height.

We optimize in the same way, but if we optimize poorly, the result is much worse in Laminar than in Turbulent regime. [13]

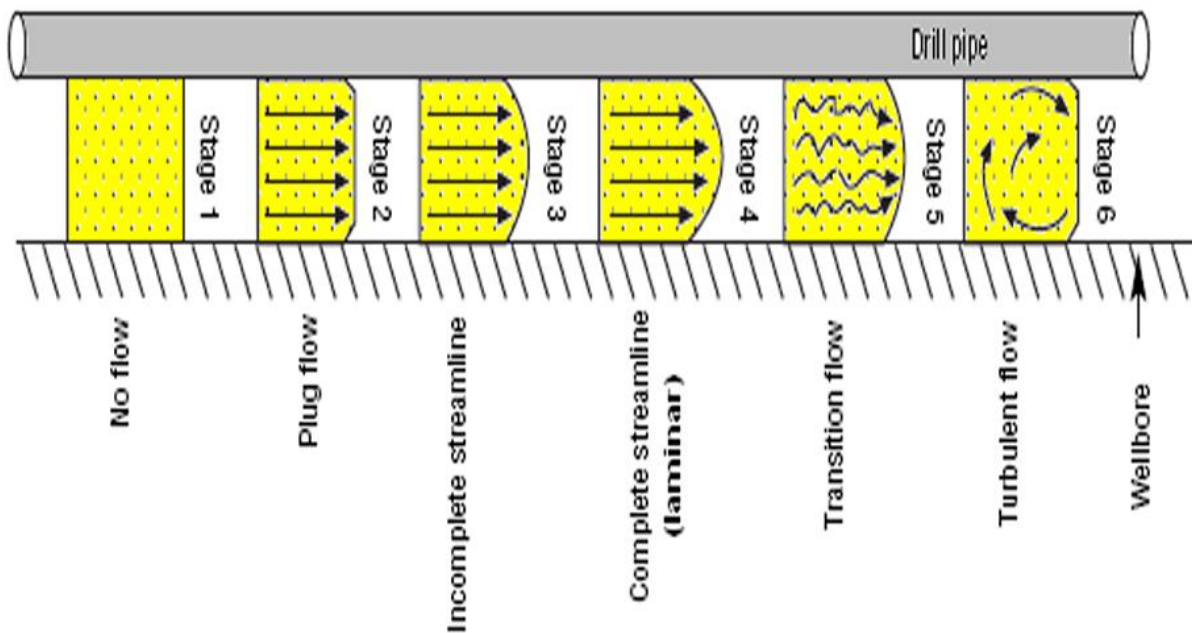


Figure 35 : Flow Regimes [6]

III.4: the volumes of the different fluids

The fluid best displaced by cement is water. If the open conditions do not allow maximum fluidization of the sludge or if conditioning proves difficult or even impossible, the following procedures will be recommended:

- pump fluidized sludge at the head of the spacer.
- pump a washer plug at the head of the cementing spacer.

The washer cap

The washer cap will be:

- water for a water slurry (with filtrate reducer if necessary).
- base oil for oil mud.

Due to its low density, it will not necessarily respect the hierarchy of friction and never that of density; but it will be in turbulent regime, even at low flow, and will create a dilution of the mud.

We will systematically check the hydrostatic loss caused by this plug.

The washer cap will have a volume equal to 50 to 100 m of annular space.

The spacer mover:

The use of a spacer is mandatory whenever the slag may be contaminated by mud.

- The density of the spacer must be: $d_{\text{spacer}} \approx d_{\text{boue}} + 10$ points

- The spacer must be compatible with mud and slag. Compatibility tests must be done to check if the rheology of the mixtures is acceptable.
- The base fluid of the spacer will be the same as that of the cement slag (the salinity of the spacer must be identical qualitatively and quantitatively to that of the slag).
- The rheology of the spacer will be intermediate between that of mud and slag.

Classically, we optimize the spacer volume according to the height to be cemented:

- ✓ 150 to 300 m in height for 500 m to be cemented, plus 20 m every 100 m in wells straight and deviated,
- ✓ the length of the drain to be cemented with a minimum of 300 m for horizontal wells.

Another criterion to take into account for the turbulent regime is the contact time of the spacer with the formation: 10 minutes. [13]

IV: preparation of fluids

IV.1: mixing water

Checklist to help prepare mixing water.

- Stock checking.
- Provide double the quantity of additives and cement required for cementing.
- Do not use open cans or bags.
- Preparation of bins.
- Use a tank isolated from the sludge circuit.
- Cleaning of the tank, circuits (manufacturing and delivery) to the cementing unit.
- Filling the tank (take into account the impumpable).
- Control of water salinity (less than 1000 ppm of chloride is required compared to the water used for laboratory tests).
- Preparation of additives.
- Prepare the exact quantity of additives and isolate it from the rest of the stock.
- Arrange them in mixing order.
- Mixing of additives.
- Who prepares the mixing water? This is the Cementing Operator with the Fluid or Drilling Supervisor.
- When to prepare the mixing water? At least 1 hour before the start of cementing. Preparation generally begins at the start of circulation, casing at the bottom.
- The order of mixing of the additives will be that of the laboratory formulation.

- Homogenize the mixing water in a blender for approximately 1 hour.
- Checking the mixing water.
- Check the final volume of the mixing water.
- Compare the chlorides in the mixing water with the values obtained in the laboratory.
- Keep a sample of 4 liters of base water and 4 liters of mixing water for testing in case of cementing problems.
- Recommendation on the life of mixing water.
- 4 hours if the water contains additives with very fine particles (microsilicas, etc.).
- 12 to 24 hours for all other mixing waters. [13]

IV.2: The spacer

The same precautions will be taken as for the preparation of the mixing water with regard to the risk of contamination and the control of the quality of the water.

- Who prepares the spacer?
- For a “homemade” spacer, it’s the muddy one.
- For a “service company” spacer, it is the cementing operator. In all cases the characteristics of the spacer must be checked by both operators.
- When to prepare the spacer?

The spacer must be ready at least 1 hour before the start of cementing, but it can be started well before that, that is to say before or during the descent of the casing. [13]

IV.3: the slag

In order to improve the quality of the slag, a recirculation system must be coupled to the cementing unit in the case where an automatic density control system is not available.

For the case of delicate cementing or small volume, the slag will be manufactured entirely on the surface and homogenized with injection.

The density will be checked with a pressurized balance and samples will be taken. mixing water and slag. [13]

V: cementation calculation

V.1: volume of slag

To calculate cementation, the following data must be available:

- Diameters of the well and casing.
- Depth of the well and height to be cemented.

- Type of mud.
- Background temperature. [13]

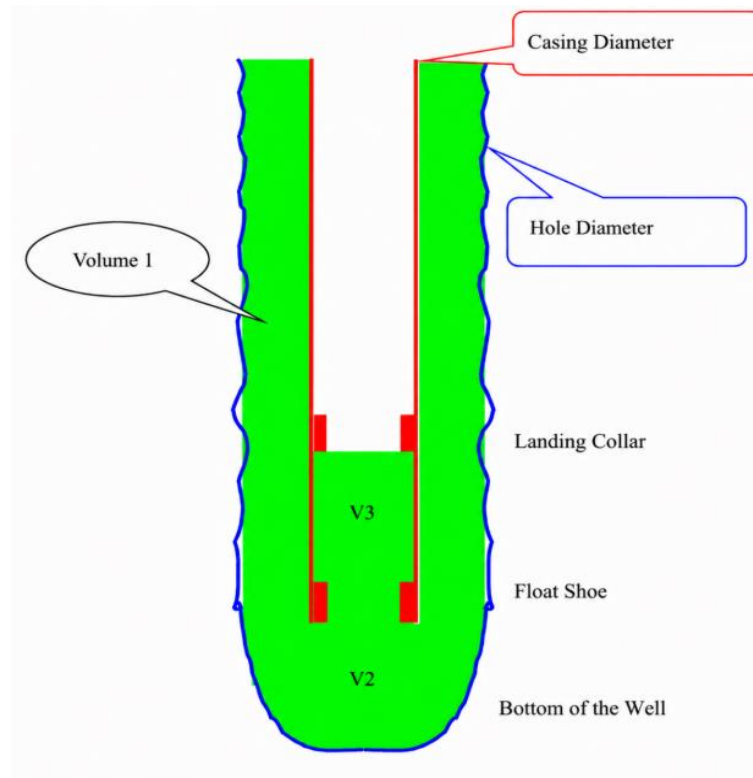


Figure 36: Diagram represents the different volumes to be cemented [13]

Example of a surface column

Volume 1

It is the volume of the Hole-Casing annular space between the shoe and the surface

Volume 2

This is the volume of the well between the bottom and the shoe. (Generally: 1 to 2 m)

Volume 3

This is the interior volume of the tubing between the shoe and the ring.

Slag volume

$$V = V1 + V2 + V3$$

Noticed: The diameter of the hole is generally larger than the diameter of the bit because of digging, particularly in salty soils. The volumes V1 and V2 must be increased by an increase coefficient. [13]

V.2: Volume of the delivery or flushing fluid

Generally, drilling mud and site pumps are used to pump the cement slag. The flush volume is equal to the interior volume of the casing between the annulus and the surface. [1]

V.3: Slag injection flow rate

It depends on the cementing unit. Practically, the injection flow rate is around 1000 L/min [1]

V.4: Delivery or flushing flow

For the slag to correctly fill the annular space, it is necessary to have a flow rate which provides turbulent flow. This flow is in most cases difficult to achieve. [1]

V.5: Discharge pressure

The maximum predictable pressure at the end of discharge is equal to the pressure difference between the annular space and the interior of the casing increased by pressure losses.

Either:

$h_{sp.e.ann}$ height of spacer in annular space.

$h_{L.e.ann}$: height of slag in the annular space.

d_L : Density of the slag.

d_{sp} : spacer density.

d_b : Sludge density.

P_{ref} : Discharge pressure at end of flush. [1]

$$P_{ref} = \left[\frac{d_L \cdot h_{L.e.ann}}{10.2} + \frac{d_{sp} \cdot h_{sp.e.ann}}{10.2} + \frac{d_b \cdot h_{b.e.ann}}{10.2} \right] - \left[\frac{d_L \cdot h_{L.int.tub}}{10.2} + \frac{d_{sp} \cdot h_{sp.int.tub}}{10.2} + \frac{d_b \cdot h_{b.int.tub}}{10.2} \right]$$

VI: Progress of the operation

Once the casing string is lowered to the bottom of the well, we proceed chronologically to the following operations:

- Screw the cementing head with its 2 plugs.
- Circulation for 1 or 2 cycles to raise all the cuttings in suspension, clean the well, homogenize the mud, etc.
- Injection of a washer cap. This 1 to 3 m³ washing cap is a liquid chemical product used to wash the walls of the well during the ascent in the annular and to separate the slag from the mud.
- Launch the lower cementing plug
- Pump the volume of slag. As the bottom cap hits the retaining ring, you should notice a slight increase followed by a drop in pressure.

This indicates that the slag has penetrated the plug membrane.

- Launch the upper cementing plug
- Hunting with mud. When the upper plug reaches the retaining ring, an increase in pressure is recorded (or pressure surge or Bump Plug) which indicates the contact of the 2 plugs.
- Stop the pumps. [1]

VII: Quality control

VII.1: CBL-VDL

If we were to state a quality criterion for cementing, we would say: "for the cementing to be considered of good quality, the cement sheath must be at least as watertight as the formation it replaces".

In fact, when drilling is carried out, different zones are connected.

The initial insulation will be restored by the casing + cement sheath assembly. This function will therefore be correctly ensured if this assembly allows a fluid leak rate (water, oil, gas) less than or equal to that which would be authorized by an equivalent section of drilled ground.

The cementing defects which can disrupt this seal are:

- micro or macro-annular cement-casing (dry or wet).
- micro or macro-annular cement-formation (dry or wet).
- mud channel at casing level.
- mud channel at the formation.
- gas percolation in the cement sheath
- gas channel in the cement sheath.

The purpose of the logs is to detect if one of these defects is present in the cement sheath. The causes of these defects can be numerous and varied:

- poor movement of the mud,
- unsuitable "spacer" formulation,
- "slag" formulation not in compliance with well requirements,
- cracks in the cemented annulus under the effect of thermal, hydraulic shock and aging,
- evolution of permeability during aging. [14]

VII.2: Cementation quality control (CBL-VDL)

VII.2.1: Definition and origin of the term "Logs"

- Diagraph

instrument which allows the image of an object to be projected onto a screen and to reproduce it following the contours.

- Logs

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

- Logging

It is the continuous recording, along the 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, clay, thickness, dip, fracturing, etc.). [15]

VII.2.2: the consequences of poor cementing

Poor cementing can cause the following problems:

- Mixing of the effluent produced with undesirable fluids.
- Migration of surface fluids through poorly cemented areas.
- Corrosion of the casing.
- Deformation of the casing (casing collapse).
- Cross flow. [15]

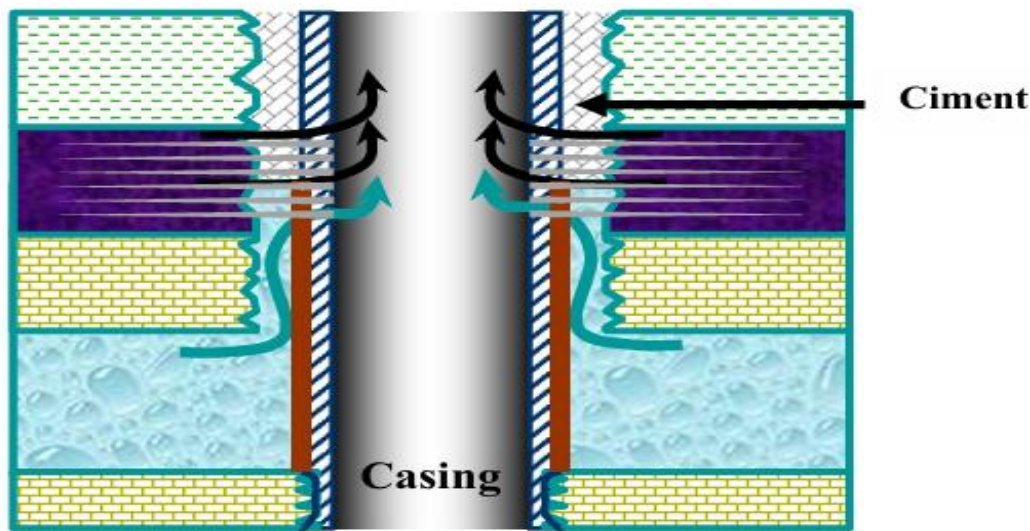


Figure 37:The consequences of poor cementing [15]

VII.2.3: The Sonics: CBL– VDL (Cement Bond Log– Variable Density Log)

VII.2.3.1: Definition

Sonic tools recording the amplitude of a sound wave in the casing whose attenuation rate is a function of the compression of the cement and the percentage of cemented circumference.

VII.2.3.2: Measurement of amplitude and transit time

The amplitude of an acoustic wave decreases as it travels through the environment it passes through. This attenuation depends on the elastic properties of the medium. Its measurement is applied to determining the quality of cementing of a casing. [14]

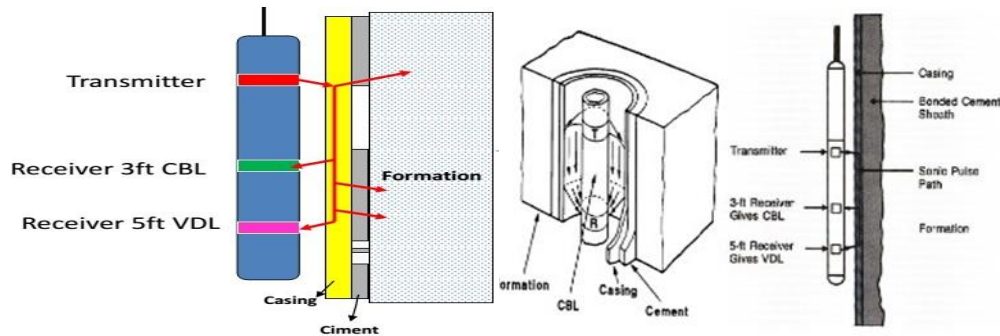


Figure 38 : The wave train of CBL and VDL [15]

VII.2.3.3: principle of CBL

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, passes through the casing, the cement and the formation if these various media are acoustically coupled, then is detected by a receiver which is located on the body of the tool (generally 3 feet from the transmitter).

The speeds of the different waves emitted and created during the passages and successive waves from one medium to another depend on the physical characteristics of the medium. Acoustic energy traveling along a tube propagates faster than formation waves which are themselves faster than mud waves. [14]

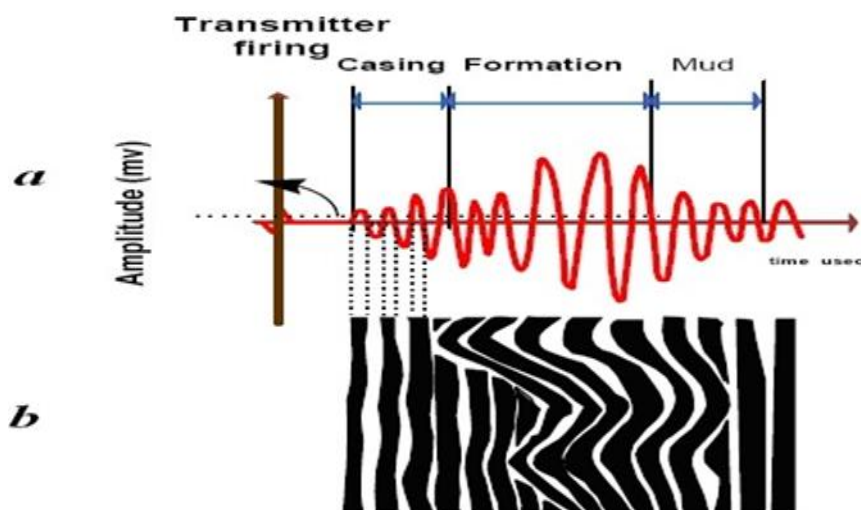


Figure 39: Recording a wave train. [16]

The detection of the first arrival is done following the same principle as that of measuring the propagation time of an acoustic wave in a formation (sonic or acoustic tool), by a minimum threshold of detectable energy (the bias). The amplitude of this first arrival (generally the casing wave) is measured by positioning a window.

This logging is commonly called "Cement Bond Log" or CBL: it makes it possible to study and quantify the quality of the cementing by measuring adhesion. [14]

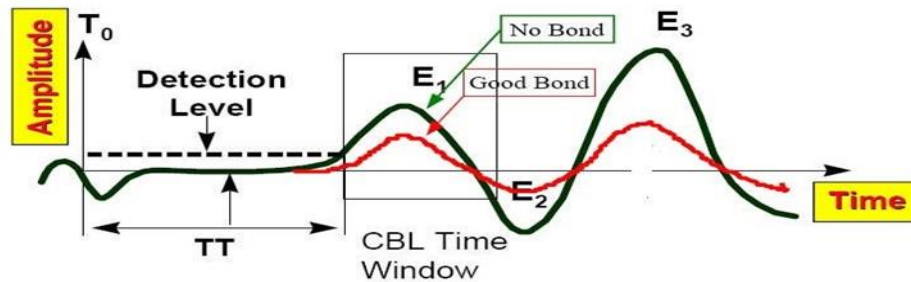


Figure 40: Cementation logging. [17]

VII.2.3.4: Interpretation of CBL

In the case of "free" (non-cemented) casing, all the acoustic energy circulates along the steel: there is very little attenuation of the wave and the amplitude of the first arch of the signal is important.

In the case of perfectly cemented casing, this energy will propagate through the cement into the formation.

In the case of poorly cemented casing, the energy is distributed between the casing and the formation. [17]

VII.2.3.5: Principle of VDL

The study of the quality of cementing can be distorted by a certain number of phenomena. It has proven useful to record the entire train of sound waves received by a receiver usually located 5 feet from the transmitter.

Registered in addition to the CBL, the VDL makes it possible to define Cement Formation adhesion.

The presentation of this recording is:

- In the form of the complete wave train or its positive part only ("Wave Form", "Signature Curve"): reading is difficult.
- In variable density (VDL), only the positive arches are reproduced in a gray scale that is darker as the amplitude is greater.

This presentation makes it possible to control the presence of formation waves and their variations as a function of depth, as well as the amplitude of the casing waves. [14]

VII.2.3.6: Interpretation

- In free casing, casing waves appear very clearly, parallel and straight across the entire free part. We cannot see the formation waves.
- In well-cemented casing, they are very weakened and can even practically disappear. The formation waves appear very clearly.
- In a moderately cemented part, casing waves are visible, more or less dark, as well as formation waves. [14]

VII.2.3.7: Conditions for good registration

- The setting of the cement must be complete. You must therefore wait at least 24 to 36 hours before carrying out the logging, sometimes more.
- Pressure variations in the casing between the time of cementing and logging can lead to a reduction in the diameter of the casing relative to the cement and the formation of a micro-annular or micro-separation in the cement himself.
- The tool must be very well centered, otherwise the amplitude of the signal risks being significantly attenuated. [14]

VII.2.3.8: Factors that can influence the measurement of CBL-VDL

- Pressure variations in the casing between the time of cementing and the log can lead to shrinkage of the casing relative to the cement by reduction in diameter and the formation of a micro-annulus. E.g.: reduction in mud density after cementing.
- The tool must be very well centered, otherwise the amplitude of the signal risks being greatly attenuated. In the case of poor centering, we see this attenuation on the CBL and a slight reduction in the T.T.

On the VDL the "casing waves" are also attenuated and are no longer rectilinear, the axis of the probe constantly changing in relation to the axis of the casing.

- For the cement drying time, wait 24 to 36 hours depending on the type of cement and the heating temperature of the well. The cement must set completely over the entire column and the compressive strength of the cement must be greater than 70 bars. [14]

VII.2.3.9: Precautions to take when interpreting

Before carrying out an interpretation of the cementation log, it will be beneficial to gather

all the data on the recording conditions and on the cementation itself:

- Type of cement, additive and fluid in the casing.
- Casing type, hole characteristics and formation types.
- Characteristics of the probe (type of centralizers, spacing between transmitters and receivers, frequencies used, etc.).

These data make it possible to know the maximum compressive strength of the cement, the transit time of the wave in the mud and the arrival time of the first wave. [14]

VII.2.3.10: CBL-VDL synths

- The CBL indicates the quality of casing/casing adhesion.
- The VDL judges the quality of the casing/cement, cement/formation adhesions and the good filling of the annular space. It is the only tool that can analyze cement/formation contact.

He is sensible

- at the micro-annular > 10 microns.
- centering the tool.
- to the variation in the density of the mud in the well.
- the compressive strength of cement.
- rapid training.
- to the cement sheath which must be > ¾"

It is not sensitive

- heavy sludge.
- calibration (there is none). [14]

Chapter IV

I: Drilling Phases Report**I.1: Phase 36" (Tubage 30" Conductor Casing)****Table 9 : Summary 36" Hole Section [3]**

Start Depth	0 m
End Depth	68 m
Interval	68 m
Duration	~ 1 day
Casing Shoe	67 m

This phase was drilled using tool N°01 of type: Tricone (EB1GS), equipped with nozzles 3×18 + 1×16 /32", in a single run. It drilled the interval from **0 m to 68 m**, with an average rate of penetration of approximately **15 m/h**. [3]

- **Tool Parameters**

Table 10 : Tool Parameters (36" Section). [3]

Type	BHA	Diam (")	Nozzles (/32")	Interval (m)	ROP (m/h)	Flow Rate (l/mn)	RPM (tr/mn)	WOB (T)
Tricone (EB1GS)	Semi Packed	36"	3×18 + 1×16	0–68 m	~15 m/h	1000–2000 l/min	60–110	1–20

- **Mud Parameters**

- Type: S
- Density: ~1.05 SG

Table 11: Mud Parameters [18]

MW (SG)	PV (cp)	YP	FV (Sec)	Filtrate	Oil /Water
1.05	ALAP	35–55	60–80	≤20	–

A casing string of **30" conductor casing**, composed of joints adapted to the shallow section, was run to a depth of approximately **68 m**, and cemented to surface. [18]

I.2: Phase 26" (18 5/8" Casing)**Table 12: Phase 26" (18 5/8" Casing) [3]**

Start Depth	68 m
End Depth	476 m

Interval	408 m
Duration	~ 6 day
Casing Shoe	475 m

This phase was drilled using tool N°01 of type: TCI bit (ES24V), equipped with nozzles 3×16 + 1×18 /32", in a single run. It drilled the interval from **68 m to 476 m**, with an average rate of penetration of approximately **15 m/h**. [3]

- **Tool Parameters**

Table 13: Tool Parameters [3]

Type	BHA	Diam (")	Nozzles (/32")	Interval (m)	ROP (m/h)	Flow Rate (l/mn)	RPM (tr/mn)	WOB (T)
TCI Bit	packed	26"	3×16 + 1×18	68–476	~15 m/h	3200	80–110	5–25

- **Mud Parameters**

Type: WBM Bentonitic

Table 14: Mud Parameters [18]

MW (SG)	PV (cp)	YP	FV (Sec)	Filtrate	Oil /Water
1.05	ALAP	35–55	60–80	≤20	–

A casing string of **18 5/8" – 87.5 ppf, K-55 BTC** was run to a depth of **476 m**, and cemented to surface.

I.3: Phase 16" (13 3/8" Casing)

Table 15: Phase 16" (13 3/8" Casing) [3]

Start Depth	476 m
End Depth	2614 m
Interval	2138 m
Duration	~ 7 day
Casing Shoe	2614 m

This phase was drilled using tool N°02 of type: TCI bit (TKC96), equipped with nozzles 10×12 /32". It drilled the interval from **476 m to 2614 m**, with an average rate of penetration of approximately **40 m/h**. [3]

- **Tool Parameters**

Table 16: Tool Parameters [3]

Type	BHA	Diam (")	Nozzles (/32")	Interval (m)	ROP (m/h)	Flow Rate (l/mn)	RPM (tr/mn)	WOB (T)
TCI Bit	packed	16"	10×12	476– 2614	~40 m/h	3200 – 2800	180–100	10–25

- **Mud Parameters**

Type : OBM.

Table 17: Mud Parameters [18]

MW (SG)	PV (cp)	YP	FV (Sec)	Filtrate	Oil /Water
1.18–1.22	ALAP	18–24	–	–	70/30–85/15

A casing string of **13 3/8" – 68 ppf, N80 BTC** was run to a depth of **2614 m**, and cemented to surface.

I.4: Phase 12 ¼" (9 5/8" Casing)

Table 18: Phase 12 ¼" (9 5/8" Casing) [3]

Start Depth	2614 m
End Depth	3282 m
Interval	668 m
Duration	~ 4 day
Casing Shoe	3281 m

This phase was drilled using tool N°04, PDC bit of type FM2663, equipped with nozzles 9×15/32". It tagged cement at **2614 m**, then continued drilling out cement and casing equipment up to **2634 m**, where the mud was displaced by OBM of density **2.02 SG**.

A Shoe Bond Test was performed after penetrating the formation. Then, tool N°05 (PDC SP619A) continued drilling from **2614 m to 3282 m**, achieving an average ROP of approximately **40 m/h**. [3]

- **Tool Parameters**

Table 19: Tool Parameters [3]

Type	BHA	Diam (")	Nozzles (/32")	Interval (m)	ROP (m/h)	Flow Rate (l/mn)	RPM (tr/mn)	WOB (T)
PDC	packed	12 ¼"	(3×19 + 6×15)	2614– 3282	~40 m/h	2400–2800	80–160	10–18

- **Mud Parameters**

Type : OBM.

Table 20: Paramètres de boue [18]

MW (SG)	PV (cp)	YP	FV (Sec)	Filtrate	Oil /Water
2.00–2.02	ALAP	10 – 12	–	–	90/10

A casing string of **9 5/8" – 47 ppf & 53.5 ppf, P110**, was run to a depth of **3282 m**, and cemented up to approximately **200 m above the 13 3/8" casing shoe**, in accordance with the cementing program .

I.5: Phase 8 ½ " (7 "Liner)

Table 21: Phase 8 ½ " (7 "Liner) [3]

Start Depth	3282 m
End Depth	4508 m
Interval	1226 m
Duration	~ 25 day
Casing Shoe	4507 m

The 8 ½" phase was initiated by running a PDC drill bit. The bit drilled out the shoe track of the 9 5/8" casing, allowing the resumption of drilling from a depth of 3282 m using an oil-based mud (OBM) with a density ranging between 1.25 and 1.40 sg, with a packed BHA configuration equipped with a downhole motor (MTR / Turbine).

Drilling was then continued through the geological formations including Triassic carbonates (Trias Carbonaté), TAGI, RKF/DH, Tournaisian, Strunian, Famennian, Frasnian, Givetian/Eifelian , Emsian , and reaching the Siegenian formations (Upper and Lower Siegenian C).

Several PDC bits were used (TKC73, GT84HE, DS811M, K505BPX – all new), with optimized drilling parameters: weight on bit (WOB) ranging from 8 to 14 tons, rotational speed

(RPM) between 90 and 120 rpm, and flow rate between 1400 and 1800 l/min, ensuring efficient hole cleaning and improved rate of penetration.

Drilling continued up to 3413 m, where the first coring operation was carried out. After resuming operations, drilling proceeded toward a second coring interval around 3702 m, with reaming and wiper trips performed to maintain wellbore stability.

The bit then continued drilling until reaching the final total depth at 4508 m. After a circulation period to clean the hole, the drill string was pulled out of hole smoothly.

Finally, a 7" production liner was run from 3282 m to 4508 m and successfully cemented, ensuring proper zonal isolation and optimal production conditions. [3]

- **Tool Parameters**

Table 22: Paramètre des outils [3]

Type	BHA	Diam (")	Interval (m)	ROP (m/h)	Flow Rate (l/mn)	RPM (tr/mn)	WOB (T)
PDC (TKC73 / GT84HE / DS811M / K505BPX)	packed	8 ½ "	3282– 4508	~ 15 m/h	1400 – 1800	90–120	8–14

- **Mud Parameters**

Type : OBM

Table 23: Paramètres de boue [18]

MW (SG)	PV (cp)	YP	FV (Sec)	Filtrate	Oil /Water
1.42	ALAP	18 – 24	–	–	95/5

Completion :

Duration: **15 days**

A milling tool of type **Champ Mill M609NQBXP (No. JK5665)**, dressed with 3 × 18/32" nozzles, was run in hole to drill out the cement and clean the 7" production liner.

As a precaution, the tool was run with continuous circulation from 3282 m down to approximately 3357 m, where the liner top (landing) was encountered. The milling operation started at this depth and continued progressively through the cemented interval down to the liner shoe at 4507 m, ensuring complete clean-out of the liner and its internal equipment.

The operation was carried out using oil-based mud (OBM), maintaining efficient hole cleaning and stable wellbore conditions. After completion of the clean-out, circulation was

performed, and the string was pulled out of hole safely to the surface. [3]

I.6: Time Details

Table 24 : Time Details [3]

BKNS-3 / ADES-802			
Activity	Depth [m]	Activity [Days]	Cum [Days]
Drill surface 36" Hole	60	1,00	1,00
Inter – Phase	60	1,50	2,50
Drill surface 26" Hole	476	6,00	8,50
Inter – Phase	476	4,00	12,50
Drill 16" Hole	2614	7,00	19,50
Inter – Phase	2614	7,50	27,00
Drill 12 ¼" Hole	3282	4,00	31,00
Inter – Phase	3282	10,00	41,00
Drill 8 ½" Hole to TD	4508	25,00	66,00
Log, run & cement 7" Liner + Tie back	4508	20,00	86,00
Testing and Completion	4508	15,00	101,00

I.7: Drilling Curve

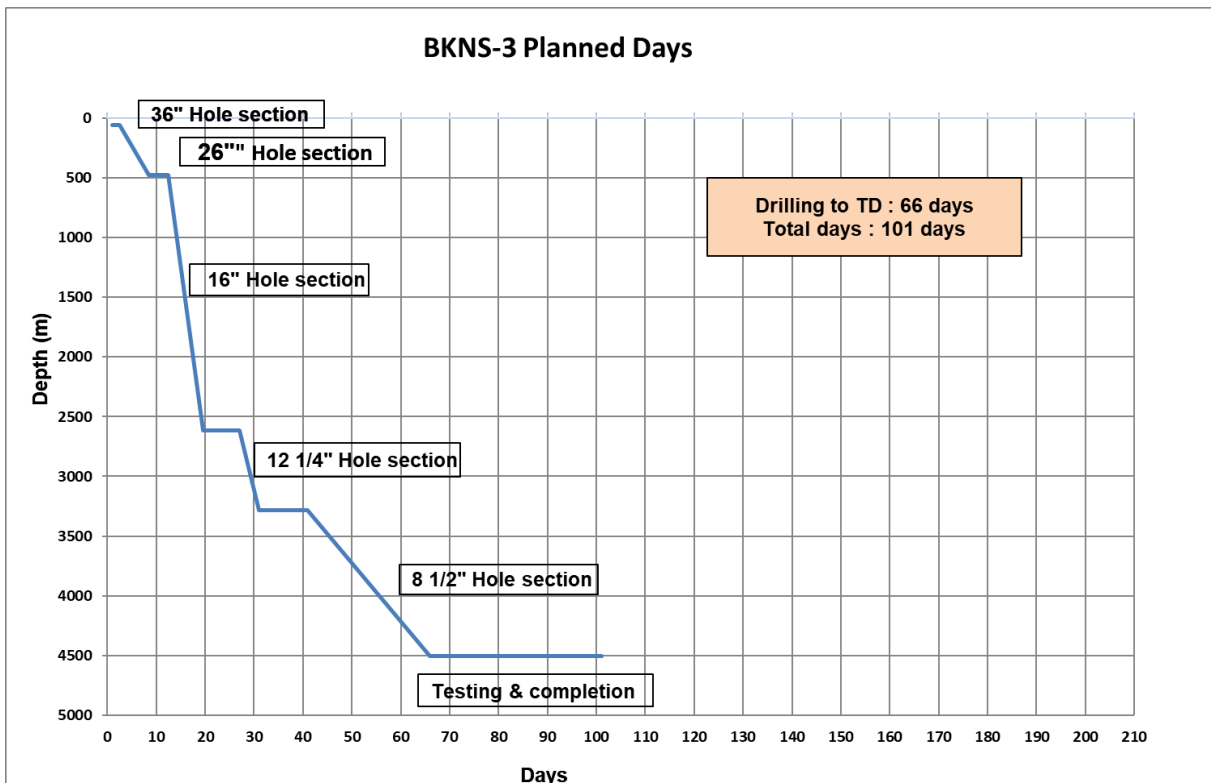


Figure 41:Drilling Curve [3]

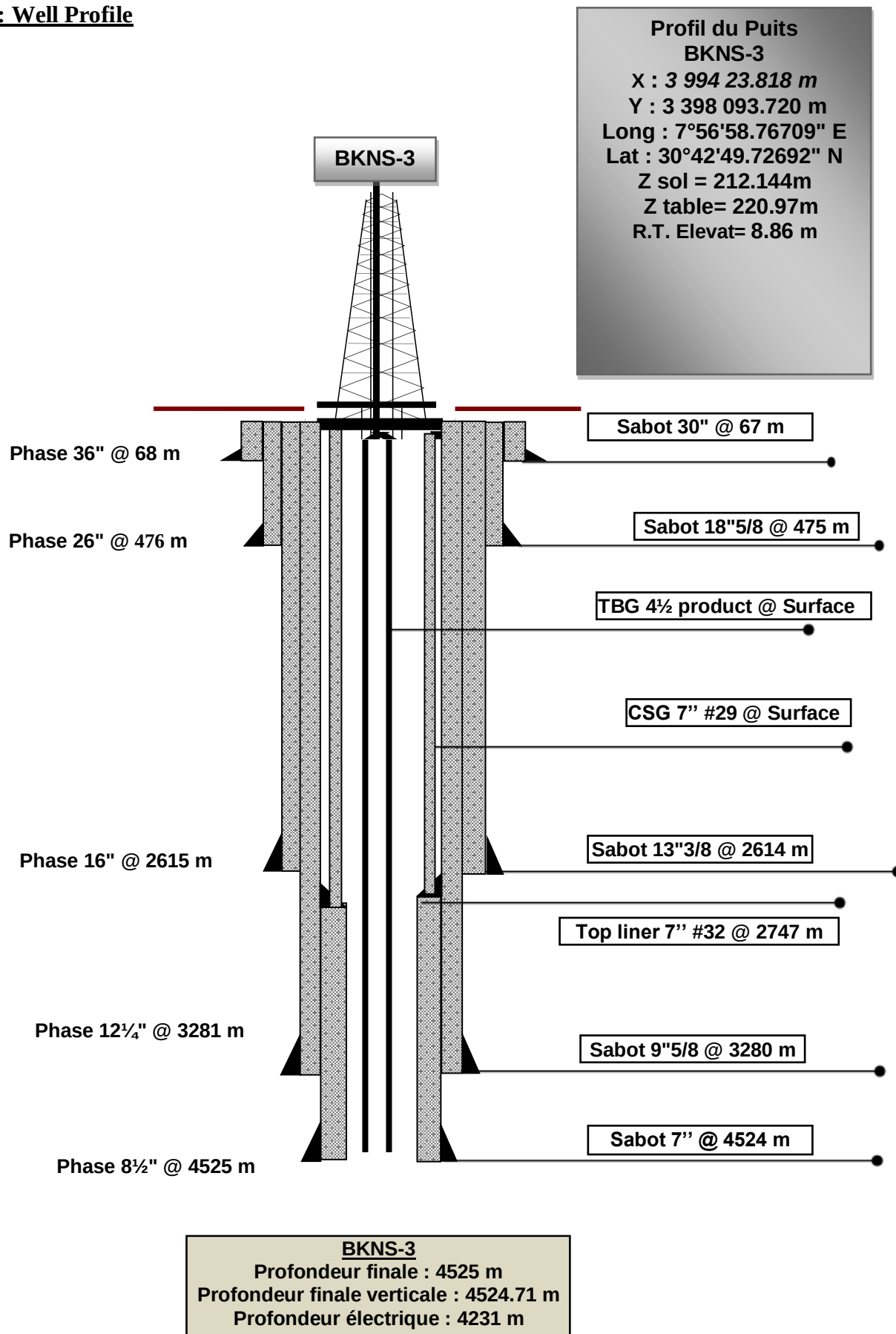
I.8: Well Profile

Figure 42 : Well Profile [3]

I.9: Casing Design**Table 25: Casing Design [3]**

String	OD/Weight/Grade	Connection	MD Interval (m)	Drift Dia. (in)	Minimum Safety Factor (Abs)			
					Burt	Collapse	Axial	Triaxil
Conductor Casing	30", 157,5 ppf, X-52	N/A	10,66-60,00	28,813	N/A	3,77	N/A	18,15
Surface Casing	18 5/8", 87,5 ppf, K-55	BTC, K-55	10,66-476	17,567	1,44	1,51	5,31	1,56
Intermediate Casing	13 3/8", 68 ppf, N-80	BTC, N-80	10,66-2614	12,259	1,24	1,16	2,18	1,53
Production Casing	9 5/8", 47 ppf, P-110	NEW VAM	10,66-1500	8,625	1,12	1,3	2,44	1,4
	9 5/8", 53,5 ppf, P-110	NEW VAM	1500-3282	8,5	1,5	*0,84	4,91	1,38
Production Liner	7", 32 ppf, P-110	NEW VAM	2727-4508	6	1,5	1,14	3,36	1,83

I.10: Section Objective

The objective here is to evaluate the target reservoirs. The pay zone formations will be covered with 7" production Liner. The drilling program plan is to set 7" liner 50m inside Sieginien C- Inferieur BOTTOM at 4508m. [3]

I.11: Preparation to drill

- Excess 5"-19.50# G105 drill pipe can be laid down.
- This hole section will use approximately 3000m of 5" 19.50# G drill pipe above BHA with the 5" 19.50# S135 drill pipe to surface. Ensure BHA will have a float valve & a TOTCO ring installed in the next connection above float valve.
- Ensure all materials and equipment required is on location. BHA components should be tallied for; length, OD, ID and fishing neck (if applicable).
- Stabilizers in this hole section should have 100% wrap with 360 degrees of coverage. The gauge on all stabilizers for this hole section should be checked. Tolerance is 1/16" under gauge.
- Have primary drill bit ready with proper nozzles installed. Backup bits should be on location.
- Have 02 wear bushing available on the Rig. [3]

I.11.1: Material requirement

Table 26 : Material requirement [3]

Item Description	Units	Qty	Spare	Total	Supplier
Consumables & Rental					
8 ½" PDC bits, nozzles 6x12	ea	6	0	6	SH
8 ½" PDC bit (rerun) as per bit program, nozzles, bit breaker	ea	2	0	2	SH
8 ½" MT bit (rerun), nozzles, bit breaker	ea	1	0	1	SH
Near Bit Stabilizer - 8-7/16" gauge, 4 ½" REG box x 4" IF box	ea	1	1	2	ADES
String Stabilizers - 8-7/16" gauge, 4" IF pin x box	ea	2	1	3	ADES
6"3/4 Drilling Jars – 6 ¾" OD, 4" IF	ea	1	0	1	Rental
TOTCO and Landing Rig	ea	1	1	2	ADES
Casing Equipment					
Float Shoe - 7" 32#, P110, NVAM	ea	1	0	1	SH
Float Collar - 7" 32#, P110, NVAM	ea	1	0	1	SH
Landing Collar - 7" 32#, P110, NVAM	ea	1	0	1	SH
Liner - 7" 32#, P110, NVAM	m	1780	100	1880	SH
Liner Hanger System - include hanger, running tool, PBR, top packer, and accessories	ea	0	0	0	SH
Dope	Pail	3	0	3	SH
BakerLock for Shoetrack	Can	1	0	1	SH
Centralizers - 7" Casing, SpiraGlide Type	ea	86	0	86	SH
Stop Collars	ea	172	0	172	SH
Nails for Centralizers & Stop Collars	LOT	1	0	1	SH
Casing Drift - 6.094"	ea	2	0	2	SH

I.12: BHA Detail

Table 27 : BHA Detail [3]

Section Type	Nbr of Joints	OD [in]	ID [in]	Length [m]	Weight [kg/m]	Buoy Wt. [T]	Cum Buoy Wt (T)	Cum Length (m)
Drill Pipe 19.50# S135	133	5,000	4,276	1236,15	33,57	33,98	141,71	4508,00
Drill Pipe 19.50# G105	323	5,000	4,276	3000,00	32,55	79,96	107,73	3271,85
Heavy Weight	6	5,000	3,000	55,80	73,96	3,38	27,76	271,85
X/O	1	6,500	2,813	1,00	136,55	0,11	24,38	216,05
Drill Collar	2	6,500	2,813	18,60	136,55	2,08	24,27	215,05
Drilling Jar	1	6,500	2,813	9,30	136,55	1,04	22,19	196,45
Drill Collar	18	6,500	2,813	167,40	136,55	18,72	21,15	187,15
Stabilizer 8 7/16"	1	6,500	2,813	2,40	170,68	0,34	2,43	19,75
Drill Collar	1	6,500	2,813	9,30	136,55	1,04	2,10	17,35
Stabilizer 8 7/16"	1	6,500	2,813	2,40	170,68	0,34	1,06	8,05
Short Drill Collar	1	6,500	2,813	3,00	136,55	0,34	0,72	5,65
NB Stabilizer 8 7/16"	1	6,500	2,813	2,40	170,68	0,34	0,39	2,65
Bit	1	8,500	NA	0,25	250,00	0,05	0,05	0,25
Mud Weight sg.	1,42							Buoyancy = 0,819

I.13: Detail Procedure**I.13.1: Drilling**

- Make up 8 ½" bit and packed BHA as per program.
- Stop at approximately 2000m and displace 2.00 sg OBM with 1.42sg OBM.
- Continue RIH and tag cement. Record actual top of cement. Displace remaining 2.00sg OBM with 1.42sg OBM.
- Drill float collar and shoe track down to near casing shoe. Ensure the bit runner monitors drilling parameters.
- Take slow pump rates and pump efficiency after displacing the last stage.
- If there was no plug bump in cementing 9 ⅝" casing. Test casing to 3500 psi before proceeding.
- Drill the Trias formation with reduced flow rate (approximately 1400lpm) to maintain laminar flow, This can be accomplished by increasing yield point to 15-18lbf/100ft² and RPM need to be limited to 130 rpm.
- Need to watch the torque and monitor the shakers for hole cavings. If either becomes a concern, the flow rate may need to be increased.
- ❖ It will be important to watch for cavings on the shale shakers after drilling the Trias formations. Other key indicators include excessive torque while drilling and high drag pulling out of the hole. Mud weight, rheology and/or drilling conditions may need to be adjusted to compensate for caving of the Trias formations. [3]

I.13.2: In order to avoid the caving of Trias Carbonate formation as follow

- ✓ Drill the Trias formations to Silurian A1 formation top with controlled parameters & reduced flow rate (1400lpm) to maintain laminar flow. Rotary RPM will need to be limited to 80-100; WOB to 10T to manage the bit.
- ✓ Maintain the yield point of mud at least 22 lbs/100.ft².
- ✓ HP/HT filter cake should be less than 4cc.
- ✓ Use continually Bridging agent to avoid caving from Trias formation by improving cake, recommended concentration calcium carbonate. More details about Bridging agents will be included in a separate fluid program.
- ✓ Carefully watch caving's on the shale shakers while drilling the Trias formation.
- Drill ahead 8 ½" hole as per recommended drilling parameters and following up SH standard procedure's, monitoring hole condition and mud rheology in/out.
- ❖ Volume should be closely monitored for sign of losses or kicks. Mud density will be

- ❖ increased if high pressure formations are penetrated.
- ❖ Ensure mud is in condition to do what it designed to do, attend/witness a complete test for mud properties with mud engineer from time to time.
- ❖ It is important to watch the volume and shape of cuttings coming over the shakers because this can be an early alert for hole problems. If cavings start appearing over the shakers pump a high density, high viscosity pill and monitor amount and size of cuttings. Do not use high density, high viscosity pills more than necessary.
- ❖ Increase mud weight if hole conditions dictate. (check with SI/FOR)
- ❖ Ream the recently drilled hole section sufficiently to avoid any problems.
- ❖ Record tight spots (depth and weights) experienced during the trips in and out of the hole.
- ❖ Limit over pull while tripping out at 05t, always give preferential to reaming.
- ❖ Avoid at all cost pipe stationary and/or without circulation while in open hole.
- ❖ Monitor gas values measured by the cabin Mud Logging: Background gas, Connection gas, gas Trip.
- ❖ Keep the hole full at all times, even if there is losses down hole.
- ❖ Fill hole continuously, use trip sheet to ensure hole is filled properly.
- At casing point, consider pulling to shoe and make a wiper trip depending on hole conditions.
- Prior to POOH for logs, circulate hole clean and ensure OBM is in good condition for logging and POOH.
- Rig up wire line loggers and run logs as directed. Run in hole with drill string for wiper trip to bottom. Circulate and condition mud for liner 7" casing job.
- Ensure rig pump efficiency has been checked and recorded.
- POOH. [3]

II: 7" Liner Design and Running Procedure

II.1: Technical Specifications of the 7" Production Liner (2727 m – 4507 m)

Table 28 : Technical Specifications of the 7" Production Liner [3]

Parameter	Grade	OD	ID	Thread Type	Liner Shoe	Top of Liner	Number of Joints
Value	P-110	7"	6.276"	New VAM	4507 m	2747 m	150

II.2: Composition and Depth Distribution of the Liner Assembly

Table 29 : Composition and Depth Distribution of the Liner Assembly [18]

	Nombre	longueur	Cumul long	comment	profondeur
Shoe	1	0.44	0.44		4523.56
casing	2	11.80	24.04	2 centraliser+ 4 Stop Collar	4499.96
Float collar	1	0.56	24.60		4499.40
casing	1	11.80	36.40	2 Cent + 4 Stop Collar	4487.60
Landing collar	1	0.27	36.67		4487.33
casing	146	≈11.80	1770.96	mixed	2753.05
Liner hanger	1	6.00	1776.96		2747.05
Stick up	1	2.54	1779.50		2744.50
5" Drill Pipe	296	2744.505	4524.00	to surface	0.00

II.2.1: Composition of the 7" Liner in Well BKNS-3:

The completion program specifies the use of a 7-inch P110 NEW VAM liner equipped with a **hydraulic liner hanger system** provided by Wellcare Oil Tools. This liner is designed for deep well applications, ensuring mechanical integrity and effective zonal isolation.

The liner string is composed of:

- Float shoe
- Float collar
- Landing collar
- Hydraulic liner hanger system (including running tool, PBR, top packer and accessories)
- 7" casing joints (32# P110 NEW VAM)
- Centralizers
- Stop collars [3]

II.2.2: Liner Components Characteristics:**Table 30 : Liner Components [3]**

composant	Type	Diamètre nominal	Poids nominal	connexion
Float shoe	Float shoe API standard	7 in	32 lb/ft	NEW VAM
Float collar	Double valve float collar	7 in	32 lb/ft	NEW VAM

Landing collar	Landing collar standard	7 in	32 lb/ft	NEW VAM
Liner hanger	Hydraulic liner hanger system (Wellcare)	7 in	—	NEW VAM
Casing	7" 32# P110 New VAM joints	7 in	32 lb/ft	NEW VAM
Centralizers	SpiraGlide type	7 in	—	—
Stop collars	Standard stop collars	7 in	—	—

III.1: Verification of casing resistance under different loads:

For the calculations, the following loads are considered:

- Collapse pressure with safety factor **Kc = 1.125**
- Burst pressure with safety factor **Kb = 1.100**
- Tensile load with safety factor **Kt = 1.750**

As well as the casing characteristics:

7" Liner, 32#, grade P110, connection New VAM

III.1.1: Collapse pressure (Pc):

It is the hydrostatic pressure in the annular space between the open hole and the casing. For verification, it is assumed that the annulus is filled with mud and the inside of the casing is empty

Hydrostatic pressure calculation:

$$P_{hyd} = \frac{H \times d_b}{10.2}$$

Where:

H = vertical depth of casing = **4508 m**

d_b = mud density = **1.42**

$$P_{hyd} = \frac{4508 \times 1.42}{10.2}$$

$$P_{hyd} = 627.6 \text{ Bars}$$

According to drilling data: Rc = **737 bar**

Verification:

$$R_c / P_c > K_c$$

$$R_c / P_c = 737 / 627.6 = 1.17 > 1.125$$

Therefore, the casing satisfies collapse resistance.

III.1.2: Burst pressure (P_b):

For verification, it is assumed that the casing is full of mud internally and the annulus is empty.

The API safety factor is **$K_b = 1.100$**

$$P_b = [P_{int} - P_{ea}] = \left[\frac{H \times d}{10.2} \right]$$

$$P_b = 627.6 \text{ Bars}$$

According to drilling data:

$R_b = 855 \text{ bar}$

Verification:

$$R_b / P_b > K_b$$

$$R_b / P_b = 855 / 627.6 = \mathbf{1.36 > 1.100}$$

Therefore, the casing satisfies burst resistance

III.1.3: Tensile strength (T_t):

To verify tensile resistance, the tensile strength is divided by the apparent weight of the casing multiplied by gravity.

Apparent weight:

$$G = G_{air} \times f$$

Buoyancy factor

$$f = 1 - \left[\frac{d_b}{d_a} \right]$$

$$d_a = 7.85$$

$$f = 1 - \left[\frac{1.42}{7.85} \right] = 0.819$$

$$f = 0.819$$

Weight in air:

$$G_{air} = G_u \times L$$

$$G_u = 20.09 \text{ kg/m}$$

$$L = 1780 \text{ m}$$

$$G_{air} = 20.09 \times 1780 = 35760 \text{ kg}$$

$$G_{air} = 35760 \text{ kg}$$

Apparent weight

$$G = 35760 \times 0.819 = 29280 \text{ kg}$$

$$G = 29280 \text{ kg}$$

Verification:

$$T_t = 188 \times 10^4 = 1,880,000 \text{ N}$$

$$G \times g = 29280 \times 9.81 = 287,300 \text{ N}$$

$$\frac{T_t}{G \times g} = \frac{1,880,000}{287,300} = 6.54$$

$$1,880,000 / 287,300 = 6.54 > 1.75$$

Therefore, the casing satisfies tensile resistance.

III.2: Verification of drill pipe resistance under different loads:

The drill pipes used are:

5" Drill Pipe, 19.50#, grades **S135** and **G105**

III.2.1: Collapse pressure:

It is the hydrostatic pressure in the annular space between the 7" casing and the drill pipe. For verification, the annulus is assumed filled with mud and the inside of the drill pipe empty.

Hydrostatic pressure calculation:

$$P_{hyd} = \frac{H \times d_b}{10.2}$$

$$H = 4508 \text{ m}$$

$$P_{hyd} = \frac{4508 \times 1.42}{10.2}$$

$$P_{hyd} = 627.6 \text{ bar}$$

According to drilling data:

$$R_c = 1752 \text{ bar}$$

Verification:

$$R_c / P_c > K_c$$

$$R_c / P_c = 1752 / 627.6 = 2.79 > 1.125$$

Therefore, the drill pipe satisfies collapse resistance.

III.2.2: Burst pressure:

For verification, the drill pipe is assumed full of mud internally and the annulus empty.

$$P_b = [P_{int} - P_{ea}] = \left[\frac{H \times d}{10.2} \right] = \frac{4508 \times 1.42}{10.2}$$

$$P_b = 627.6 \text{ bar}$$

According to drilling data:

$R_b = 1713 \text{ bar}$

Verification

$$R_b / P_b > K_b$$

$$R_b / P_b = 1713 / 627.6 = 2.73 > 1.100$$

Therefore, the drill pipe satisfies burst resistance.

III.2.3: Tensile strength (Tt):

To verify tensile resistance, the tensile strength is divided by the apparent total weight (drill pipe + liner).

Buoyancy factor:

$$f = 1 - \left[\frac{d_b}{d_a} \right]$$

$$f = 1 - \left[\frac{1.42}{7.85} \right] = 0.819$$

$$f = 0.819$$

Weight in air (Drill Pipe):

$$G_u S135 = 33.57 \text{ kg/m}$$

$$G_u G105 = 32.55 \text{ kg/m}$$

- S135: $G_{air1} = 33.57 \times 1236.15 = 41490 \text{ kg}$
- G105: $G_{air2} = 32.55 \times 1508.355 = 49096 \text{ kg}$

$$\text{Total } G_{air} (\text{DP}) = 90587 \text{ kg}$$

Apparent weight (DP):

$$G = G_{air} \times f$$

$$G (\text{DP}) = 90587 \times 0.819 = 74190 \text{ kg}$$

Liner weight

$$G (\text{liner}) = 29280 \text{ kg}$$

Total apparent weight:

$$G_{\text{total}} = G (\text{liner}) + G (\text{DP})$$

$$G_{\text{total}} = 74190 + 29280 = 103470 \text{ kg}$$

Verification

$$G_{\text{total}} \times g = 7103470 \times 9.81 = 1015047 \text{ N}$$

$$T_t = 217.3 \times 10^4 = 2,173,000 \text{ N}$$

$$\frac{T_t}{G_{\text{total}} \times g} = \frac{2,173,000}{1015047} = 2.14$$

$$2,173,000 / 1015047 = 2.14 > 1.75$$

So .The drill pipes satisfy tensile resistance. [7]

III.3: Cementing of the 7" Liner

For the cementing of this type of liner, the following parameters must be calculated:

- Slurry volume required to fill the entire liner annulus
- Quantity of cement required for this slurry volume
- Mixing water
- Mud volume required for displacement
- Pumping time, displacement time, and total cementing duration
- Displacement rate
- Pumping pressure

III.3.1: Available Data:

- Tool diameter: 8 ½ "
- Well depth:
 - ✓ Measured Depth (MD): 4525 m
 - ✓ True Vertical Depth (TVD): 4508 m (vertical well)
- 7" shoe depth: 4507 m
- Top of liner: 2753 m (TOL)
- 9.625" Shoe : 3280 m
- Landing collar depth: 4487 m
- Distance landing collar – top of liner: 1734 m
- Top of cement (TOC): 2703 m
- Mud density: $d = 1.42$ sg

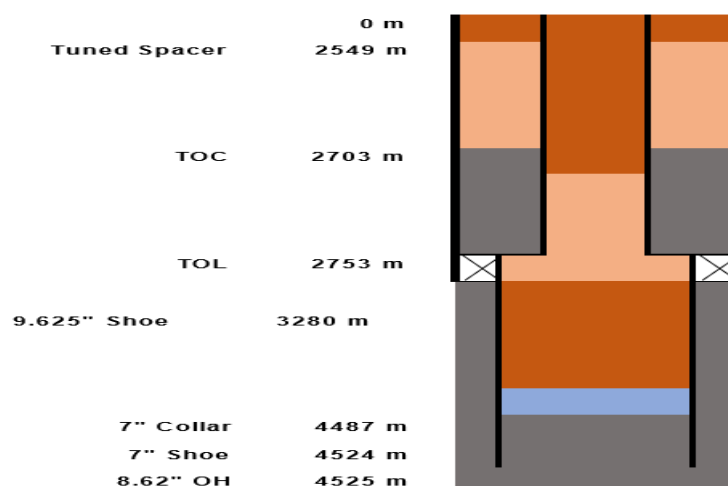


Table 31: Schematic Representation of the Liner Cementing Profile [20]

III.3.2: Characteristics of tubular material**Table 32 : Characteristics of tubular material [20]**

	Poids		Grade	Filetage
	Lb /ft	Kg /m		
Casing 9 $\frac{5}{8}$ "	47	69,95	P110	New Vam
Liner 7"	32	47,62	P110	New Vam
DP 5"	13,30	19,79	G105	IF

Table 33 : Table of unit volumes [20]

Open Hole	8.62	in
Csg	7	in
8.62" OH x 7" Csg 32#	12.815	l/m
7", 32#/ft Liner	18.820	l/m
9.625" x 5 Drill Pipe	24.240	l/m
OH 5% Excess	13.456	l/m

III.3.3: Total Cement Slurry Volume Calculation

The total cement slurry volume for the 7" liner cementing operation is calculated using the following equation:

$$V_L = V_1 + V_2 + V_3 + V_4 + V_5$$

Where:

- (V1): Internal volume of the 7" liner shoe track.
- (V2): Open hole volume below the liner shoe.
- (V3): Annular volume between the 8.62" open hole and the 7" liner.
- (V4): Annular volume between the 9 $\frac{5}{8}$ " casing and the 7" liner.
- (V5): Annular volume between the 9 $\frac{5}{8}$ " casing and the 5" drill pipe.

N.B: The actual borehole volume is generally larger than the bit gauge volume; therefore, the volumes V2 and V3 must be increased by an excess factor depending on the formation characteristics. [7]

► Calculation of (V1)

The internal volume of the 7" liner shoe track is calculated by:

$$V_1 = U_{C7''} \times H_{FL}$$

Where:

- $U_{C7''} = 18.82 \text{ L/m}$
- $H_{FL} = 37 \text{ m}$

Therefore:

$$V_1 = 18.82 \times 37 = 696.34 \text{ L}$$

$$V_1 = 0.70 \text{ m}^3$$

► Calculation of (V2)

The open hole volume below the shoe is calculated as follows:

$$V_2 = U_{OH} \times H_T$$

Where:

- $U_{OH} = 31.64 \text{ L/m}$
- $H_T = 1 \text{ m}$

Thus:

$$V_2 = 31.64 \times 1 = 31.64 \text{ L}$$

$$V_2 = 0.03 \text{ m}^3$$

► Calculation of (V3)

The annular volume between the 8.62" open hole and the 7" liner including 5% excess is calculated by:

$$V_3 = U_{CT} \times H_{CT}$$

Where:

- $U_{CT} = 13.46 \text{ L/m}$
- $H_{CT} = 1244 \text{ m}$

Therefore:

$$V_3 = 13.46 \times 1244$$

$$V_3 = 16.74 \text{ m}^3$$

► Calculation of (V4)

The annular volume between the 9 $\frac{5}{8}$ " casing and the 7" liner is calculated by:

$$V_4 = U_{CC} \times H_{CC}$$

Where:

- $U_{CC} = 12.73 \text{ L/m}$
- $H_{CC} = 527 \text{ m}$

Thus:

$$V_4 = 12.03 \times 527 = 6339.81 \text{ L}$$

$$V_4 = 6.34 \text{ m}^3$$

► Calculation of (V5)

The annular volume between the 9 $\frac{5}{8}$ " casing and the 5" drill pipe is calculated by:

$$V_5 = U_{CD} \times H_{CD}$$

Where:

- $U_{CD} = 24.24 \text{ L/m}$
- $H_{CD} = 50 \text{ m}$

Therefore:

$$V_5 = 24.24 \times 50 = 1212 \text{ L}$$

$$V_5 = 1.21 \text{ m}^3$$

► Total Cement Slurry Volume

$$V_L = 0.70 + 0.03 + 16.74 + 6.34 + 1.21$$

Hence:

$$V_L = 25.02 \text{ m}^3$$

Therefore, the total cement slurry volume required for the 7" liner cementing operation is:

$$V_L = 25.02 \text{ m}^3 \approx 157.37 \text{ bbl}$$

Table 34: Cementing Volume Calculations for the 7" Liner [20]

			Volume	
Wellbore Geometry	Cap L/m	Length	m ³	bbl
7, 32#/ft Liner	18.82	37 m	0.70	4.38
9.625" x 7" Annulus	12.03	527 m	6.34	39.88
9.625" x 5" Annulus	24.24	50 m	1.21	7.62
8.62" OH x 7" Annulus + 5 % Excess	13.46	1244 m	16.74	105.29
8.62" OH rat hole	31.64	01 m	0.03	0.20
Total			25.02	157.37

III.3.4: Calculation of Cement Quantity and Fresh Water Volume

The cement slurry density is:

$$d_l = 1.90 \text{ SG}$$

The slurry yield obtained from the laboratory report is:

$$75.08 \text{ L/100kg}$$

which corresponds to:

$$R = 0.7508 \text{ m}^3/T$$

The total slurry volume required is:

$$V_L = 25.02 \text{ m}^3$$

► Cement Quantity Calculation Q_C

The cement quantity is calculated by:

$$Q_C = \frac{V_L}{R}$$

Substituting:

$$Q_C = \frac{25.02}{0.7508} = 33.3 \text{ T}$$

Therefore:

$$Q_C = 33.3 \text{ T}$$

► Fresh Water Volume Calculation V_E

According to the laboratory report, the total mix fluid is:

$$40.29 \text{ L}/100\text{kg}$$

Therefore:

$$V_E = 0.4029 \times 33.3$$

Thus:

$$V_E = 13.40 \text{ m}^3$$

which is identical to the operational program value. [7]

III.3.5: Total Displacement Volume Calculation

The displacement volume is calculated by:

$$V_{ch} = V_{DP} + V_{Liner}$$

► Drill Pipe Internal Volume V_{DP}

For the 5" drill pipe:

- Unit capacity:

$$UC_{DP} = 9.05 \text{ L}/m$$

Length:

$$H_{DP} = 2753 \text{ m}$$

Thus:

$$V_{DP} = 9.05 \times 2753 = 24914.65 \text{ L}$$

$$V_{DP} = 24.91 \text{ m}^3$$

Table 35 :Displacement Volume Calculations [20]

				Volume	
Displacement		Cap L/m	Length	m ³	bbl
5", DP		9.050	2753 m	24.91	156.7
7, 32#/ft Casing		18.820	1734 m	32.63	205.3
Total	4487 m			57.55	362.0

► **7" Liner Internal Volume V_{Liner}**

For the 7" liner:

- Unit capacity:

$$UC_{7''} = 18.82 \text{ L/m}$$

Length:

$$H_{Liner} = 1734 \text{ m}$$

Thus:

$$V_{Liner} = 18.82 \times 1734 = 32633.88 \text{ L}$$

$$V_{Liner} = 32.63 \text{ m}^3$$

► **Total Displacement Volume**

$$V_{ch} = 24.91 + 32.63$$

Therefore:

$$V_{ch} = 57.55 \text{ m}^3$$

Which corresponds to:

$$V_{ch} = 362.0 \text{ bbl}$$

The batch mixing time is:

$$T_m = 1:30 \text{ hr}$$

according to the cementing program. [7]

III.3.6: Slurry Injection Time Calculation: T_I

The total injection time is equal to the sum of the spacer injection time, lead slurry injection time, and shoe slurry injection time.

$$T_I = T_{Spacer} + T_{Slurry} + T_{Shoe Slurry}$$

Where the injection time of each fluid is calculated using:

$$T_i = \frac{V_i}{Q_i}$$

With:

- V_i : injected volume.
- Q_i : pumping rate. [20]

Table 36 : Spacer and Slurry Injection Time [20]

Fluid	Volume (m^3)	Rate (m^3/min)	Injection Time
Tuned Spacer	6.00	0.7	0:08
Slurry	24.32	0.7	0:34
Shoe Slurry	0.70	0.7	0:01

Thus, the total injection time is:

$$T_I = 8 + 34 + 1$$

Therefore:

$$T_I = 43 \text{ min}$$

III.3.7: Displacement Time Calculation: T_{ch}

The displacement operation is performed using water followed by OBM mud. The total displacement time is obtained from the displacement schedule shown in the cementing program.

Table 37: Displacement Time [20]

Fluid	Volume (m^3)	Rate (m^3/min)	Time
Water	1.60	0.7	0:02
OBM Mud	21.31	0.7	0:30
OBM Mud	2.00	0.2	0:10
OBM Mud	7.22	0.7	0:10
Spacer	2.00	0.7	0:02
OBM Mud	19.41	0.7	0:27
OBM Mud	4.00	0.2	0:20

Thus, the total displacement time is:

$$T_{ch} = 2 + 30 + 10 + 10 + 2 + 27 + 20$$

Therefore:

$$T_{ch} = 101 \text{ min}$$

III.3.8: Total Cementing Time Calculation: T

The total cementing operation time is obtained from the cementing schedule as follows:

Table 38 : Cementing Operation Time Schedule [20]

Operation	Time
Pumping Time	1:57
Thickening Time	8:14
Batch Mix Time	1:30
Disconnect running tool, POOH and set the packer	0:45
Circulate one bottom up @ 900 L/min	1:30
Safety Margin	2:31

Thus:

$$T = 1:57 + 8:14 + 1:30 + 0:45 + 1:30 + 2:31$$

Therefore:

$$T = 16:27$$

Hence, the total estimated cementing operation time is:

$$T = 16 \text{ hr } 27 \text{ min}$$

Table 39 : Cementing Pumping Program [20]

Nr.	Fluid		Volume	Rate	Time
			m3	m ³ /min	hr:min
1	OBM Mud	oc	N/A	N/A	N/A
2	Tuned Spacer	oc	6.00	0.7	0:08
3	Slurry	oc	24.32	0.7	0:34
4	Shoe Slurry	ic	0.70	0.7	0:01
Drop Dart and start Displacement					
5	Water	ic	1.6	0.7	0:02
6	OBM Mud	ic	21.31	0.7	0:30
7	OBM Mud	ic	2	0.2	0:10
First Bump					
8	OBM Mud	ic	7.22	0.7	0:10
9	Spacer	ic	2.00	0.7	0:02
10	OBM Mud	ic	19.41	0.7	0:27
11	OBM Mud	ic	4	0.2	0:20
Final Bump					
Pressure to land the plug : 1307 psi			Total Time		1:57

Thickening Time	8:14
Batch Mix Time	1:30
Disconnect running tool, POOH and se the packer	0:45
Circulate 1 bottom up @ 900 l / min	1:30
Safety Margins	2:31

III.3.9: Displacement Pressure Calculation (P_{ref})

The maximum expected displacement pressure at the end of the cementing operation is equal to the pressure difference between the annulus and the inside of the liner. [7]

$$P_{ref} = \frac{H_b d_b + H_s d_s + H_L d_L - H_i d_b - H_e d_w - H_{st} d_L}{10.2}$$

Where:

- H_b : mud height in the annulus.

$$H_b = 1754 \text{ m}$$

- H_s : spacer height in the annulus.

$$H_s = 330 \text{ m}$$

- H_L : slurry height in the annulus.

$$H_L = 1244 \text{ m}$$

- H_e : water height.

$$H_e = 66 \text{ m}$$

- H_i : mud height inside the drill pipe.

$$H_i = 2753 \text{ m}$$

- H_{st} : shoe track length.

$$H_{st} = 37 \text{ m}$$

Fluid densities:

- Cement slurry density:

$$d_L = 1.90$$

- Mud density:

$$d_b = 0.86$$

- Spacer density:

$$d_s = 1.42$$

- Water density:

$$d_w = 1$$

Substituting the values:

$$P_{ref} = \frac{1754 \times 0.86 + 330 \times 1.42 + 1244 \times 1.90 - 2753 \times 0.86 - 66 \times 1 - 37 \times 1.90}{10.2}$$

Therefore:

$$P_{ref} = 171.5 \text{ bar}$$

Thus:

$$P_{ref} = 171.5 \text{ bar}$$

III.4: Characteristics of the Used Fluids

III.4.1: Spacer

The spacer used is a Tuned Spacer.

Its properties are:

- Volume:

$$V_s = 8 \text{ m}^3$$

- Density:

$$d_s = 1.42$$

- Total Mix Fluid:

$$885.54 \text{ L/100kg}$$

Table 40 : Spacer Composition [20]

Additive	Unit	Concentration	Total
Fresh Water	L	797	6376
Tuned Prime Spacer	Kg	90	720
Barite	Kg	603	4824
Musol-A	L	6	48
SEM-1205	L	6	48

III.4.2: Slurry

The cement used is ThermaCem II Blend.

The following data were obtained from the laboratory report.

- **Thickening Time**

Table 41 : Slurry Thickening Time versus Consistency [20]

Consistency	Time
40 Bc	08 h 14 min
50 Bc	08 h 15 min
70 Bc	08 h 23 min
100 Bc	08 h 31 min

- **Free Water**

0 cc

- **Fluid Loss**

25 mL/30min at 1000 psi

- **Slurry Properties**

- Volume:

$$V_L = 25.02 \text{ m}^3$$

- Density:

$$d_L = 1.90$$

- Slurry Yield:

$$75.08 \text{ L/100kg}$$

- Total Mix Fluid:

$$42.12 \text{ L/100kg}$$

Table 42 : Slurry Rheology [20]

RPM	BHCT
300	230
200	168
100	93
6	13
3	9
PV (cP)	205.5
YP (lb/100 ft²)	24.5

Table 43 : Slurry Composition [20]

Slurry	Concentration and Volume		
Additives	Unit	per Ton.	25.02 m ³
ThermaCem II Blend	Tonne	1	33.3
D-Air 3000L (D-Air 3500L) (Defoamer)	kg	1.00	33
Halad-413	kg	5.00	167
CFR-3 (Dispersant)	kg	10.00	333
GasStop (Gas Control Additive)	kg	3.00	100
Halad-344 (Fluid Loss)	kg	0.50	17
SCR-100	kg	6.20	206
Water	m ³	0.40	13.40

IV: Preparation before running the liner:**IV.1: Hole preparation:**

The well must be carefully prepared before running the 7'' liner in order to ensure smooth operations. The following operations shall be carried out:

- Record the well deviation using a TOTCO survey tool at casing points and during intermediate trips
- The 9 5/8'' casing shoe is set at 3280 m and the TD is at 4525 m
- Circulate the well prior to cementing with 140 m³ at 800 lpm and a maximum pressure of 800 psi
- Estimate any possible losses during circulation
- The maximum recorded temperature in BKNS-3 well is 136°C
- Run logging tools including: GR Spectral , SONIC P&S , CALIPER , DENSITY–NEUTRON–GR , RESISTIVITY–GR , pressure measurements and sampling
- Check the stability of the wellbore walls
- Condition and homogenize the mud before running the liner. [3]

IV.2: Equipment preparation:

- Verify the availability of all WELLCARE 7'' 32# P110 N.VAM liner equipment
- Pick up the Float Shoe and connect it to the first joint using Thread Lock, then check the float
- Connect the second joint and then the Float Collar using Thread Lock

- Connect the third joint and check the float
- Connect the Landing Collar and the fourth joint using Thread Lock
- Continue running the 7'' 32# P110 N.VAM liner joints with a make-up torque of 11557 lb.ft
- Fill up the liner every 10 joints
- At the 150th joint, carefully prepare the Liner Hanger Assembly
- Connect the Liner Wiper Plug to the Setting Tool using 6 shear screws and apply grease
- Connect the Liner Hanger Assembly to the liner
- Change the DP elevator and DP slips
- Fill the TBR (PBR) with water and polymer
- All drill pipes shall be drifted with more than 2.6'' drift diameter
- The recommended running speed is 2 minutes per stand
- Do not exceed 800 psi while running in hole with Drill Pipes. [3]

V: Running the 7'' liner in BKNS-03 well:

The objective is to run and cement a 7'' 32# P110 N.VAM liner to the final depth of 4525 m inside the 8 1/2'' hole section with the 9 5/8'' casing shoe set at 3280 m.

Liner composition :

- Float Shoe;
- Two casing joints;
- Float Collar;
- One joint;
- Landing Collar;
- 7'' 32# P110 N.VAM liner;
- WELLCARE 7'' Liner Hanger Assembly.

Running the 7'' Liner :

1. Pick **Float shoe** and connect it to the first joint with Thread lock and check float-OK
2. Connect a second joint and then **Float Collar** with Thread Lock
3. Connect third joint and check float
4. Connect the **Landing Collar** and fourth joint with Thread Lock
5. Continue RIH with 7'' 32# P110 N.VAM liner joints with M/up torque **11557 lb.ft** and fill up every **10 joints**

6. At the last joint (**150th**) **call the Liner man** and pick up the Liner Hanger Assembly carefully by crane.
7. Connect the Liner Wiper Plug to the Setting Tool using **6 shear screws** and grease it.
8. Connect the Liner Hanger assembly with the liner and **pick up 2m** while keeping the sleeps in the table to confirm that the setting tool is carrying the liner.
9. Change the DP elevator & DP slips
10. Fill up the TBR (PBR)with water and **polymer**
11. Start circulating **120%** liner volume (40 m3) (**MAX Pressure=800psi**)
12. Continue RIH with DP and fill every 10 stands and confirm return
13. All drill pipe will be calibrated with more than **2.6" drift**
14. Do not exceed **800 psi** when RIH with DP
15. Running speed is 2 min by stand as average
16. At shoe **9-5/8"** call the liner man and **break circulation** (**MAX Pressure=800psi**)
17. Note the pick up / slack off weight and pressures
18. Continue RIH in Open Hole **Running speed 2-3min/std**
19. If drag inform SV/SH and Liner man (MAX 5 ton)
20. Wash down the **last stand** Call SV/SH on rig floor before start washing
21. Tag Bottom with **2 tons**
22. Record the pick-up/Slack off weight
23. Space out and circulate **bottom up**
24. Insert the **setting ball** and the **dart** in the cementing Head
25. Rig up Cementing Head and connect it to the string
26. Wash down, tag bottom and pick up 1 m.
27. Drop the setting ball
28. After around **45 min the pressure** will start increasing
29. Stop at **2100 psi** and check if the Liner is set, then slack the **liner weight + 10 T**
30. If the setting confirmed, increase pressure to **2900 psi**.
31. Bleed off **to 500 psi** and check the release of the setting tool by **raising 1 m**
32. If the Liner weight is lost increase pressure until the shearing of the Ball Seat at **3400 psi**.
33. If the setting is not released, use mechanical release by left hand ration +3 T slack-off and then a slack off 12 T.
34. Continue circulation and start mixing spacer and cement. [21]

VI: 7" liner cementing procedure:

At bottom 2545

1. Circulate **100 m3** at 800 lpm (**Max pressure 800 Psi**)
2. Rig up wellcare cementing Head , Hall Manifold & test line at **500-5000 Psi**
3. Set liner hanger & release running tool **as per liner engineer Instructions**
4. Circulate **140 m3** prior cement job at **800lpm (Increase flow rate gradually)**
 - Estimate down hole losses while circulation (Mud eng / Mud logger)
5. Cement job as per program (**Mud eng / Mud logger to estimate losses during cement job**)
 - **700 lpm = 4.40 bbl/min , 200lpm= 1.18 bbl/min**
 - Pump 06 m3 spacer 1.50sg (37.73 bbls) at 700lpm
 - Pump 25.02 m3 (157.35 bbls) of batch mixed Slurry cement 1.90sg at 700lpm
 - Drop Dart plug
 - Pump 1.6 m3 (10 bbls) of water behind
 - Displace with mud (cement unit): 21.31m3 (**134 bbls**) at 700 lpm +02 m3 **12.57 bbls** of mud at 200 lpm
 - **Got first bump (157bbl)**
 - Continue displacement pump 7.22 m3 of mud (45.40bbl) @700lpm + 2.0m3(12.58 bbl) of Spacer top of liner @700lpm + 19.41 m3 of mud (122.07bbl) at 700 lpm + 4m3 of mud (25.15)
 - **Got final bump (362bbl)**
 - **Final Bump plug test liner @ 4000 psi**
6. Pooh 10m, and circulate out excess cement & spacer (Mud eng to estimate cement recovered at surface)
7. Pooh running tool meanwhile lay down excess 5"DP. (66 stands =1880m) [22]

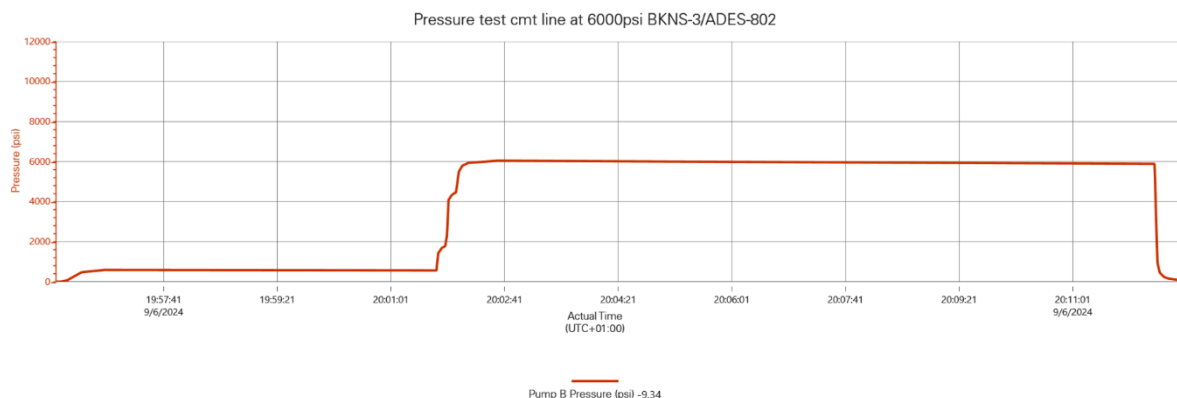


Figure 43 : Pressure test of cementing lines at 6000 psi [22]

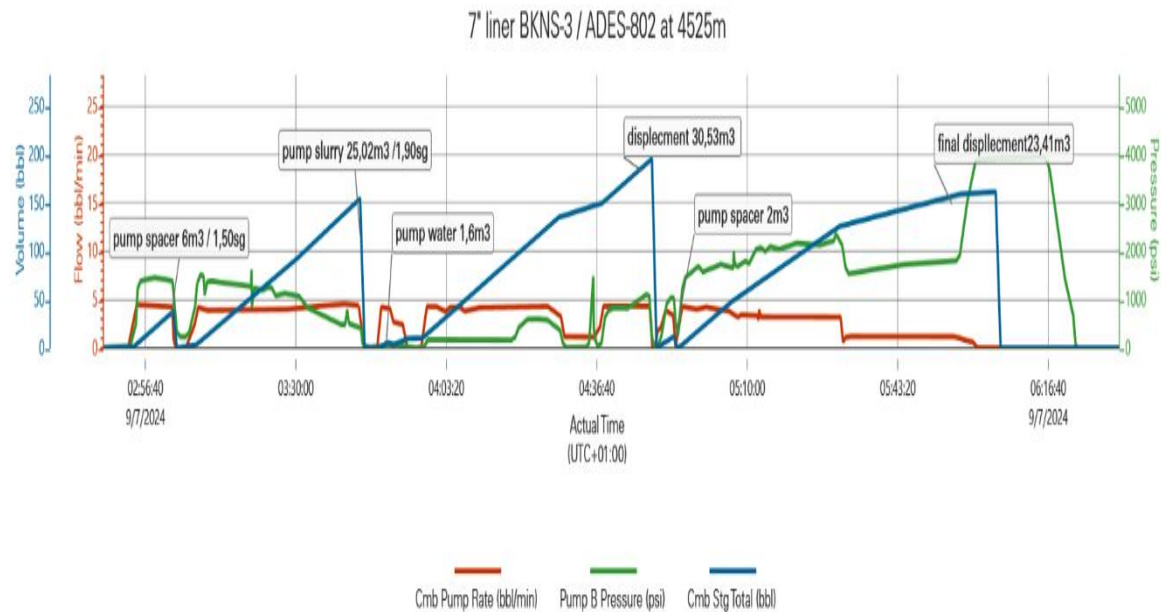


Figure 44 : Monitoring of the 7" liner cementing parameters in BKNS-3 well [22]

VI.1: Logging Evaluation of the 7" Liner Section

Several logging operations were conducted in the 8 1/2" hole section of BKNS-3 well before running the 7" liner in order to evaluate the wellbore condition and prepare the liner cementing operation. The logging program included GR Spectral, SONIC P & S, CALIPER, DENSITY–NEUTRON–GR, RESISTIVITY–GR logs, in addition to pressure measurements and formation sampling operations.

The CALIPER log was used to evaluate the borehole geometry and determine the hole condition before running the liner, while the SONIC and RESISTIVITY logs were recorded to characterize the formation and support cementing preparation. Pressure measurements and sampling operations were also performed as part of the formation evaluation program.

After the 7" liner was run and cemented inside the 8 1/2" open hole section, cement evaluation logging operations were carried out inside the 7" casing. The recorded evaluations included CBL–VDL–GR and GR–CCL–VDL–CBL logs in order to assess cement bond quality, verify cement placement around the liner and evaluate liner integrity.

The interpretation of the recorded logging data showed satisfactory hole conditions before running the liner and confirmed acceptable cement quality after the cementing operation. The results also indicated that the 7" liner was properly cemented and that the liner section was in good condition.

Conclusion

This case study presented the drilling, running, cementing, and evaluation operations of the 7'' production liner in BKNS-3 well. The 8 ½'' hole section was successfully drilled from 3282 m to the final depth of 4508 m using several PDC bits with optimized drilling parameters and oil-based mud systems adapted to the encountered formations. Continuous monitoring of drilling conditions, mud rheology, circulation parameters, and wellbore stability ensured safe and efficient drilling operations throughout the section.

A 7'' – 32 ppf, P110 NEW VAM production liner was then successfully run from 2747 m to 4508 m inside the 8 ½'' open hole section. The liner string included the float shoe, float collar, landing collar, liner hanger assembly, centralizers, and stop collars, ensuring proper positioning and mechanical integrity of the liner inside the well.

The cementing operation was carefully designed based on well geometry, slurry properties, displacement volumes, pumping rates, and pressure calculations. The calculated total slurry volume was approximately 25.02 m³, corresponding to about 157.37 bbl, using ThermaCem II Blend slurry with a density of 1.90 sg. Spacer fluids, displacement sequence, and pumping schedules were selected to optimize mud removal and ensure good cement placement around the liner.

Mechanical verification calculations demonstrated that the 7'' liner satisfied collapse, burst, and tensile resistance criteria with safety factors higher than the required operational limits. Similar verification performed on the drill pipe string also confirmed adequate mechanical resistance under expected operating conditions.

Logging operations carried out before and after cementing provided an effective evaluation of the hole condition and cement quality. Open-hole logs including GR Spectral, SONIC P&S, CALIPER, DENSITY–NEUTRON–GR, RESISTIVITY–GR, pressure measurements, and formation sampling confirmed satisfactory wellbore conditions before running the liner. Cement evaluation logs such as CBL–VDL–GR and GR–CCL–VDL–CBL confirmed proper cement placement, acceptable cement bond quality, and good liner integrity after cementing.

Overall, the drilling and cementing operations of the 7'' production liner in BKNS-3 well were completed successfully according to the operational program. The obtained results confirmed good well integrity, effective zonal isolation, and suitable conditions for future production operations.

REFERENCES

- [1] Guerfi Djelloul and Siagh Mohammed Samir, *Study and Analysis of Poor Cementing Problems in the 8"1/2 Phase: Case of TAOSW#1 Well*, Professional Master's Thesis, Université Kasdi Merbah Ouargla, Faculty of Hydrocarbons, Department of Drilling and Petroleum Construction Mechanics, 2024/2025. accessed in March 2026
- [2] Salem Yassine Abderrahim and Sellaoui Abdelghani, Optimization of Non-Productive Time Using a New 7" Liner Architecture (Berkine Ouest Field), Professional Master's Thesis, Université Kasdi Merbah Ouargla, Faculty of Hydrocarbons, Renewable Energies and Earth and Universe Sciences, Department of Drilling and Petroleum Construction Mechanics, 2018/2019, accessed in April 2026.
- [3] Sonatrach, *BKNS-3 Drilling Program*, Division Forage, Rig: ADES-802, March 2024.
- [4] Djennadi Idriss Moulay, *Cementing and Its Importance in Oil Drilling: Case of Cementing a 7" Liner in a Real Well*, Master's Thesis in Mining Engineering, École Nationale Polytechnique, Department of Mining Engineering, June 2015, accessed in March 2026.
- [5] [J.P.N 93] Jean-Paul NGUEN: Techniques d'exploitation pétrolière -Le Forage ,Editions TECHNIP,1993,PARIS.
- [6] Derradji Mansour and Hamouda Hicham, *Running and Cementing of 7" Liner with Hydraulic Liner Hanger: Application on BBKNP-1 Well*, End-of-Study Thesis, Université Kasdi Merbah Ouargla, Faculty of Hydrocarbons and Renewable Energies and Earth and Universe Sciences, Department of Drilling and MCP, 2016/2017, accessed in March 2026.
- [7] Benchohra Miloud and Elmerahi Mohammed Elhachemi, *Running and Cementing of 4"1/2 Liner in the Hassi Messaoud Field (OMO323)*, Master's Thesis, Université Kasdi Merbah Ouargla, Faculty of Hydrocarbons, Renewable Energies and Earth and Universe Sciences, Department of Drilling and Petroleum Construction Mechanics, 2015/2016, accessed in March 2026.
- [8] Tebib Mahdi, Nouis Fares and Chaïter Abdeslam, *Running and Cementing of 4"1/2 Liner in the Hassi Messaoud Field*, End-of-Study Thesis for the Master Degree in Petroleum Drilling, Université Kasdi Merbah Ouargla, Faculty of Hydrocarbons, Renewable Energies and Earth and Universe Sciences, Department of Drilling and Petroleum Construction Mechanics, 2016/2017, accessed in April 2026.

[9] Le liner Fait par : A. Slimani DIVISION FORAGE DEPARTEMENT FORMATION
Décembre 2002.

[10] HAMOUDA, H. and M. DERRADJI, *POSE ET CIMENTATION DU LINER 7" avec liner hanger hydraulique (Application sur le puits BBKNP-1)*.2017

[11] Aiche, O. and A. Kadi, *La caractérisation du ciment pétrolier local*.2022

[12] Nassima, H. and H. Malha, *Procédure de contrôle de qualité du ciment pétrolier et de l'efficacité des additifs du ciment en deux systèmes de laitiers doux et salé*. 2017.

[13] IFP Training, LA CIMENTATION PRIMAITRE, ENSPM Formation Industrie, 1998.

[14] IFP Training, LES DIAGRAPHIES DE CIMENTATION, ENSPM Formation Industrie, 2005.

[15] Dr Mohamed Said Beghoul, Les diagraphies différées Principes des outils et bases de l'interprétation, IAP Boumerdes, 06-10 Décembre 2015.

[16] Zerrouki, S., *Étude de stimulation d'un puits par fracturation hydraulique (exemple du puits A du réservoir III-A dans le bassin d'Illizi, Algérie)*. 2021, Université Mouloud Mammeri.

[17] DANOUNE, N., *Réalisation de l'opération de cimentation et vérification de leur qualité par la méthode CBL-VDL Application sur la phase 12 ¼"*. 2016.

[18] UDFC, *BKNS-3 ADES-802 Drilling Fluids Program*, SONATRACH Division Forage, March 2024.

[19] WELLCARE, ADES-801 Liner Tally Wellcare, fichier Excel technique, puits BKNS-03, 2024.

[20] Halliburton, *BKNS-3 7in Liner Cement Program V-2 Final*, Well: BKNS-3, Rig: ADES-802, September 2024.

[21] Sonatrach, *Instruction to Run WELLCARE 7" Liner*, Rig: ADES-802, Well: BKNS-3, September 2024.

[22] WELLCARE, *Instruction Cement 7" Liner*, Rig ADES ADES-802, Well BKNS-03, 06/09/2024.