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MEMORY

To obtain the Master's Degree
Option Professional Production

Presented by

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-THEME-

EVALUATION AND INTERPRETATION OF WELL TESTING DATA FROM CASES OF WELLS IMPLANTED IN UNCONVENTIONAL RESERVOIRS (WELL OMKZ421 HMD)

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Dedication

To my source of inspiration … My beloved mother.

To my first and eternal supporter… My dear father.

To my brothers & sisters.

To my friends & colleagues.

To My mentor and examiner for his guidance …

PhD. Zakaria ADJOU.

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And last but not least, I warmly dedicate this work to My Woman.

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Dedication

I dedicate this modest work

Above all to my dear parents who were and my dear wife and children always before me.

To my dear sister and brother each one has his name.

Remember my dear grandparents.

To my great family, my friends and all my gratitude.

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Summary

Résume

Le champ pétrolier de Hassi Messaoud est connu pour sa grande superficie et l'hétérogénéité de ses réservoirs pétroliers, résultant des caractéristiques géologiques et structurelles de la région. Cela a conduit à la nécessité d'effectuer des tests de puits afin de déterminer les propriétés physiques du réservoir, telles que la perméabilité, le facteur de dommage et autres, qui permettent de connaître le modèle de réservoir et ses limites. L'objectif de cette étude est d'utiliser des techniques de test de puits, en particulier le test (Build-Up) dans le puits OMKZ421 a Hassi Messaoud, à l'aide du logiciel SAPHIR KAPPA. Notre étude a identifié la présence de différents régimes d'écoulement, bien que parfois ceux-ci puissent être obscurcis par le stockage du puits de forage lors de l'utilisation d'un dispositif de fermeture de surface. Pour résoudre ce problème, nous avons proposé une solution qui consiste à réduire le stockage du puits de forage en utilisant des vannes d'étranglement de fond de trou au lieu de dispositifs de fermeture de surface.

Mots clés SAPHIR KAPPA, essais des puits, build-up, fermeture au fond, fermeture en surface, débit, pression

الملخص

يتميز حقل حاسي مسعود نفطي بكبر مساحته و عدم تجانس خزائنه البترولية نظرا لطبيعة جيولوجي و هيكلي للمنطقة و هذا الذي أدى إلا ضرورة القيام باختبار البئر التي تسمح بتحديد معاملة الفيزيائية للخزان، مثل النفاذية وعامل الضرر وغيرها ، والتي تستخدم لمعرفة نموذج الخزان وحدوده. الهدف من هذه الدراسة هو استخدام تقنيات اختبار الآبار ، استخدام تقنيات اختبار الآبار وتحديداً اختبار الإغلاق (Build-up) في بئر بحاسي مسعود OMKZ421 مع برنامج سافير كابا. حددت دراستنا وجود أنظمة تدفق مختلفة ، على الرغم من أنه في بعض الأحيان يمكن حجبها عن طريق تخزين حفرة البئر عند استخدام جهاز إغلاق السطح. لمعالجة هذه المشكلة ، اقترحنا حلاً يتضمن تقليل تخزين حفرة البئر باستخدام صمامات خنق قاع البئر بدلاً من أجهزة إغلاق السطح.

الكلمات المفتاحية طرق التفسير، build-up ، إغلاق قاع البئر، إغلاق السطح، معدل التدفق، الضغط

Abstract

The Hassi Messaoud oil field is known for its large area and the heterogeneous nature of its oil reservoirs, resulting from the geological and structural characteristics of the region. This has led to the need for well testing in order to determine the physical properties of the reservoir, such as permeability, damage factor and others , that use to know the reservoir model and its boundaries. The objective of this study is to utilize well testing techniques, specifically the Test Build-Up (TBU) test, in the well OMKZ421, using the SAPHIR KAPPA software. Our study has identified the presence of different flow regimes, although sometimes these can be obscured by wellbore storage when using a surface shut-in device. To address this issue, we have proposed a solution that involves reducing wellbore storage by using downhole choke valves instead of surface shut-in devices.

Keywords SAPHIR KAPPA, build up, bottom closure, surface closure, flow rate, pressure

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P' derivative of pressure.

Pw1hr dynamic bottom pressure at 1 hour (Psi).

Q flow rate (bbl./d).

rw radius of the well (ft).

re drainage radius (ft).

S drainage area (ft 2).

s skin factor.

t time (h).

tp Production time (h).

te equivalent time (h).

B volumetric factor. (FVF= RB/STB).

GOR Gaz Oil Ratio.

C Wellbore storage coefficient (bbl/stb)

CD Dimensionless well capacity.

Ct total compressibility.

hu useful reservoir height.

kw effective water permeability.

ko effective oil permeability (md)

M mobility ratio.

Pwf dynamic background pressure.

Pws static background pressure.

tD Dimensionless Time.

ΔPskin Pressure drop due to skin.

Φ porosity.

µw viscosity of water.

µO viscosity of the oil.

DD Draw Down.

BU Build Up.

LBU Long Build Up.

FO Fall Off.

DST Drill Stem Test.

DHST Down hole shut in tool.

General introduction

In general, the primary objective of conducting well testing is to gather valuable information about both the well and the reservoir it is connected to. This involves manipulating the flow rate of the well, which in turn disrupts the existing pressure conditions within the reservoir. By carefully measuring changes in pressure over time and analysing the results, we can gain crucial insights into the reservoir's behaviour and the productivity of the well.

Transient well testing has gained popularity due to increased drilling activity, and it involves analysing test data using conventional and innovative techniques. Generally, interpreting transient tests that are preceded by variable rate histories requires computer processing. A customized type curve needs to be constructed for each well test, except for the analysis of pressure build-up tests in wells that have undergone an extended drawdown period before the test. However, analysing well test curves remains complex, and interpretation can be challenging due to the wide range of results and potential issues associated with reservoirs and closure tools. The limitations of traditional curve analysis can be overcome by constructing curves that account for flow changes occurring before and during the test. Advancements in computing techniques have facilitated the development of custom curves, resulting in significant progress in well test interpretation. Analysts can also create type curves that consider the potential impact of complex reservoir geometries on the pressure response. These computer-generated type curves are displayed alongside the data and carefully matched to derive precise values for reservoir parameters.

Overall, a comprehensive interpretation of acquired data is crucial for efficient reservoir development and management. It enables the quantification of flow parameters that characterize the dynamic response of the reservoir, such as permeability, effective length, and damage. Therefore, this note presents five chapters. The first chapter provides a brief overview of general aspects related to Hassi Messaoud's field. Chapter Two offers a comprehensive overview of the well tests used in the field and provides a thorough understanding of fundamental reservoir parameters. Chapter Three introduces essential tools for evaluating underground well closure during testing. Moving on to Chapter Four, the methods for interpreting a build-up test are outlined, along with their practical application. Lastly, in the final chapter, we address the challenge of measuring well production characteristics, including skin and porosity, and propose an improved methodology to obtain more accurate results by conducting a build-up test on one of the unconventional wells in the Hassi Messaoud field (OKMZ421 well).

CHAPTER I

Hassi Messaoud Field Generalities

Introduction

The Hassi Messaoud deposit is one of the largest and most complex deposits in the world. During geological history, this deposit underwent an intense tectonic evolution during its burial until the deposit took the current form. These events can improve Petro-physical parameters (natural fracturing, dissolution) as they can reduce them (reduction of porosity, cementation of grains, creation of small grain matrices, creation of impermeable barriers).

This field covers an area of about 2500 km2. Discovered in 1956 and put into widespread production in 1958, the Hassi Messaoud field continues, after more than 50 years, to provide Algeria with this natural resource that is crude oil. Significant investments have been made and others will be made in the future to extract the maximum amount of oil and thus increase the final recovery.

I.1 Hassi Messaoud in the map

I.1.1 Location

The Hassi Messaoud field is located 650 km South-South-East of Algiers and 350 km from the Tunisian border (Figure I.1). Its location in coordinates Lambert is as follows 790.000 @ 840.000 Est * 110.000 @ 150.000 North

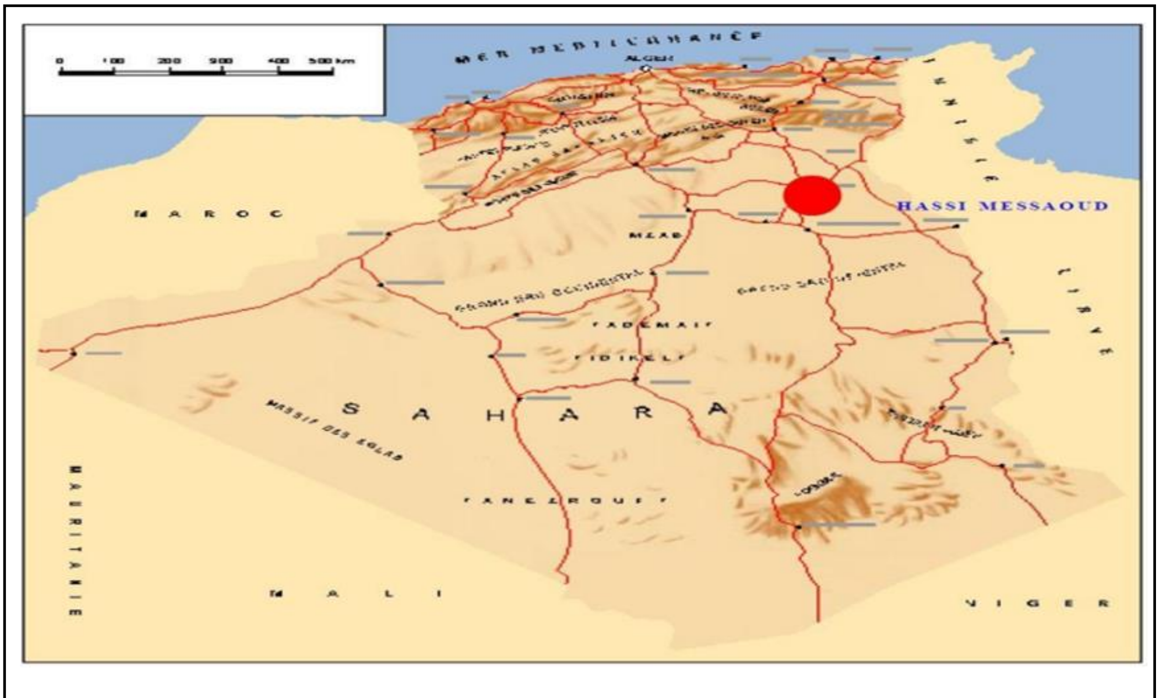

Figure I.1 : Geographical location of the Hassi Messaoud field [1]

I.1.2 Geological situation

The Hassi Messaoud field occupies the central part of the Triassic province east of the Oued M'a depression in district IV which by its area and reserves is the largest petrogaseïfere province(Figure I.2). It is the largest deposit in Algeria which extends over 53x44 km of area. It is limited

- To the northwest by the deposits of Ouargla (Guellala, Ben Kahla and Haoud Berkaoui).
- To the southwest by the deposits of El Gassi, Zotti and El Agreb.
- To the south-east by the deposits; Rhourde El Baguel and Mesdar.
- On a larger scale, it is limited
- To the west by the depression of Oued M'ya.
- To the south by the pier of Amguid El Biod.
- To the north by the Djamâa - Touggourt structure.
- To the east by the shoals of Dehar, Rhourde El Baguel and the depression of Ghadames.

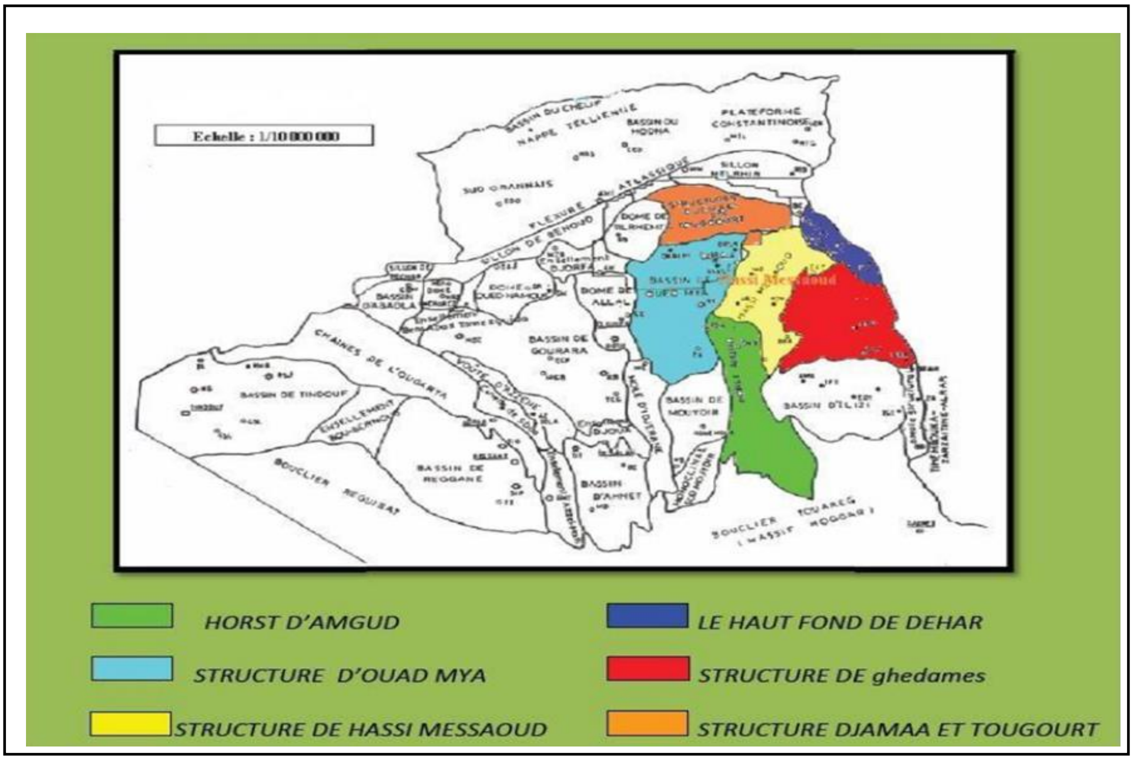

Figure I.2 : geological situation of the Hassi Messaoud field [1]

I.2 Description of the HMD reservoir

The Hassi Messaoud deposit has a depth that varies between 3100 and 3380 m. Its thickness goes up to 200 m, it includes three sandstone reservoirs of Cambrian age, resting directly on the granite basement. It is represented by a sandstone series whose Paleozoic post erosion affects part in the center of the field.

It is subdivided from top to bottom of :

- **Ri** Isometric zone whose thickness is 45m essentially quartzite with fine grains and Tigil lites. It corresponds to drain D5.
- **Ra** Isometric zone with an average thickness of about 120m, composed of silico-clay cement sandstone of medium to coarse grains. It is subdivided into drains respectively from bottom to top D1, ID, D2, D3, D4.
- **R2** Clay cement sandstone series, with an average thickness of 80 m.
- **R3** With a height of about 300 m, it is a very coarse to micro-coagulometric sandstone series, very clayey resting on the granite base that was encountered at a depth of less than 4000m, it is a pink porphyroid granite.

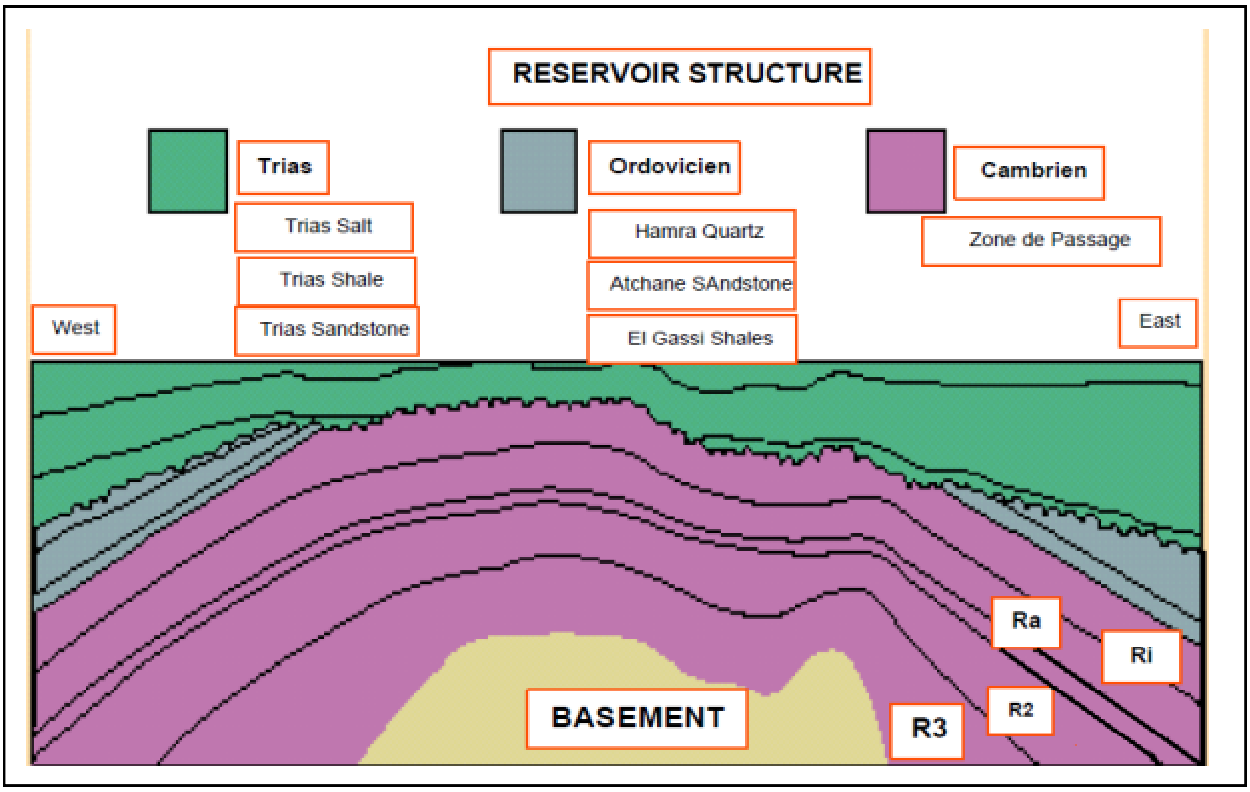

Figure I.3 : geological section of the Hassi Messaoud field [2]

I.3 Zonation and well numbering

The Hassi Messaoud field is divided into numbered areas. This division is naturally deduced from the characteristics of production and geology.

Changes in well pressures, depending on production, have made it possible to subdivide the field into 25 producing zones (Figure I.4). A production area is defined as a set of wells that communicate with each other but little or nothing with those in neighboring areas. It should be noted that the current subdivision is not satisfactory because the same area can be subdivided into subzones.

The Hassi Messaoud field is divided from east to west into two distinct parts the south field and the north field, each has its own numbering.

The North Field It is a geographical numbering supplemented by a chronological numbering, example Omo38, Onm15, Ompz16*

O Capitalization, Ouargla permit. m area of the oil zone 1600 km2. o Minuscule, area of the oil zone of 100 km2, 3 Abscissa and 8 ordinate.

The South field Zone numbering is chronological. Ex MD1, MD3, MDZ509

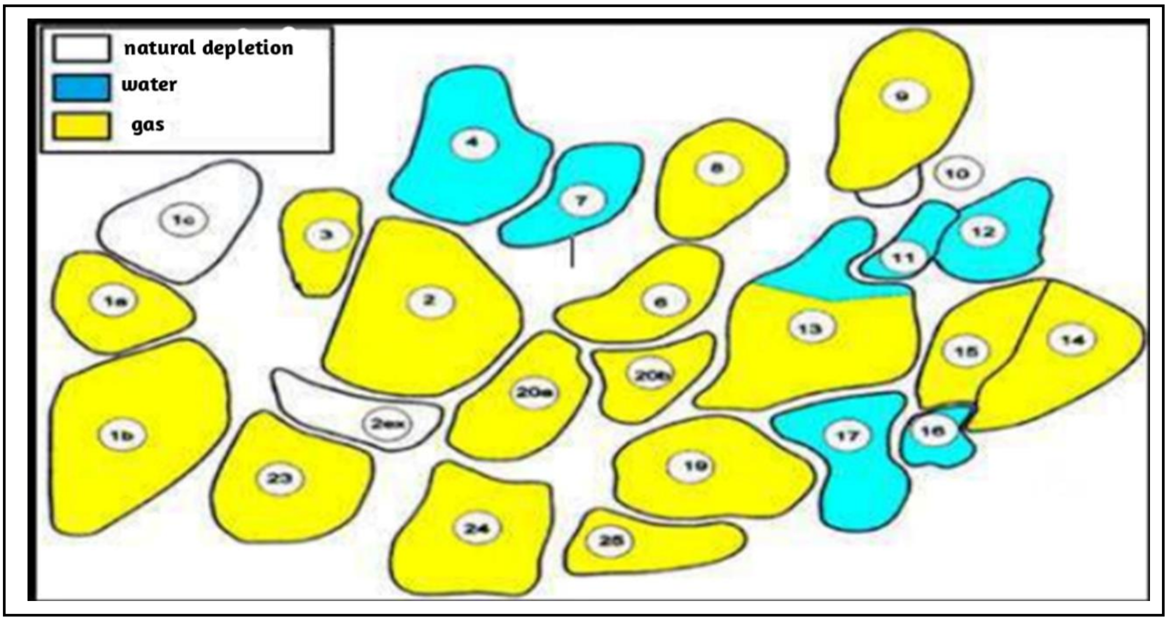

Figure I.4 : Zonation of the Hassi Messaoud field [10]

CHAPTER II

Theoretical and background on well testing

Introduction

It is crucial for producers to have a solid grasp of the reservoir concept and petrophysical parameters while also assessing the condition of the well's surroundings and evaluating the operations performed on the well. To achieve this, a well test must be conducted, and the results must be interpreted using various methods. The skin and permeability are the most critical factors to consider. The skin and pressure losses resulting from it indicate the level of blockage within the deposit rock by different agents such as drilling mud, cement, and residues from perforation operations.

This chapter aims to provide a fundamental understanding of well testing and interpretation techniques, particularly the methods used to determine skin due to blockages.

II.1 Principle of well tests

The basic principle of a well test is to create a disturbance of the existing pressure regime in the reservoir by changing the flow rate of the well. The evolution of the transient well pressure as a function of time is recorded over a period determined according to the intended purpose of the test. Then we make an interpretation of the results.

In general, flow rates are measured at the surface while pressure is recorded at the bottom of the well. The pressure is constant and uniform in the reservoir before the well is put into production. Then it decreases during the flow period. On the other hand, in the event that the well is closed following a production period, this pressure rises. **[18]**

The evolution of pressure is interpreted using some laws of fluid mechanics.

II.2 The purpose of well testing

The analysis of well tests provides information about the reservoir and the well. The results of well tests, combined with geological and geophysical studies, are used to construct the reservoir model, which will be used to predict field behavior and recovery, depending on operating conditions. The quality of communication between the reservoir and the well indicates the potential to improve well productivity.

In general, the purpose of well testing is

- Assess the production capacity, or potential, of each well.
- Determine the nature and/or characteristics of the fluids produced.
- Evaluate the characteristics of the reservoir.
- Control the effectiveness of a completion or treatment on the reservoir.
- Control the efficiency of production operations.
- Determine the effective production rate of each well.

For this, it is necessary

- Take a sample of the fluids produced.
- To know the flow rate of the fluids produced.
- To know the evolution of the background pressure and the bottom temperature following a variation in flow.

II.3 Information obtained from well tests

Each well test must be followed by an interpretation to derive the necessary information for the reservoir engineering.

The main search parameters are

- Static pressure.
- Knowledge (nature) of fluids.
- Well productivity (PI).
- Well and reservoir configuration **[3]**
- Reservoir limits.
- The drainage area.
- Permeability.
- Damage to the area around the well.
- The radius of investigation.
- Anisotropy of permeability.
- Flow efficiency.
- Fault detection, and distances between faults and the well.

II.4 Types of well testing

Well tests can be classified by several criteria

- **According to the test timeline**

We have the initial tests (drill stem test), and periodic tests. Online test (GOR test)

- **Depending on the number of wells included in the test**

We have single-well tests (build up, draw down, fall off); and multi-well tests (interference test; pulse test)

- **Depending on the type of well**

test of producer wells (build up; draw down) and tests of injector wells (injectivity test; fall off).

- **Depending on the test mode**

By closing the well (build up; fall off)

By opening the well (draw down; injectivity test)

In several successive closures and openings (DST; test interference; pulse test)

II.4.1 Draw down

The well initially in the static state (closed) is opened for flow at a supposedly constant flow (Figure II.1), for a time. From flow -t-, the pressure decline is recorded.

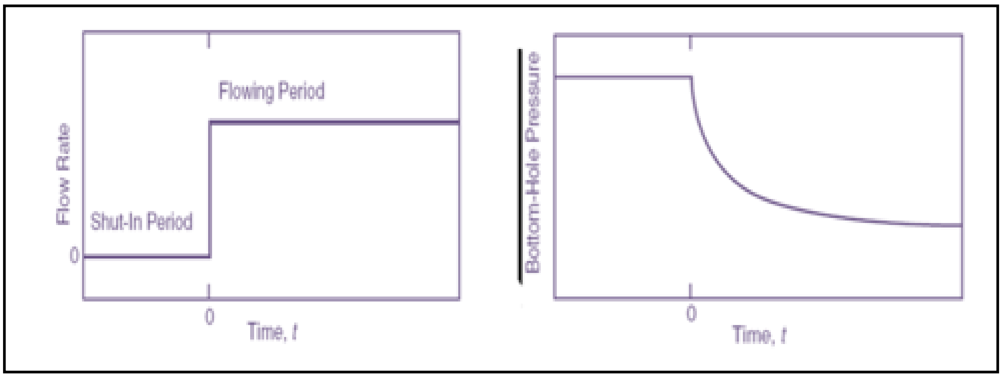

Figure II. 1 : Draw down [11]

Disadvantages

- ➢ Difficult to control the flow of the constant well.
- ➢ Difficult to master the well in static condition.

- **The advantages**

- ➢ No influence on (economic) production.
- ➢ Good methods to test the limits of the reservoir of the or significant flow time.

II.4.2 Buildup

The pressure rise test is an operation opposite to the draw down, the well that is in production at a constant flow rate is closed for time (Figure II.2),

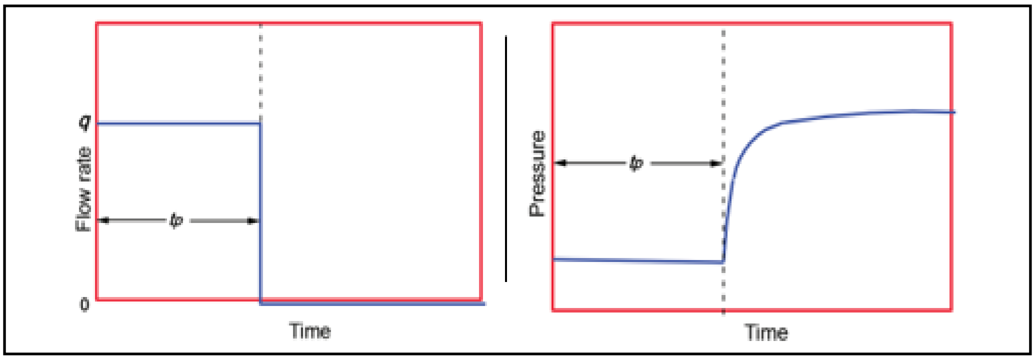

Figure II. 2 :Test build up [13]

- **Advantages**

- ➢ The practical advantage of the test is that the flow rate is made stable.

- **Disadvantages**

- ➢ Loss of production at well closure.

II.4.3 Injection

The injection test is identical to Build up, except that the pressure is at the place of falls.

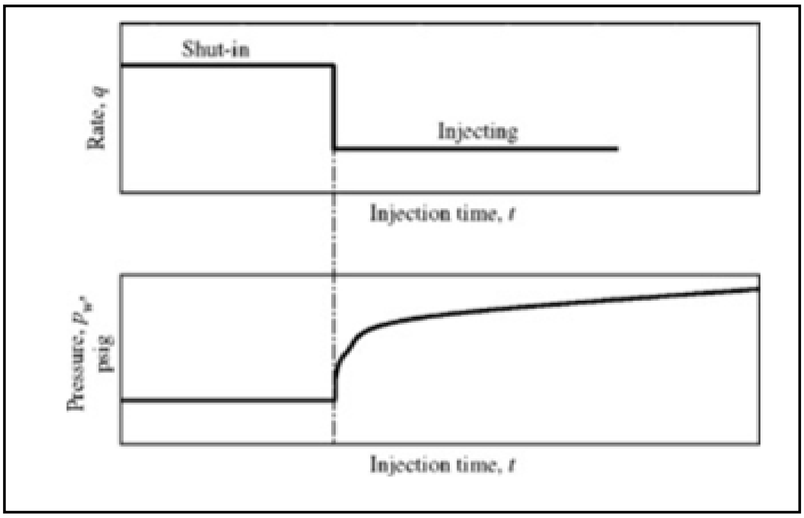

Figure II. 3 : Injection test [15]

- **Disadvantages**

➢ Analyses can be complicated by injection fluid effects unless the injected fluid is simulated as a fluid produced

- **Advantages**

➢ The injection rate is often well and easily controlled

II.4.4 Fall off

A fall off measures the pressure decline that corresponds to the closure of the injection well (Figure II.4),.. Interpretation is very difficult when the injecting fluid is different from the reservoir fluid.

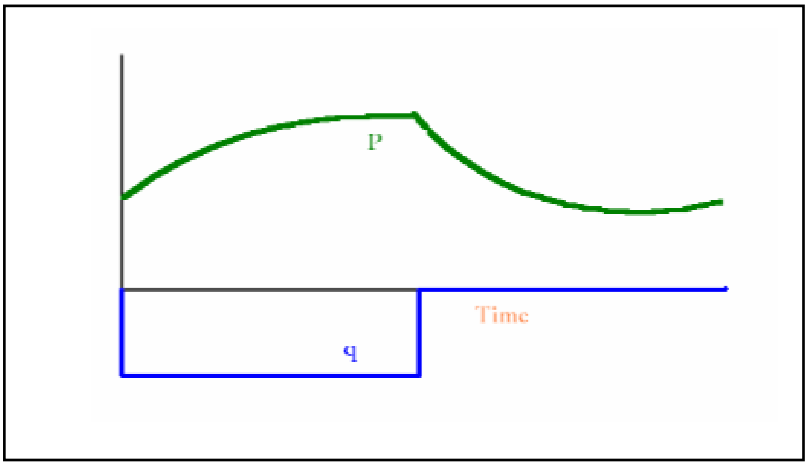

Figure II. 4 : Fall off test [14]

II.4.5 Interference Test

This test requires a well in production and the pressure is observed on at least 3 closed wells, this test is very useful to characterize the properties of the reservoir on a very large scale compared to simple tests, pressure changes at a distance from the producing well can be very small.

So, the interference test requires very sensitive pressure sensors and this test takes a long time to perform and can also be done without looking at the type of indirect pressure change by active wells, (draw down, build up, injection, fall off).

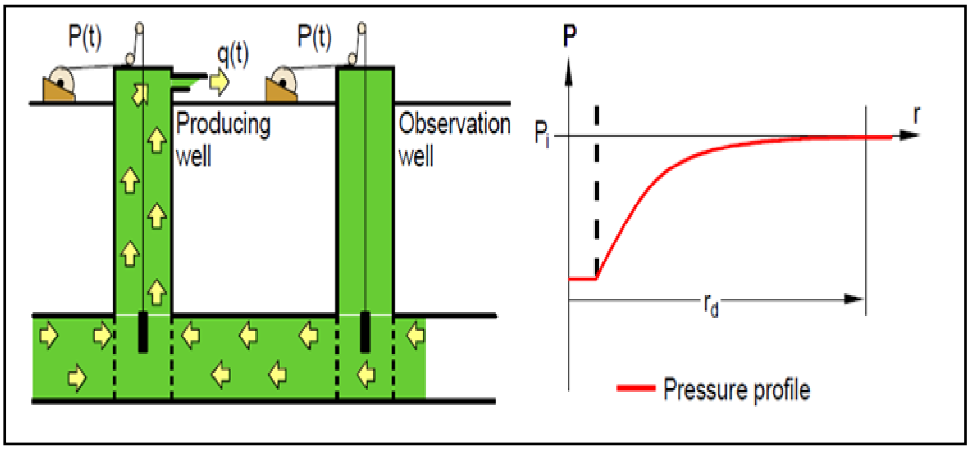

Figure II. 5 : Interference test [4]

II.4.6 D. S. T (Drill Stem Test)

It is a test used in a newly drilled well we use special tools mounted at the end of a rod (Drill string). A common test sequence is to produce, shut in, produce again and shut in again. Drill stem tests can be quite short, since the positive closure of the downhole valve avoids wellbore storage effects (described later). Analysis of the DST requires special techniques (Figure II. 6), since the flow rate is not constant as the fluid level rises in the drill string. Complications may also arise due to momentum and friction effects, and the fact that the well condition is affected by recent drilling and completion operations may influence the results. [12]

II.5 Well testing equipment

II.5.1 Surface Testing equipment

The basic surface equipment is as follows

- **Control head also called eruption head**

It is equipped, among other things, with a safety valve.

In particular, it makes it possible to direct the effluent to the surface installations and to close the overhead well if necessary.

- **Choke manifold**

it is used to control flow rate and reduce fluid pressure to protect downstream process equipment [16]

- **Heater or steam exchanger**

It heats the gas to prevent the formation of hydrates. In this case, the gas expansion is not done all at once at the Choke manifold, but in several times. In particular, there is a mid-coil nozzle in the heater or exchanger.

- **Separator**

It makes it possible to separate the different fluids (gas, oil and water possibly) and thus it allows the counting and sampling of each of these fluids separately.

- **Storage bin**

At certain times during the test, the oil leaving the separator is sent there. This makes it possible to calibrate the oil meter (s), to take into account certain phenomena such as the degassing of the oil downstream of the separator or the additional settling of water that is still dispersed (emulsion) in the oil at the outlet Separator oil.

- **Basin and gas torch or burners**

They make it possible to evacuate the fluids produced.

- **Emergency Shut Down (ESD) system**

It allows the well to be closed and the surface equipment to be brought

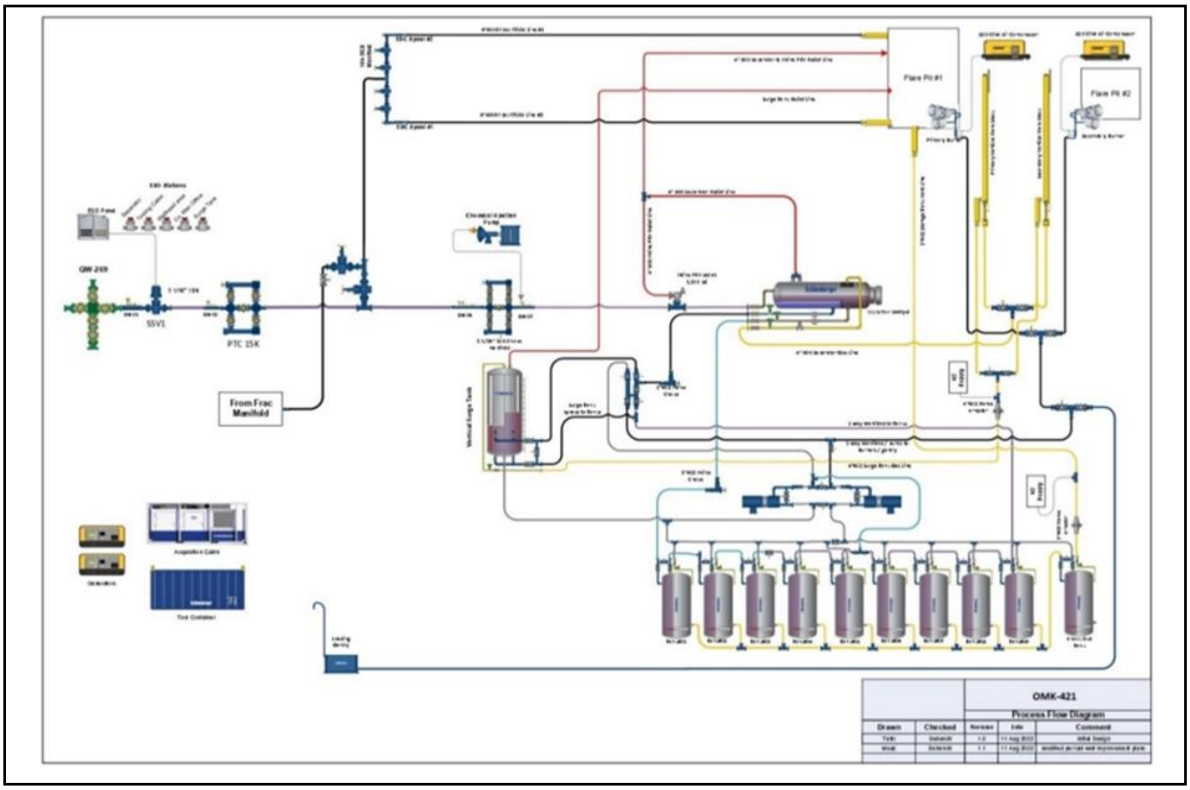

Figure II. 6 : PFD Surface Testing Equipment

II.5.2 Down Hole equipment

The basic elements of a test trim, in particular to perform the functions seen in the previous paragraph, are as follows

- **The tubular itself**

consisting as the case may be of drill pipes or tubing. This tubular is used for

Duct for the effluent that will be produced,

Support for other elements.

Drill pipes are particularly used in the case of short-term Drill Stem Test

(DST) of a low or medium pressure area. In other cases, and especially if

there is a risk of sulfuric acid (H2S), it is preferred to use tubing that

have a better seal at the level of the connections

- **Tester**

It is mainly a valve that can be opened or closed at will.

Lowered closed, it is surmounted inside the rods by a cushion of liquid of suitable density and height (water or diesel buffer for example) so that the corresponding hydrostatic pressure is lower than that of the fluids present in the area to be tested.

- **Packer**

This rubber sleeve located above the area to be tested is applied to the walls of the hole by compression, performs the seal and separates the well into two zones without communication between them.

- **Recorder holders**

They receive the pressure and temperature loggers.

Depending on their position and arrangement in the lining, pressure recorders make it possible to record either the pressure inside the lining or the pressure outside the lining, and therefore in particular the evolution of the bottom pressure during the flow phase (draw down) and during the closing phase. (build-up).

- **Equalization valve**

Performing the test results in a pressure regime under the packer that is different from the hydrostatic pressure of the sludge above the packer.

In order to be able to decompress and unanchor the packer at the end of the test, it is essential to equalize the pressures on both sides of the packer. **[19]**

For this we use an equalization valve located between the packer and the tester. At the end of the test, it opens a communication between the ring finger and the inside of the test lining (part below the tester) and therefore

- To equalize the pressures on both sides of the packer.
- To repel the effluents produced (located in the lining below this point) into the tested formation by pumping drilling mud at the head of the annular space, the annular jaws of the BOPs being closed.

➢ **Reverse circulation device**

At the end of the test, if the well has been productive, the test train is partially or completely filled with effluent. It is then dangerous to perform the ascent maneuver with this flammable fluid inside the test lining.

A reverse circulation device, located above the tester, allows an opening on the annular space and the effluent located in the seal to be recovered by circulation. For safety reasons this valve is usually doubled.

II.6 Well testing closure methods

To perform a well test that requires closure (BU_DST) one of the following two modes can be applied

II.6.1 Surface closure

Generally, until today, the closures of producing wells for background pressure recordings are done on the surface by default of tools allowing the closure at the bottom of the well, knowing that the closer we approach to the reservoir or perforated areas, the faster the pressure rises and this helps us to eliminate or at least to minimize the phenomenon of fluid compression (wellbore storage) which is determinate to the interpretation of the Well tests to locate the first radial.

Surface closure for pressure build-up recording can even be observed during end-of-drill production (DST) test operations by failure of downhole valves lowered with the test string.

II.6.2 Downhole closure

is increasingly important to better analyse the PBU (Pressure Build Up) well tests carried out on the various producing wells in Hassi Messaoud by reducing the capacity effect of the WBS (Wellbore Storage) well, pressure responses will not be masked in this way the pressure and the derivative will be representative and lead us to a good interpretation of the test.

For this reason, we have made a general study on the Down Hole Shut in Tool (DHST); In the following we will present

- The technical specifications and operation of different tools lowered into the wells of the HMD field.
- The advantages and disadvantages of the tool.
- Constraints of use.

So far, there are three models of operational closure tools in Hassi Messaoud that belong to service companies.

The trade names of these tools are BEST, DATACAN and SMART.

Conclusion

A well test is a meticulous operation that requires careful preparation to ensure the acquisition of comprehensive information while prioritizing maximum safety. It is crucial to gather as much relevant data as possible during the test, including pressure transient data, fluid composition, and reservoir characteristics. This information allows engineers and geologists to accurately evaluate the reservoir's properties, such as its size, permeability, and potential for hydrocarbon extraction. Additionally, recording detailed information about the test's execution is essential for future reference and analysis. By meticulously planning and executing well tests, operators can make informed decisions regarding reservoir management, production optimization, and overall operational efficiency.

CHAPTER III

Description of down hole shut-in tool DHST

Introduction

The down hole shut in tool is a tool that aims to ensure well openings and closings, near the perforation area by minimizing production downtime (expensive). During operations called flow after flow or isochronous test (with the same principle as DST), therefore, the test will provide extended data (mainly pressure) for future reservoir project planning.

III.1 Operating principle

Down Hole Shat-in Tool (DHST) It is an electromechanical tool; its operating principle is to lower the tool into the well by a lock mandrel and the seat at the Nipple (RN) in order to ensure one or more openings and pre-programmed well closures on the surface (Figure III.1),.

The (DHST) is a very reliable solution for the Build-up test which is will provide data thus extended (mainly pressure) for future project planning of the reservoir.

III.2 Composition of DHST

The down hole shut-in tool consists of three essential parts

a) mechanical part (the valve).

b) electronic part (brain)

c) Power supply part (battery).

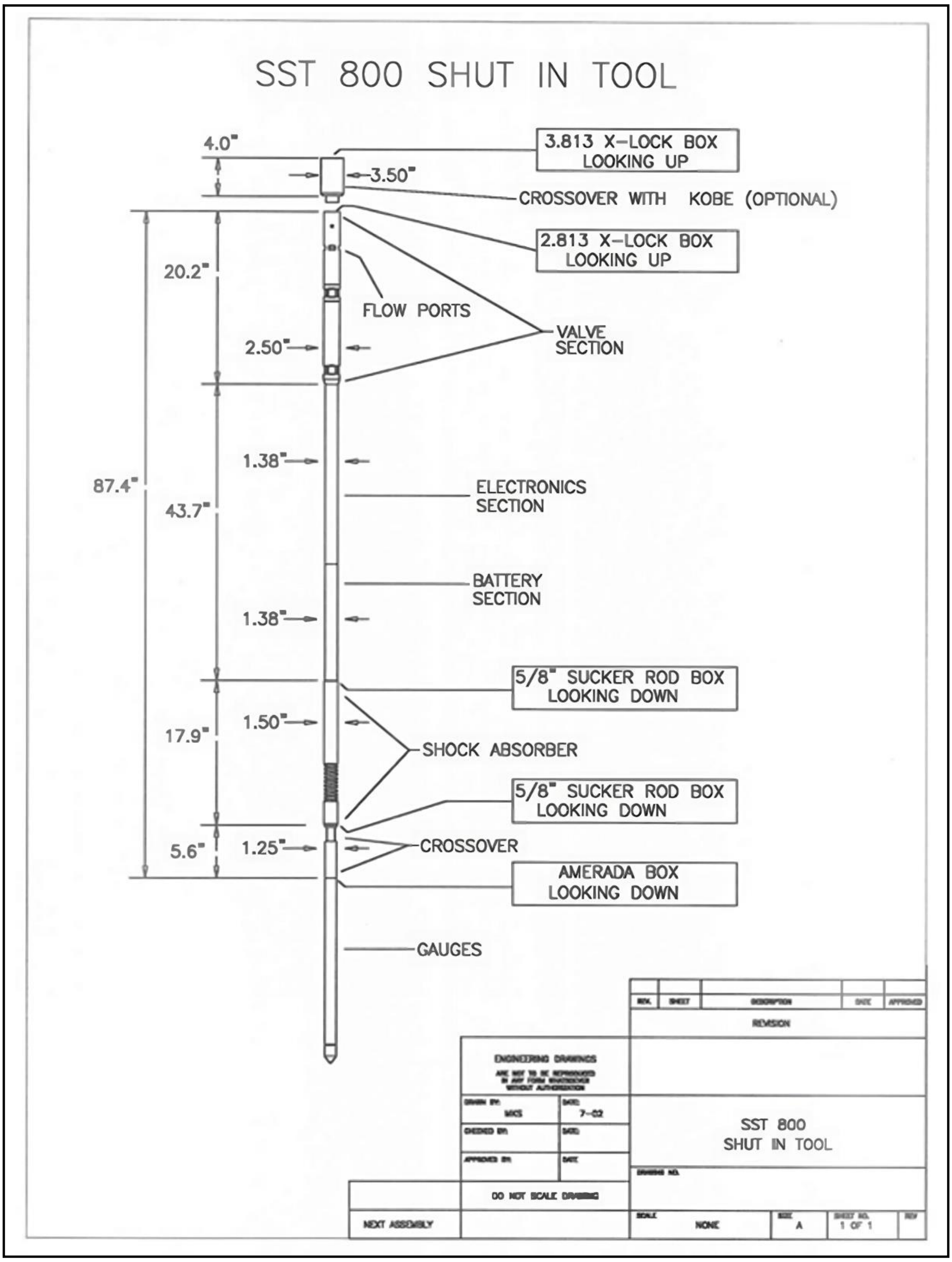

Figure III. 1 : DHST tool composition[5]

III.3 Types of DHST

The types of this tool can be classified according to the diameter of the completion column as follows

SST500 → 2”7/8

SST800 → 3.5”, 4.5”

SST1200 → 5”

III.4 Advantages

a) Short closing time (less than 60 seconds).

b) Custom programming up to 20 cycles via computer (you can get to 40 cycles with a specific type of batteries).

c) Manual programming of surface events without the use of a computer (single shot).

d) The entire construction is made of stainless steel which allows durability and corrosion resistance.

e) pressure responses will not be masked well bore Storage.

III.5 Disadvantages

a) Very sensitive to solid and debris (asphaltenes).

III.6 Tool feature

Down hole shut in tool for a 3 1/2'' tubing

Table III. 1 : Characteristic of DHST for a 3 1/2'' tubing

Waist	**1.6 m with short battery pack**
Outer diameter	**6.35 cm maximum**
Inner diameter	**4.5 cm**
Temperature	**160°C**
Max Pressure	**103. Kpa**
ΔP max	**69 Kpa**
Flow area	**2.4 in^2 (6.1 cm^2)**
Doors	**20 cycles**
Power Supply	**18 V**
Weight	**12.7 kg**

III.7 Course of the operation at the well

During the course of operations at a well, a carefully orchestrated sequence of steps is followed to ensure the efficient and safe execution of various tasks , Operation requires several the assembly consisting of Slickline and Downhole shut-in tool, to the bottom of the well . See Appendix

CHAPTER IV

Methods of Interpreting a Build Up test

Introduction

Of the many methods used to interpret a well test, these methods can be classified into two main families

- Conventional methods.
- Methods using standard curves.

The methods of interpretation depend on the nature of the well, the nature of the reservoir and the boundaries of the reservoir. For this, the methods of interpretation are always conditioned by the limits of application. Interpretation methods (whether conventional or based on standard curves and these derivatives) use certain mathematical tools. The main equation used in this field is the diffusivity equation based on mathematical equations that express physical phenomena. In these methods we take as consideration monophasic flow of oil in the case of a vertical well in an infinite homogeneous reservoir. Methods using standard curves appeared in the 1970s, but were not disseminated and did not take their full extension until the 1980s. On the other hand, conventional methods were developed from the 1930s, they were the only ones available until 1970.

IV.1 Fundamentals of well testing

IV.1.1 Well capacity

When performing build-up or draw-down tests, the flow rate changes slowly at the bottom of the well. This is due to the well capacity effect because when the volume of the fluid column is large, the compressibility of it is no longer negligible. The volume of fluid delays the establishment of the flow setpoint.

$$C = \frac{\Delta V}{\Delta p} = \frac{Volume\ Variation}{pressure\ variation} \qquad \text{(IV.1)}$$

The disadvantage of this well capacity is that it often masks the initial data of well tests. this is why most conventional tests take a long time to record the test data (long-time tests) in order to overcome this capacity effect. Wellbore Storage is due to the compressibility of the fluid column of the formation at the point of closure. **[20]**

IV.1.2 The skin

The surroundings of wells (damaged zone) have different characteristics from the remote zone of the deposit (known as virgin zone). This phenomenon can have many sources Damage due to drilling, well treatment, various deposits. The skin characterizes the effect of this damaged area on fluid circulation. It is defined quantitatively by the dimensionless pressure drop

$$\Delta P_S = \frac{\alpha q B \mu}{kh} S \qquad \text{(IV.2)}$$

Where ΔP is the pressure drop in the damaged area.

IV.1.3 Radius of investigation

The investigation radius is a depth characteristic of the evolution of the flow profile in the reservoir it corresponds to the compressible zone.

IV.1.4 Flow regimes

Several flow regimes that depend on the position of the compressible zone.

The flow regime is influenced by the type of well, the well reservoir configuration, the heterogeneity of the reservoir. See Appendix

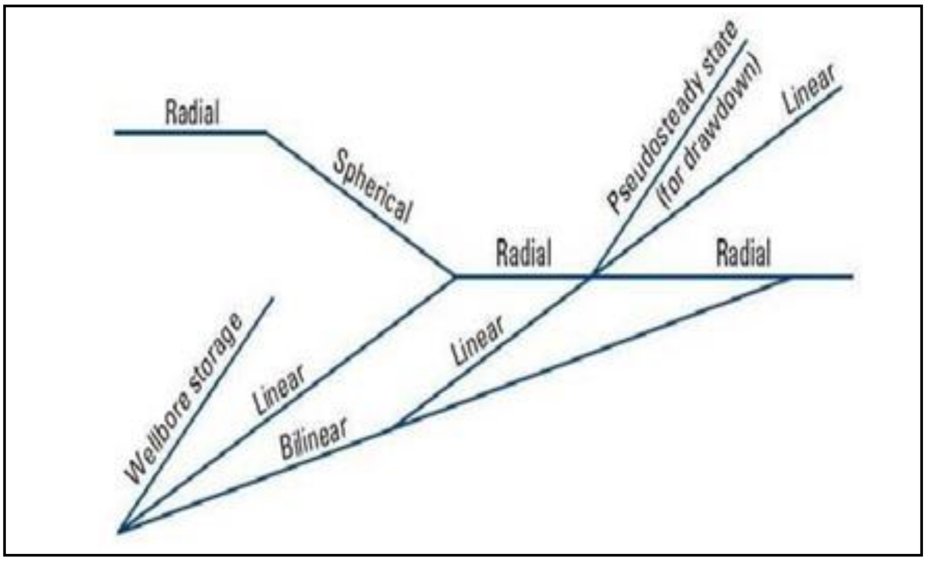

Figure IV. 1 : Flow regimes [6]

IV.2 Objectives of build-up test

The objectives of this test are to evaluate and analyze

- The effective permeability of the reservoir.
- The trouble Interpretation (the effect capacity) [6].
- The average reservoir pressure.
- The boundaries of the reservoir.
- The rate of damage to the formation (SKIN).

IV.3 Methods of interpretation

IV.3.1 Classic methods of interpretation

Horner method

The concepts used are

- Pwf (t) The flow pressure; time is running out since the beginning of production.

- Pws (Δt) The pressure rising pressure; the time is counted from the moment tp of well closure Pws (Δt = 0) = Pwf (tp If we draw the graph that shows the variation of the pressure as a function of time

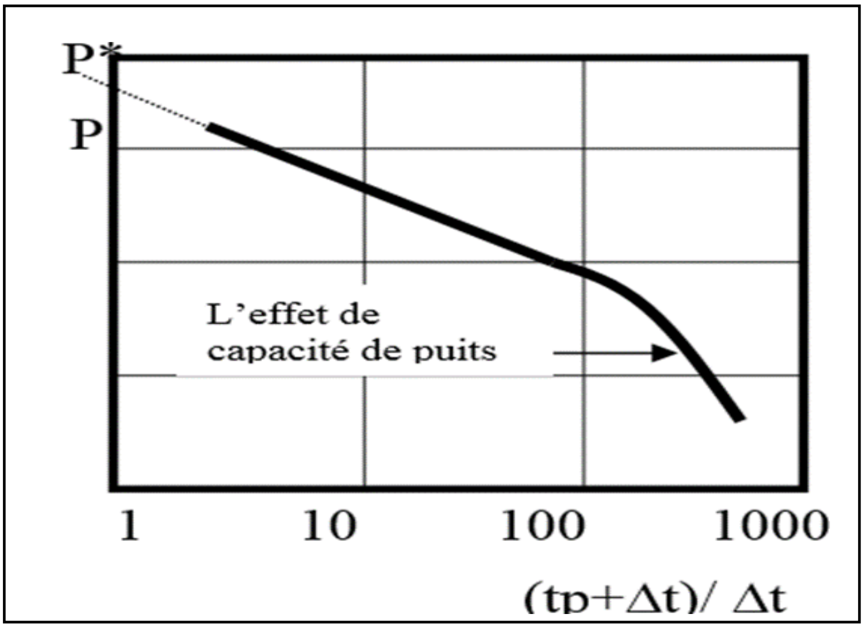

Figure IV. 2 : Horner curve. [7]

- ❖ **Permeability**

En can calculate the reservoir permeability from the previous equation

$$k = \frac{162.6\, q\, B\, \mu}{mh} \qquad \text{(IV.3)}$$

- ❖ **Interprétation**

Once the effect of the well capacity is completed, a straight slope m is observed. This value (m) is given by Saphir software

$$m = \frac{162.6\, q\, B\, \mu}{kh} \quad \text{(US)} \qquad \text{(IV.4)}$$

- ❖ **Pressure drop due to skin**

$$\Delta Ps = \frac{141.2q}{kh} = 0.87mS \qquad \text{(IV.5)}$$

- ❖ **The skin**

The skin value is calculated from the difference between

- the value of the pressure after 1 hour of pressure rise on the semi log line.
- and the value of the pressure at the time of well closure. In deducted

$$S = 1.151[\frac{P_{1h} - P_{wf}(t_p)}{-m} + \log\frac{t_p+1}{t_p} - \log\frac{k}{\emptyset\mu\, C_t r_w^2} + 3.23] \qquad \text{(IV.6)}$$

❖ **The extrapolated pressure**

The extrapolated pressure value (P*) is calculated from graph when

$$\Delta t \to \infty \ \text{soit} \ \frac{t_p+\Delta t}{\Delta t} = 1 \tag{IV.6}$$

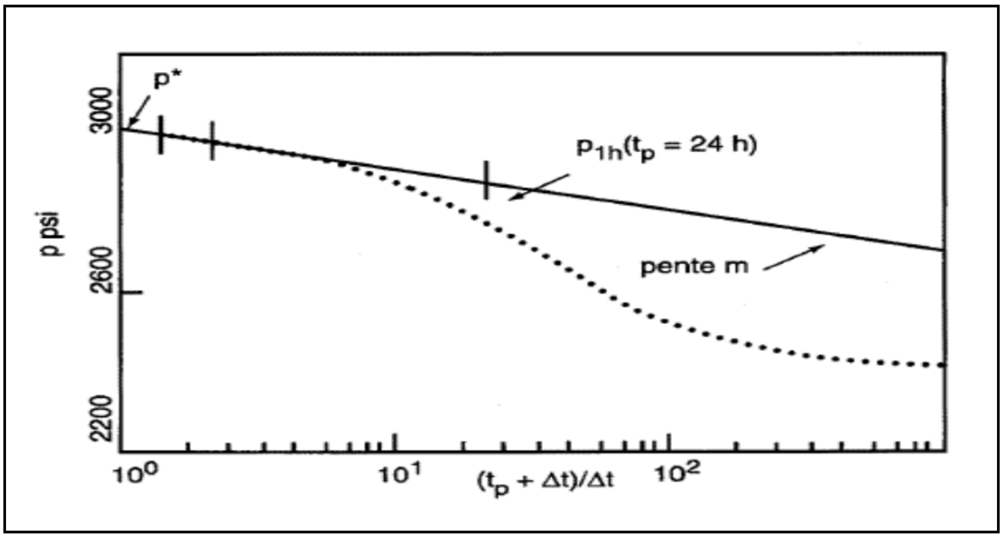

Figure IV. 3 : Pressure extrapolated from Horner curve [17]

❖ **Flow efficiency**

$$FE = 1 - \frac{\Delta Ps}{p_m - p_{wf}} \tag{IV.7}$$

With Pm the average pressure

Note

To interpret a pressure, rise after any production history, replace the history with one flow = the last flow

Fictitious production time is equal to

$$t_{pf} = \frac{\text{Cumulative production}}{\text{last flow}} \tag{IV.8}$$

Semi-logarithmic analysis

The semi-logarithmic approximation method gives a solution of the differential equation. This method uses the principle of superposition, HORNER presented it as the basis for build-up analyses; or he gives it its name.

$$\frac{\partial^2 p}{\partial r^2} + \frac{1}{r}\frac{\partial p}{\partial r} = \frac{\phi \mu c_t}{k}\ \frac{\partial p}{\partial t} \tag{IV.9}$$

The HORNER method gives the expression of the pressure Pws by the formula

$$P_{ws} = Pi - \frac{162.6\ q\ \beta\ \mu}{kh} \log \frac{tp+\Delta t}{\Delta t} \tag{IV.10}$$

With

pi The initial reservoir pressure (psi) .

q The fluid flow velocity over a specified period expressed in (STB/B).

B The volumetric factor of the background (RB/ STB).

h The height (ft.)

µ The viscosity (cp) .

k Permeability (md).

tp Production time (hr).

The semi-log plot of log ((t p + Δ t)/ Δ t) against

The pressure, which builds a straight slope. Equal to

$$\mathbf{M} = -\frac{\mathbf{162.2\ q\ B\ \mu}}{\mathbf{k}} \tag{IV.11}$$

From this value of the slope, we draw the unknown kh. The extrapolation of the line on the y-axis represents the pressure value for a t=1hour. The expression of the skin according to HORNER is

$$\mathbf{S = 1.15(\frac{p_{1hr} - p_{wf(\Delta to)}}{m} - \log\frac{k}{\phi\mu c_t r_w^2} + 3.23)}$$

(IV.12)

P_{wf} (Δt=0) =The value of the pressure at the bottom of the well.

MDH method (miller- dyes and Hutchinson)

$$\boldsymbol{P_i - P_{ws}(\Delta t) = \frac{\alpha q\mu B}{kh}\log[\frac{t_p+\Delta t}{\Delta t}]} \tag{IV.13}$$

- The expression shows that the pressure varies linearly as a function of logarithm of (tp+Δ t)/Δt.
- This expression can take a simplified form whenever the production time tp is important in front of the pressure rise time Δt, so (tp + Δt / tp). Then the equation becomes as follows

$$\mathbf{P_i - P_{ws} = \frac{162.6q\mu B}{kh}[\log t_p - \log\Delta t]} \tag{IV.14}$$

Δp represents the actual pressure rise

Δp MDH represents the pressure rise treated by MDH.

The gap between Δp and Δp MDH is negligible when Δt is small in front of tp (Figure IV.4).

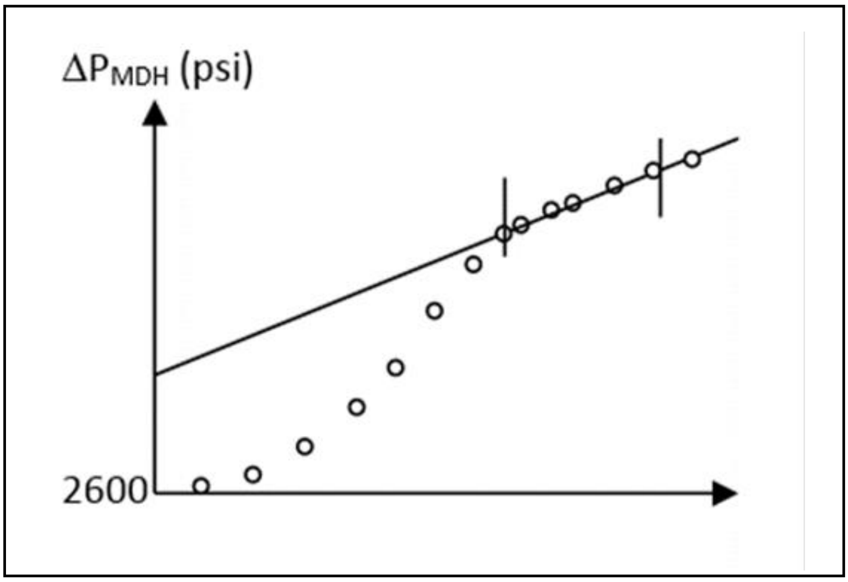

Figure IV. 4 : MDH méthode [17]

❖ **Interprétation**

By carrying ΔPMDH as a function of Δt one observes, once the capacity effect ends, a semi-log slope right m

$$m = \alpha \frac{q.u.B}{Kh} \Rightarrow Kh = \frac{\alpha.q.B.u}{m} \quad \text{(IV.15)}$$

This method has the advantage of being a very simple job. It has two major disadvantages

- It does not allow to determine the extrapolated pressure p*
- It can only be used for small values of Δt in front of tp When tp < Δt. **[7]**

IV.4 Modern methods

IV.4.1 Typical curves

Standard curve boards appeared in petroleum literature in the 1970s. Several curves exist to interpret the test of a vertical well in an infinite homogeneous reservoir.

In recent years, the techniques for interpreting well tests have evolved very rapidly. In addition to the so-called conventional methods of interpretation, often assimilated to semi-log analyses, the so-called modern methods have appeared, which practically boil down to different plates of standard curves.

Despite an impressive number of publications around the world, these modern methods sometimes remain poorly known and often highly controversial in the oil industry. It therefore seemed essential to take stock of these methods, by carrying out a detailed critical analysis of the various new analytical solutions and the many standard curve plates that have emerged from them.

Objectives of the standard curves

Let's first go back to conventional methods. They are based on the choice of a line commonly called semi-log line by simplification of language but which is obtained in fact either by a semi-log graph

(Horner, MDH*) or by Cartesian graph (superposition function). From there two criticisms must be made the choice of this often very delicate right is based on imprecise criteria that do not always make it possible to avoid possibly huge errors. In addition, conventional methods do not exploit all the measurements recorded during a test and then systematically eliminate all points inside the semi-log right.

The main objectives of standard curves are characterized by

- To locate the beginning of this semi-log right.
- Take into account all recorded pressure measurements.
- To provide another estimate of the usual parameters (kh and S) for comparison with the results of semi-log analyses.
- To provide additional information, generally inaccessible by conventional methods.
- To facilitate the diagnosis of the type of reservoir encountered, by showing characteristic looks of test curves.

Principles and general methods of using standard curves

- Standard curves, first introduced in hydrology by C.V. Theis, first appeared in the petroleum literature on well testing in 1970.
- Each type of reservoir has an analytical model. The results of simulations, using this model, can be translated into a family of curves. In this family, each curve is associated with the values of certain parameters. A curve represents the evolution of the pressures that would have been recorded during a flow test carried out under the conditions defined both by the choice of the family of curves.
- Standard curves are always presented on log-log paper with dimensionless variable groupings on the axes. Most often, pressure appears on the ordinate (Δp) and time on the abscissa (Δt). The multiplicative factors, allowing to pass from Δp and Δt to the dimensionless variables of the axes, correspond to translations on these logarithmic scales. In other words, when we have succeeded in setting the measurement points (Δp, Δt) on a standard curve, the translations carried out parallel to the axes are known, so the multiplicative factors too. The parameters sought, which are contained in these multiplicative factors, are then easily deduced.

The methods of interpretation consist of

1. Plot the measured pressures on tracing paper of the same log-log scale as the family of standard curves chosen (same module length).
2. Look for the superposition of these measurement points, on a standard curve, allowing only translations (the respective axes parallel to each other).
3. Note the wording of this standard curve.

4. Arbitrarily choose a reference point (mach point), whose coordinates are read in each axis system (on the layer, on the one hand, and on the map of typical curves, on the other hand). The multiplicative factors corresponding to each axis can be deduced immediately (the American literature speaks of "pressure mach" and "time mach").
5. From the information obtained in 3 and 4. Calculate the parameters sought (kh, C, S).
6. The method just described is general and common to all standard curves.

Log-log plot

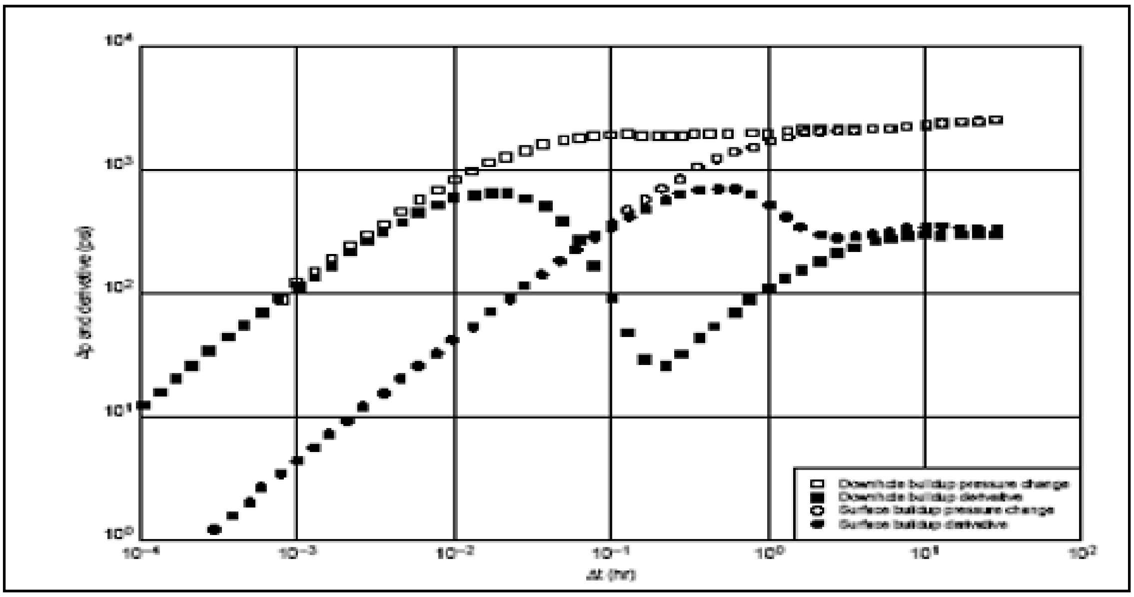

Figure IV. 5 : The pressure response during the well test according to Log log plot

For a period of the trial; the pressure variation Δ P is plotted in log-log scale as a function of the elapsed time Δ t. The log-log plot is considered a robust way to diagnose the behavior of the pressure response. The response of the well is compared to a catalogue of theoretical curves present in dimensionless terms.

The figure shows several pieces of information on the pressure responses during the well test first of all the Well Bore Storage effect is manifested by a single slope.

The analysis of well tests has become a technology that consists of diagnostics, using the log-log plot.

There are three problems with the log plot method

- The tests are often short for the flow to reach the reservoir limits.
- For reservoirs of different geometries and fractured and double porosity wells; the answers are not proven.
- The results of pressure responses in reservoirs of different characteristics are very difficult to distinguish them, especially with short well tests.
- For these reasons, another more detailed method of analysis is used; the pressure derivative.

IV.4.2 The derivative method

Methods using the pressure derivative exploit the advantages of standard curve representation and remedy the disadvantages of logarithmic representation.

These methods are based on one observation in a well test, the change in pressure is more significant than the pressure itself. This is illustrated by the fact that it is from the slope of semi-log rights that information about the reservoir is derived in conventional methods.

Different forms of derivatives were proposed in the petroleum literature in the early 1980s. Among these approaches, the most interesting is that due to D. Bourdet.

Representation

The derivative of pressure, in the representation of D. BOURDET, is calculated with respect to the time function of the circular radial flow in transient mode.

$$\frac{dPD}{dt\,n(\frac{tp}{C_n})} \quad \text{in flow} \qquad \textbf{(}IV.16)$$

$$\frac{dPD}{dln\frac{tp+\Delta t}{\Delta t}} \quad \text{in pressure rise after a period of constant flow} \qquad (IV.17)$$

$$\frac{dD}{d} \quad \text{[overlay function] more generally, with any Flow History} \qquad (IV.18)$$

The derivative is represented on a log-log chart as a standard curve.

Properties of the derivative

In circular radial flow, the dimensionless pressure is expressed in flow by

$$\mathbf{PD = \frac{1}{2}(\ln tD + 0.81 + 2S)}$$

(IV.19)

It can also be in the form

$$\mathbf{PD = \frac{1}{2}[\ln(tD + cD) + 0.81 + \ln cDexp\,(2S)]} \qquad (IV.20)$$

The derivative of pressure with respect to the time function of circular radial flow is expressed by

$$P_p^- = \frac{dPD}{d\,u(\frac{t_D}{C_D})} = 0.5 \qquad (IV.21)$$

All typical curves therefore have as asymptote a line of ordinate 0.5 during the circular radial flow.

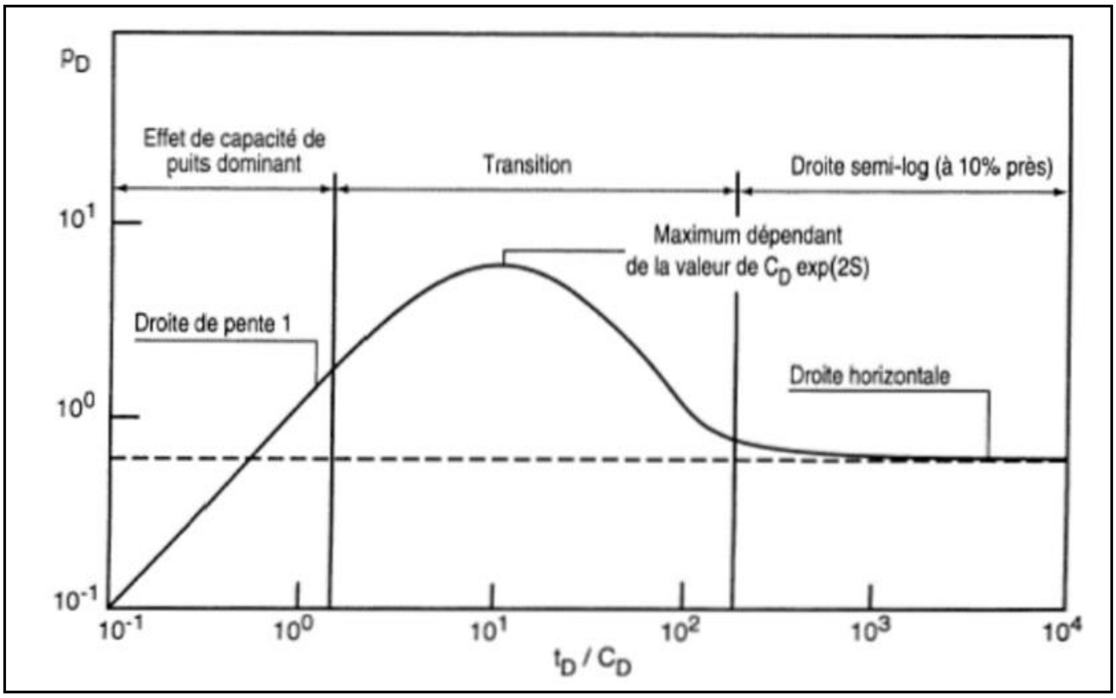

Figure IV. 6 : The derived curve. [9]

Direct interpretation using the derivative

The permeability of the reservoir, the capacity of the well and the skin can be determined directly using the standard curve and its derivative since the stabilization of the derivative has been achieved.**[8]**

❖ **Skin**

The value of the skin can be calculated by knowing the coordinates of a point on the semi-log line ΔPs, Δts .

The Skin is calculated from the conventional expression given by the semi-log law. For one pressure rise following a constant flow period

$$S = 1.151 \left[\frac{\Delta P_s}{2.303 \Delta P'st} - \log \frac{\Delta t_s}{1+\frac{\Delta t_s}{t_p}} - \log \frac{k}{\phi \mu C_t r_w^2 + 3.23} \right] \quad (IV.22)$$

❖ **Well capacity**

The capacity of the well can be calculated by knowing the coordinates of a point on the slope line 1 ΔP1 and Δt1, indeed, while the well capacity effect is dominant

$$\Delta P_1 = \frac{qB}{24C} \Delta t_1 \quad (IV.24)$$

Therefore

$$C = \frac{qB}{24} \frac{\Delta t_1}{\Delta p_1} \quad (IV.24)$$

❖ **Reservoir kh**

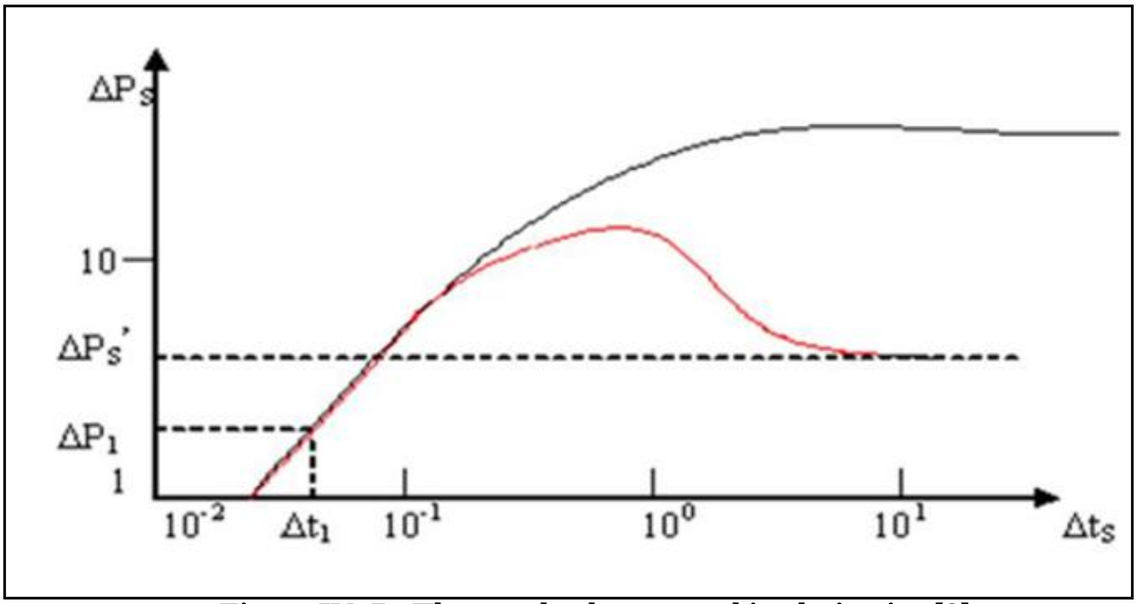

Figure IV. 7 : The standard curve and its derivative [8]

The permeability is calculated from the value ΔP' represents the stabilization of the derivative. The value of this derivative expressed in dimensionless quantities is known. It is 0.5.

The expression from Δ P St by report à 0,5 is

$$\Delta P'_{st} = \frac{141.2qB\mu}{kh} 0.5 \quad \text{(IV.25)}$$

It is used to calculate the kh of the reservoir

$$kh = \frac{141.2qB\mu 0.5}{\Delta P' st} \quad \text{(IV.26)}$$

CHAPTER V

Case Study Of OKMZ421

Introduction

Well test interpretation is a method used to assess the condition of a well and reservoir by determining various parameters, including permeability, skin, average layer pressure, KH, effective length, reservoir boundaries, and more. Knowledge of these parameters enables producers to forecast production and make informed decisions about deposit development, such as the need for stimulation operations or assisted recoveries.

Over time, well test interpretation methods have evolved from conventional techniques using standard curves by hand to computer tools like the Ecrin environment, which is KAPPA's fourth version. Ecrin v4.02.06 integrates all KAPPA applications and allows for their independent use, including Diamond, Topaz, Sapphire, and Ruby.

This chapter focuses on the interpretation of build-up tests conducted in four wells at the Hassi Messaoud field, specifically OMKZ 421. The objective is to determine reservoir permeability, skin damage factor, capacity effect, reservoir pressure, and demonstrate reservoir models using Saphir software. This study is based on practical internship experience at SONATRACH DP-IRARA service-WELL TEST-.

V.1 Description and use of SAPHIR SOFTWARE

During this work we used the Saphir software (KAPPA) for the interpretation of the Buildup.

The methodology of this software has always been based on the Bourdet derivative as a primary diagnostic tool; calibration of empirical data on the model, taking into account the detailed production history.

Saphir can load unlimited gauges, flows, pressure and other data in almost any format, including ASCII, Excel, PAS and databases of all kinds via OLEDB and ODBC. Saphir has real-time links with data acquisition systems.

V.2 Testing results analysis OKMZ 421 WELLS

❖ Introduction

The horizontal well OKMZ 421 of the HZN zone was drilled in 17/0 9/2020 at a depth of 4007m, and completed in 4 1/2’’ anchored, top liner reservoir, with a total displacement of 809.47m, azimuth N119.7°, inclination 89.5°. An LBU was carried out on this well on 28/02/2016 which gave a flow of 1.5 m3/hr.

❖ Well data

Table.V 1 : Well data OKMZ 421 data

Rw	µ	Bo	Hu	Ct	∅
7.62 cm	0.212 CP	1.78	14 m	$4.58\ 10^{-5}$ cm² /kg	6%

- **Test data**

Table.V 2: The necessary test data of OKMZ421 wells

Tp	Q
65876.67	6.72
64	0

V.1.1 Surface closure

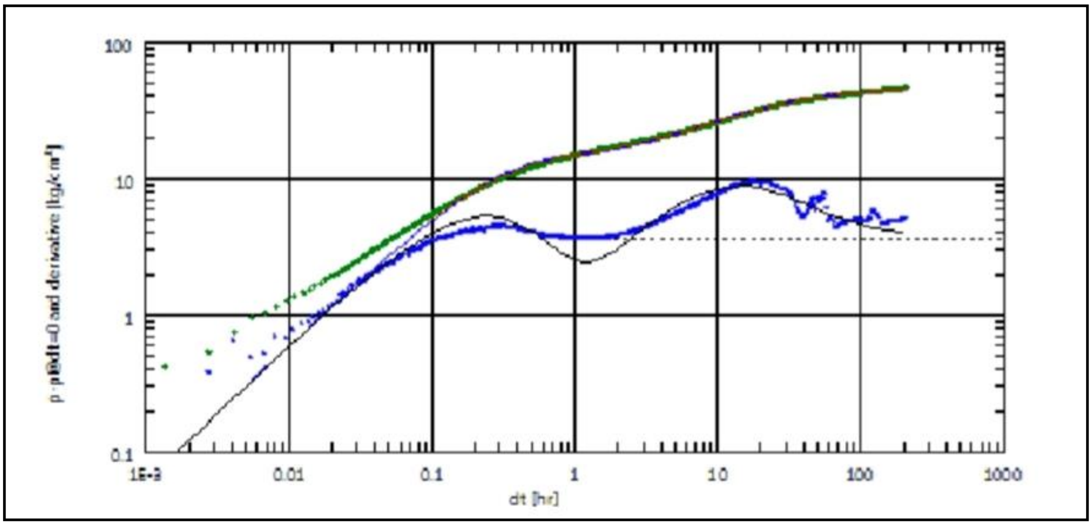

Figure V. 1 : Surface closure of OKMZ 421 wells

- **Interpretation results**

Table.V 3:OKMZ421 Well Surface Closure Results

Reservoir model	double porosity PSS.
Reservoir boundary	Infinite
T Match	$0.485 hr^{-1}$
P Match	$0.136\ psi^{-1}$
C	$0.798\ m^3 cm^2.\ Kg^{-1}$
Kh	37.5 md.m
K	3.31 MD
Pi	246.642 psi
Skin	0.347
Geometric skin	-3.52
Total skin	-3.17

❖ Commentary

According to the graph of the pressure and its derivative given by the BU test, the reservoir model is of the double porosity type with infinite limits. As well as the negative skin that shows that the well is stimulated with low permeability.

V.1.2 Downhole Closure

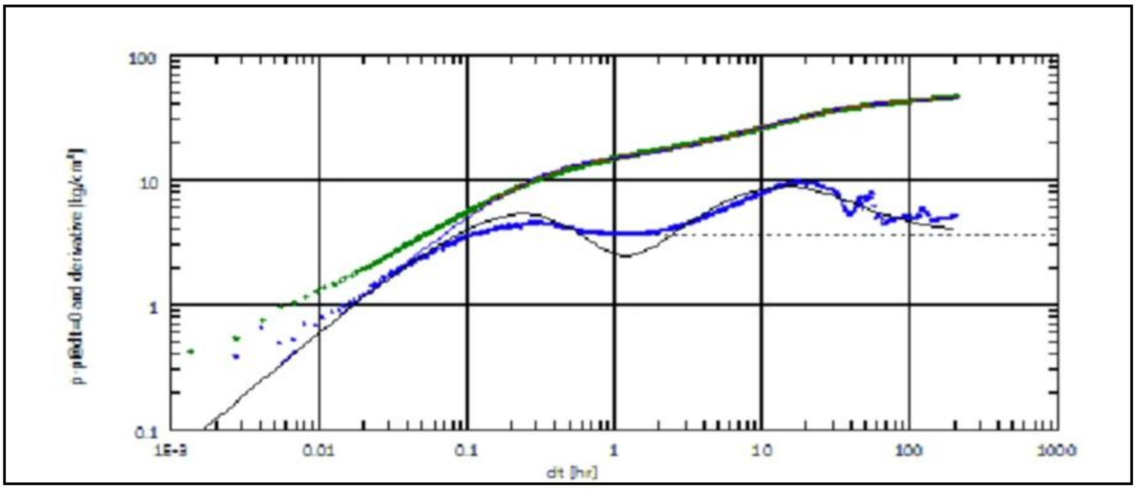

Figure V. 2 : Downhole closure of OKMZ 421 shafts

❖ Interpretation results

Table.V 4:OKMZ421 Well DOWN Hole Closure Results

Reservoir model	**double porosity PSS.**
Reservoir boundary	**Infinite**
T Match	**1.7 hr^{-1}**
P Match	**0.0398 psi^{-1}**
C	**0.0923 m^3cm^2. Kg^{-1}**
Kh	**19 md.m**
K	**1.46 MD**
Pi	**317 psi**
Skin	**-8.11**
Geometric skin	**15.8**
Total skin	**7.73**

❖ Commentary

According to the graph of the pressure and its derivative given by the BU test, the reservoir model is of the double porosity type with infinite limits. As well as the positive skin that shows that the well is clogged with very low permeability.

Conclusion and Recommendations

Conclusion

The Hassi Messaoud deposit stands as one of the largest deposits globally, providing Algeria with a valuable natural resource crude oil. Effectively harnessing this resource necessitates a comprehensive understanding of the reservoir's characteristics to maximize well productivity. Achieving this understanding involves conducting a well test, encompassing various stages such as Build-Up, drawdown, DST and, To execute well test, a range of multi-surface equipment like a Choke manifold, Separator, Storage bin, and bottom equipment such as DHST . In this memory, particular emphasis was placed on the Build-Up test, enabling the determination of permeability tensors across distinct flow regimes. However, during interpretation, challenges were encountered due to the capacitive effect and fluid separation phenomenon after surface closure, which masked the identifiable flow regimes specific to horizontal wells.

Moreover, the influence of double porosity within fractured reservoirs could also be concealed by the aforementioned factors. Nonetheless, these flow regimes were clearly observed during the latest DST test, wherein closure occurred at the bottom. However, the reservoir's behavior in this test resembled that of a homogeneous reservoir, disregarding the imprint of double porosity.

The extended duration of the test facilitated the observation of pseudo-radial flow and facilitated the determination of horizontal permeabilities and damage factors. It should be noted that the damage factors consistently exhibited negative values, leading to reduced pressure drops. The wide range of permeabilities observed can be attributed to the reservoir's heterogeneity.

Due to the non-occurrence of the pseudo-permanent regime, the test did not reach the limits of the reservoir, consequently assuming it to be infinite.

Recommendations

After studying the well tests in the horizontal field wells of Hassi Messaoud, we recommend

- Decrease the effect of capacity and the phenomenon of separation of fluids with the execution of closures at the downhole, we use background test tools (test actuator).
- The use of numerical models for interpretation of well tests in heterogeneous reservoirs can lead to more correct results.
- The intensification of flow measurement operations so that we have an accurate and exploitable history in interpretation.

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Flow regimes

In a porous medium, monophasic flows are governed by

Darcy's Law.

The conservation of mass.

The equation of state.

In a porous medium, there are three flow regimes

I. Transitional arrangements

As long as the compressible zone has not perceived the influence of another well, the reservoir behaves, at the test levels, as if it were infinite.

During this period the flow regime is transient.

In a transient regime the pressure varies according to a non-linear law with time.

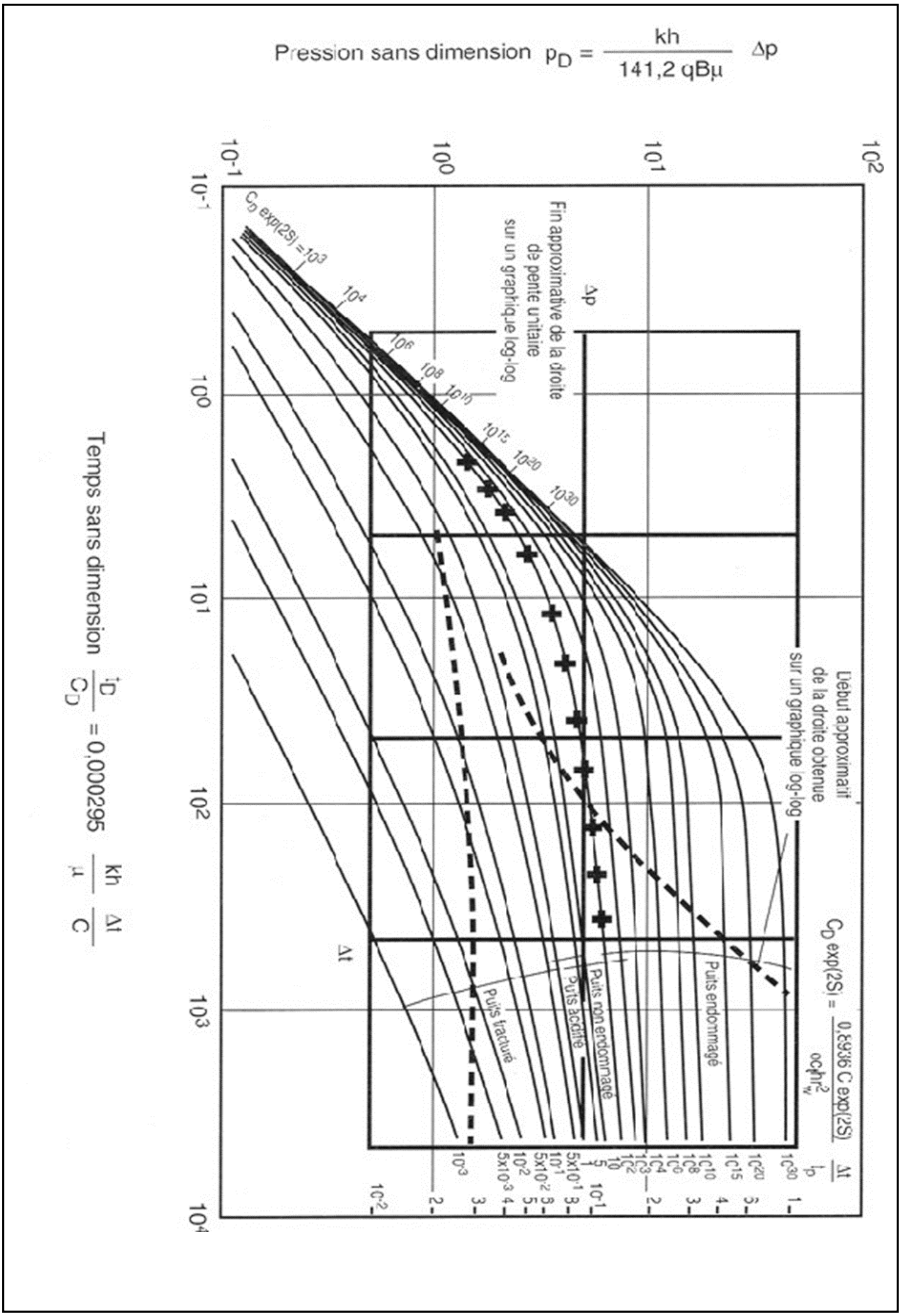
II. Steady-on-state status

When the compressible zone is subjected to the effect of a set of limits at constant pressure, the flow regime becomes permanent, it is the flow regime existing in production in a reservoir subject to the influence of a gas cap or aquifer, when the mobility of the water is high before that of oil.

In a permanent flow regime, the pressure remains constant as a function of the time.

III. Pseudo-permanent regime

When the compressible zone reaches a set of limits with zero flow, the flow regime becomes pseudo permanent it is the regime existing in a closed reservoir not fed in production, in a pseudo permanent regime the pressure varies linearly with time. A well test almost always takes place in transient mode even if the effect of some limitations is felt.


Pression sans dimension $p_D = \frac{kh}{141,2\ qB\mu} \Delta p$
Temps sans dimension $\frac{t_D}{C_D} = 0,000295 \frac{kh}{\mu} \frac{\Delta t}{C}$
Fin approximative de la droite de pente unitaire sur un graphique log-log
Début approximatif de la droite obtenue sur un graphique log-log
$C_D \exp(2S) = \frac{0,8936\ C \exp(2S)}{\phi c_t h r_w^2}$
Puits endommagé
Puits non endommagé
Puits acidifié
Puits fracturé
Δp
Δt

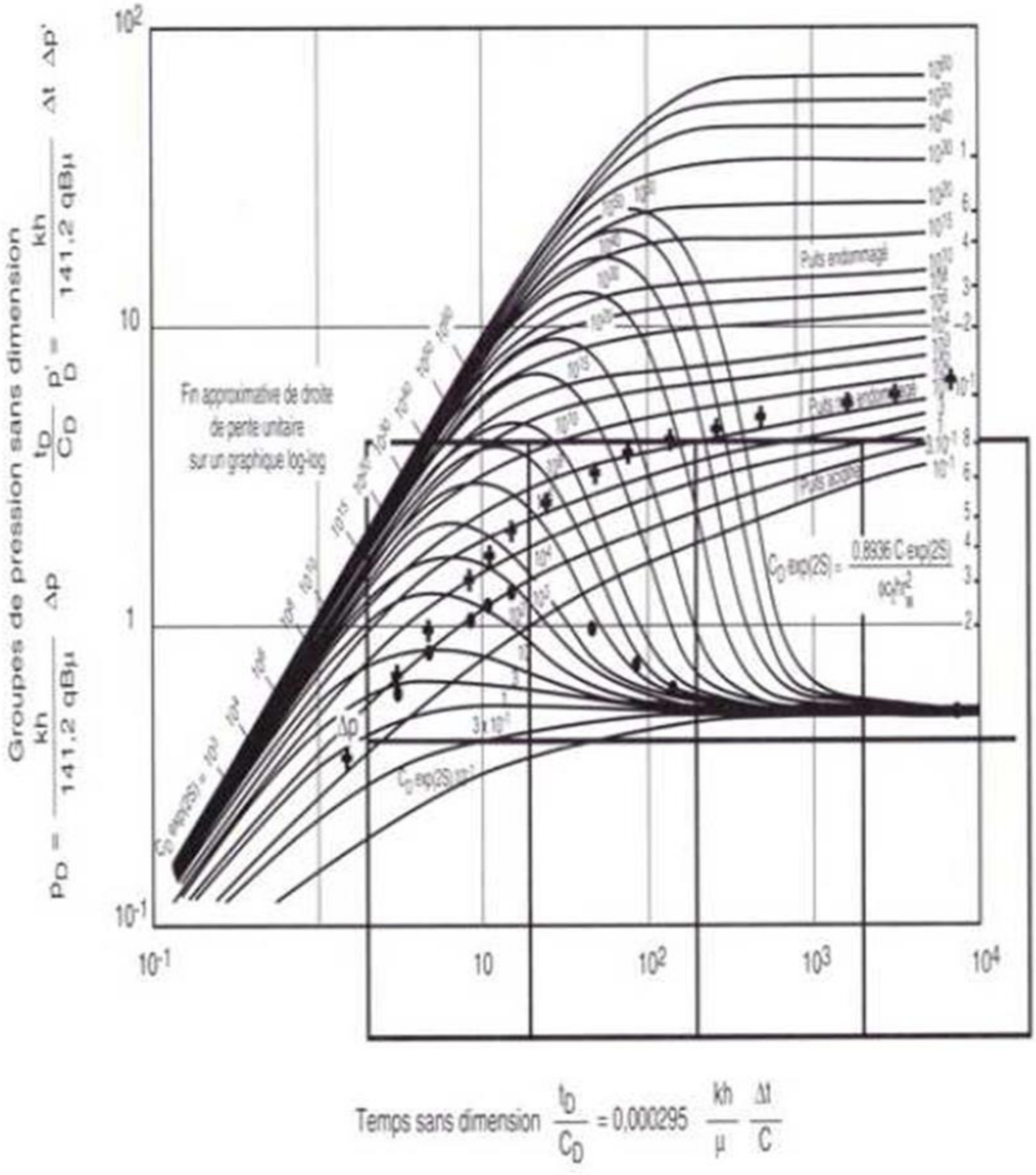
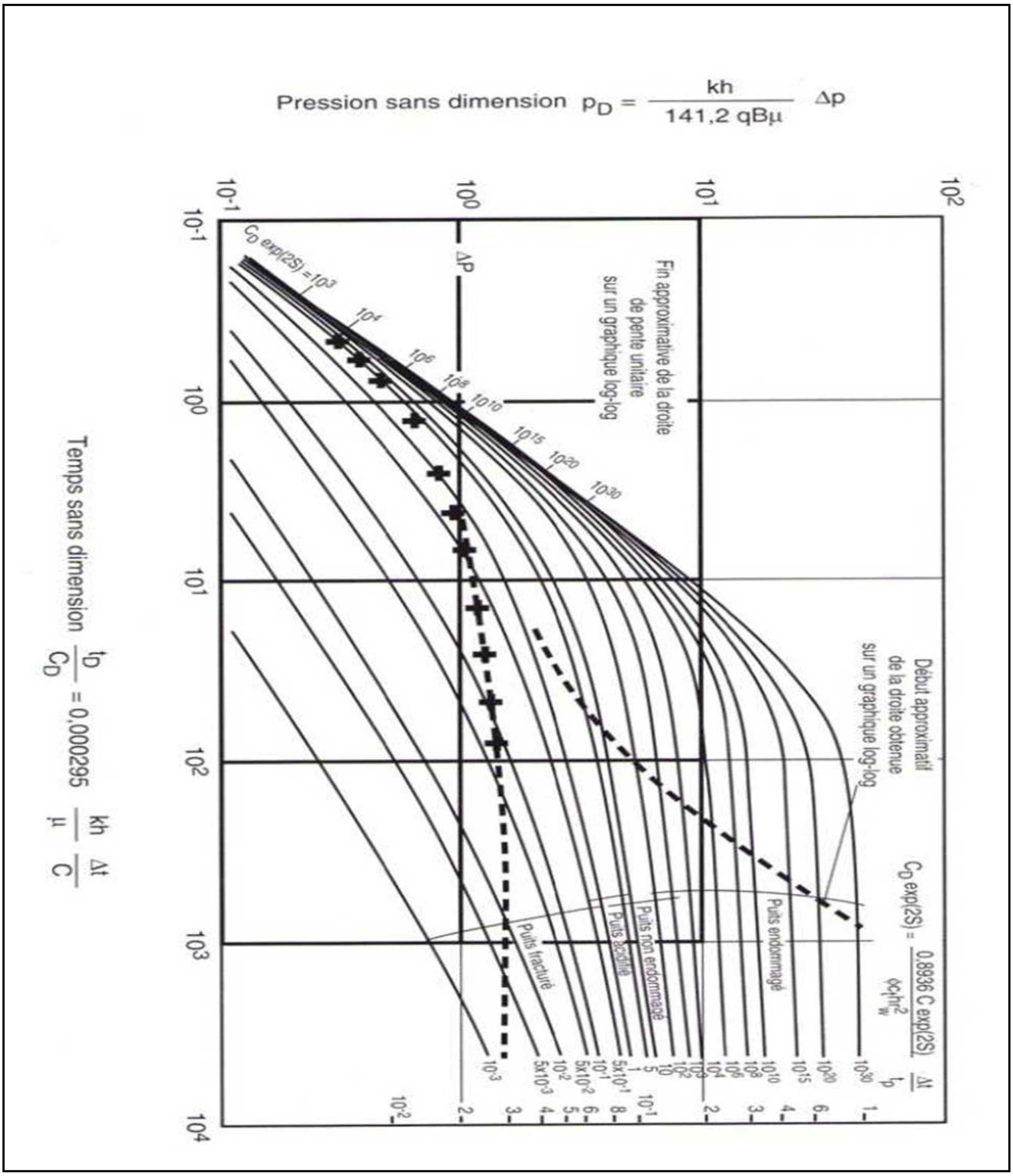
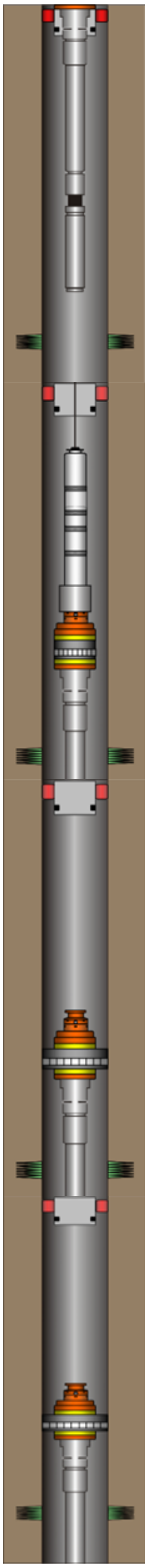


Fig. 6.3b Calage vertical.

Courbes types pour un puits avec capacité de puits et skin (comportement de réservoir homogène infini)


Pression sans dimension $p_D = \frac{kh}{141,2\ qB\mu} \Delta p$
Temps sans dimension $\frac{t_D}{C_D} = 0,000295 \frac{kh}{\mu} \frac{\Delta t}{C}$
Fin approximative de la droite de pente unitaire sur un graphique log-log
Début approximatif de la droite obtenue sur un graphique log-log
$C_D \exp(2S) = \frac{0,8936\ C \exp(2S)}{\phi c_t h r_w^2}$
$C_D \exp(2S) = 10^3$
ΔP
Puits endommagé
Puits non endommagé
Puits acidifié
Puits fracturé



a. As the well is closed on the surface the assembly Slickline and Downhole shut in tool descends to the bottom.

b. Descent in progress.

c. Arrival at the bottom.

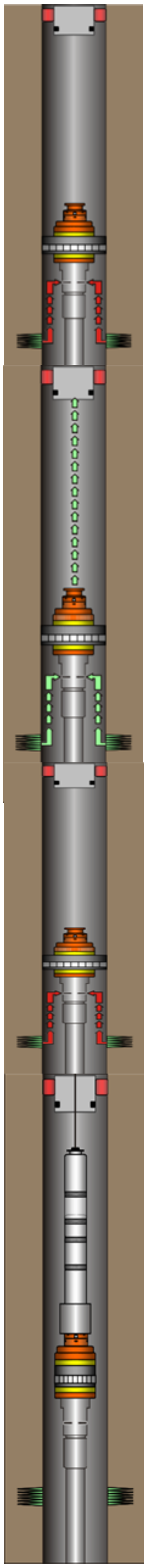
d. Anchoring of the Lock mandrel in the Nipple.

e. The V-packing of the Lock-mandrel will ensure a good seal, and the downhole Shut-in Tool will work as programmed on the surface

f. Rise of the Slickline setting tool to the surface.

g. Start of well test operations.

h. The well is opened, pressure equalization and start of the test



i. Tool valve closes, beginning Build up

j. The opening of the valve will make it possible to measure the surface flow under different nozzles
Duse 1''
Duse 1 1/2''
Duse 2''

k. Closing the Shut-in tool down hole valve will allow a second build up to be recorded

l. End of test, closure of the surface well and descent Slickline GS pulling tool to reassemble the assembly.

m. The rise of the assembly.

n. End of operation.

Figure : Series of figures shows the course of the well operation