American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-10, Issue-05, pp: 31-42
www.ajer.org
Research Paper Open Access

Sensitivity Analysis of Pressure Gauges Used in Niger Delta For Effective Pressure Measurements for Drilling Operations, Reservoir Data Analysis and Well Testing

ODAGME, B. S and MAMUKUYOMI, J. B
[1,2](Department of Petroleum and Gas Engineering, Faculty of Engineering
Federal University Otuoke, Bayelsa State, Nigeria)
Corresponding Author: baridorodag@yahoo.com

ABSTRACT
The success of well test and reservoir analysis largely depends on the degree of accuracy of the data provided. In this work, the differential pressure analysis and QA/QC test were used to determine the sensitivity, accuracy and resolution of pressure gauges from oil companies X and Y from gauge manufacturing companies (ABC and DEF). The results showed that pressure gauges from different manufacturing company had varying pressure readings due to variation in the resolution and sensitivity of these different gauges. After a robust sensitivity analysis using Ecrin 4.3 software and differential pressure analyses, it was found that some of the pressure gauges provided inaccurate pressure readings which would affect the well test analyses and most likely mislead Reservoir analysist. Further, the effect of such false pressure data on well panning for Drilling operations could lead to wrong reservoir pressure and fracture gradient prediction for both reservoir and drilling Engineers which has very dangerous consequences and could undermine the success of the well design. The results show that pressure gauge manufacturing company ABC had better resolution and sensitivity with an error margin of +/-2.52% as against the gauge from company DEF with an error of 11.34% with readings taken at same depth and wellbore condition. These variation in pressure gauge readings poses a great challenge to well test and reservoir analysts in the determination of fluid contact, permeability barriers and more dangerous for drilling engineers when such pressure data are used as offset data for well planning and big data gathering for the petroleum industry. Therefore, the study showed that the resolution of pressure gauge increasingly becomes very important when taking pressure measurement in the thinner the beds and lead to errors in the determination of pressure gradients as seen in the results. Therefore, in the Niger Delta which are predominately thin bed and low energy conditions and oxygen deficiency of the Akata formation. high resolution and sensitivity of pressure gauges are inevitable to enhance the degree of accuracy in the data for well testing, reservoir analyze and pressure data used in planning drilling programmes for matured as obtained in the Niger Delta.

KEYWORDS** **Pressure Gauge, Sensitivity Analyzes, Big Data, Reservoir Pressure Profile, Pressure Gradient
----
Date of Submission: 27-04-2021 Date of acceptance: 11-05-2021

I. INTRODUCTION

Pressure gauges are instrument used for the measurement of pressures. Pressure gauge specification considerations is key to obtaining good results in practical well testing and pressure monitoring in drilling operations. However, transmission of signal is limited to serial communication because only a single conductor is available for communication as well as power after every cycle, a synchronization pulse is sent up hole for the wellhead equipment. The wellhead interface board converts the analog data into digital format and transmits to the platform. Processing software uses high-order polynomial functions to compute the pressures from the three frequencies (Onyekonwu, 2000, Gilly and Horne 1998). The coefficients of these polynomials are high-order curve fits to experimental data for each and every gauge. Thus, each gauge has its own set of coefficients. The temperature measurements are used for pressure compensation purposes because the output of any pressure sensor is a function of pressure and temperature. A pressure-gauge system is composed of the pressure gauge, transmission and measurement electronics, associated software, and hardware for data conversion and storage.

For our purposes, the gauge itself consists of the transducers and the associated down hole electronics. The system components depend on the application at hand. For a slick-line-operated memory gauge, the requirements are minimal and the gauge assembly is almost the entire system. For a surface readout and/or a permanent system, the components usually are the following: I. Transducer. 2. Down hole electronics. 3. Signal transmission (equipment/cable etc.). 4. Decoding/encoding (subsea interface board electronics). 5. Data processing software. 6. Data-storage facility. Furthermore, the limitation of Downhole Measurements constrain well test and well control due to Insufficient data rates, measurement could be limited to data from near the bit, and other condition unknown during static periods such as the wellbore environment and the dynamic metrological parameters (transient responses at temperature and pressure variations etc.(Athichanagorn et al., 2002, Thomas 2006), and these problem affects the accuracy, sensitivity and durability, so that the need to know the actual gauge specification to used is eminent for well test analysis and production measurement (Gilly and Horne 1998, Stewart 2011). Monitoring fluid contacts accurately in highly fractured reservoirs has always posed a challenge due to these limitations in the measurement tools. In this light, Gradiomanometer surveys and electronic fluid property surveys lack the depth resolution need to locate contacts, and direct measurement methods are time consuming, and yield no secondary information for quality control (Kuchuk & Biryukov.,2014, Onyekonwu, 2000, Athichanagorn et al 2002). It is therefore, imperative to carry out sensitivity analysis on pressure gauges used in the Niger for drilling purposes, well testing and reservoir analyses to ascertain their accuracy as it impacts on reservoir data gathering and save drilling operations in the Niger Delta

1.2. Research Objectives

The research objectives include to**;**

1**.** Carry out a sensitivity analysis on pressure gauges used in the Niger Delta
2. Determine the most appropriate and accurate type of gauge for the area of study
3. Recommend the best type of gauge for pressure measurement in the Niger Delta.

1.3 Significance of Study

This study is significant to operators in the oil and gas as it would enable them determine the reliability of pressures used for drilling, reservoir data analysis and well testing. Thus, helping them to reduce of cost of unscheduled event resulting from error in pressure measurement while drilling and error in well test data used for reservoir analyses. This would ensure stability of multilateral junction which directly depends on bottom hole pressure measurement for calculation leading to improved performance.

1.4. Types of Pressure Gauges

Different types of gauges are used for measuring bottom-hole pressure and the sensitivity and the accuracy of the gauges vary (Onyekonwu, 2000). The accuracy of a gauge is principally concerned with systematic errors, often attributed to the calibration of the gauge (Onyekonwu 2000, Gilly and Horne 1998). The three basic types of gauges are:

1. Amerada Gauges
2. Strain Gauge
3. Electronic Gauges (Quartz Crystal)

Tables 1.1 and 1.2 shows the types of pressure gauges and their respective accuracies and sensitivities.

Table 1.1 Types of gauges and principles of operation

Type of Gauge	Principle of Operation	Accuracy	Sensitivity
Amerada	Bourdon tube (Mechanical)	± 0.2% FSD	0.05% FSD
Strain Gauge	Change in resistivity	± 0.05% FSD	0.0025% FSD
Quartz Crystal (Electronic)	Change in frequency	±0.035% R	0.0001% FSD
FSD = Full Scale Deflection, e.g. 5000 or 10000 psi R = Reading, i.e. the measured pressure			

SOURCE: Onyekonwu, M.O (2000)

Table 1.2 Sensitivity and accuracy of gauges

Type of Gauge	FSD = 5000 psi		FSD = 10,000 psi
Accuracy	Sensitivity	Accuracy	Sensitivity

Amerada Strain Gauge Quartz Crystal (Electronic)	10 psi 2.5 psi 1.75 psi	2.5 psi 0.125 psi 0.005 psi	20 psi 5.0 psi 3.5 psi	5.0 psi 0.25 psi 0.01 psi

SOURCE Onyekonwu M.O (2000)

Amerada Gauges

Onyekonwu (2000) reported that Until 1994, about 80% of bottom-hole pressure tests in Nigeria were run with Amerada gauges. However, for it clearly shows the components of any gauge: a clock, pressure sensor and recorder.

1.5. Pitfall in Pressure Gauge Performance

1.5.1 Gauge Resolution

The overall gauge resolution depends on the performance of a number of components. The accurate detection of the frequency at the wellhead (which requires a high-speed clock), number of storage registers on the accumulator unit, characteristics of the transducers.

1.5.2. Signal Quality

Empirical curve-fits on the gauge characteristics, filtering algorithms, and signal degradation are a few critical components that govern the signal quality. These can be classified into the following categories: I. Gauge related. 2. Detection/measurement related. 3. Transmission/cable related. 4. Software related.

1.5.3. Gauge Synchronization

The practical problem to generate representative differentials is to synchronize the two gauges, as only very rarely will these two gauges have identical gauge times (Stewart, 2011, Athichanagorn et al., 2002). This is accomplished by means of specially-written software which will allow shifts in time of less than the gauge sampling interval.

1.6. Static and Dynamic Metrological Parameters

Metrology is defined as the science and process of ensuring that a measurement meets a specific degree of precision and accuracy (Czichos et al., 2011). Studies show that the performance of bottom hole pressure gauges largely depends on the static and dynamic metrological parameters thereby affects the quality of pressure measurement (Czichos et al., 2011, Athichanagorn et al., 2002). Static metrological parameters incudes: Accuracy, Resolution, Stability and sensitivity whereas dynamic metrological parameters are: the transient response with temperature variations, the transient response with pressure variations, dynamic responses when there is temperature or pressure shock and the dynamic temperature correction on pressure measurement taking into cognizance that the deeper the gauge the higher the temperature **(**Kuchuk & Biryukov.,2014, Thomas 2002**).**

1.6.1 Accuracy

Accuracy is the maximum pressure error exhibited by the pressure transducer under the following applied conditions: fitting error, pressure hysteresis, and repeatability. The fitting error, also called the mean quadratic deviation (MQD), is a measure of the quality of the mathematical fit of the sensor response at a constant temperature. Pressure hysteresis is the maximum discrepancy of the transducer signal output between increasing and decreasing pressure excursions. Repeatability is defined as the discrepancy between two consecutive measurements of a given pressure at the same temperature.

1.6.2 Resolution

Resolution is the minimum pressure change detected by the sensor. When referring to the resolution of a bottom hole pressure gauge, it is important to account for the associated electronics, because the gauge is always used in series with the electronics (Gilly and Hornes 1998). Thus, the resolution of the measurement is the lower of the resolution of the gauge and its electronics. Another important consideration is that the resolution must be evaluated with respect to a specific sampling rate, because an increase of the sampling rate worsens the resolution. The electronic noise of strain-gauge transducers is often the major factor affecting resolution. Mechanically induced noise may further limit gauge resolution because some gauges behave like microphones or accelerometers. This effect may be significant during tests when there is fluid or tool movement downhole.

1.6.3 Stability

A pressure sensor is stable if it can retain its performance characteristics for a relatively long time period. Stability is quantified by the sensor mean drift (psi/D) at a given pressure and temperature. Three levels of stability can be defined: short-term stability for the first day of a test, medium-term stability for the following 6 days, and long-term stability for a minimum of one month.

1.6.4 Sensitivity
Sensitivity is the ratio of the transducer output variation induced by a change in pressure to that change in pressure. The ratio represents the slope of the line produced by a plot of the transducer output vs. pressure input. The plotted sensitivity should be, but is not always, linear with respect to pressure.

1.7. Pressure Gauge-Related Problems
The major problems that plague the gauge performance are th wellbore environment, degradation of mechanical component, gauge temperature and cable problems.

1.7.1 Wellbore Environment.
The downhole environment can also affect gauge response and sensitivity (Stewart, 2011). If the wellbore is unstable, there is the tendency that pressure data obtained from the within the problem zone could be erroneous while a fairly stable wellbore with minimum hole problems is more likely to produce a more accurate pressure data for reservoir analysis and well testing (Qasem, et al., 2002).

1.7.2. **Degradation of mechanical components**
Every mechanical equipment has a life span and the older the equipment the more likely the resolution and sensitivity would reduce due to degradation of the components of the equipment (Czichos et al., 2011), thus the need for calibration of pressure gauges to minimize errors (Dejam et al., 2018, Qasem, et al., 2002) because a pressure difference of 0.1psi could cause a great damage if measured in error.

1.7.3.Gauge.Temperature
The wellbore environment can be divided into problems related to pressure cycles (surges) and wellbore temperature. Changing temperatures can cause problems with the compensation characteristics of the software. This is especially true in injection wells and can lead to false interpretation of the reservoir parameters.

1.7.4 Cable Problems
These occur because of high-line resistance owing to depth and temperature and excessive signal degradation owing to line noise. Long cable lengths act as low band pass filters degrading the higher frequency components more than the lower frequency components. The resulting changes in the shape, amplitude and angular modulation (phase jitter) of the signal can cause the detection system to have problems reconstructing the signal with resulting losses in resolution as reported by Kikani et al., (1997).

II. LITERATURE REVIEW

Reservoir engineers have emphasized the need to understand the Performance characteristics and limitations of high-performance pressure gauges in well testing and reservoir analyses (Nomura, 2006). These gauges provide the basic measurements for the analysis and interpretation process (Elshahawi, et al, 2000). If not properly selected, applied, and understood, pressure gauges can introduce significant and costly errors in the assessment and production of oil and gas resources (Stewart, 2011,) .More so, the use of Pressure Gauge Differentials in Well Test Quality Control and Well Performance Evaluations has also been identified as critical to quality data acquisition(Fekete et al 2016a, Odagme,et al., 2016) and better analyzes of reservoir data for enhanced accurate Bottom Hop pressure for effective well design (Odagme,et al., 2016, Thomas 2002).

Welch and Bishop in Stewart (2011) provided an introduction to a technique used in interpreting pressure signals, the Kalman filter: “The Kalman filter is a set of mathematical equations that provides an efficient computational (recursive) means to estimate the state of a process, in a way that minimizes the mean of the squared error”. The Kalman filter has been applied in signal processing in the fields of medicine and engineering.

Yu *et al*. in Dejam et al., 2018, studied leakage detection in crude oil pipelines and interpreted pressure and flow rate signals using the combined Kalman filter-discrete wavelet transform method. The result of the study was a method for denoising pressure data and for extracting leakage locations in crude oil pipelines based on the extracted filtered signal. However, the Sensitivity and Accuracy of these pressure gauges were limited in terms of signal reception (Qasem et al., 2002, Fekete et al 2016b). It is therefore imperative to analyze the sensitivity of pressures gauges for the purpose of acquiring accurate data for reservoir analyses, well testing and save drilling operations.

2.2. Production Optimization
Differential Pressure Analysis has been used to confirm actual rate variations related to wax deposition and wax removal operations in oil field Data such as these has enabled the frequency of wax removal operations to be optimized (Qasem et al., 2002).

Gas Well Testing
BHP/THP Differential Pressure Analysis can be used to provide accurate rate deconvolution for gas well test analysis.
Lacy et al. (1992) defined the horizontal well, from the operational standpoint as the deviated well above 70 to 75 from the vertical, where conventional wireline tools cannot be used. From reservoir engineering standpoint,

the deviated well beyond 80 to produces as a typical horizontal well. The most recent developed technology provides more advanced and feasible tools to drill horizontal wells in many areas around the world. Joshi in Dejam et al., 2018 summarized the classification of horizontal well drilling methods, based upon their turning radius which would have great impact on the placement of downhole pressure gauges for accurate pressure measurement.

Integrated Analysis of Horizontal Well Pressures

The most recent of Shell Gabon's horizontal wells have permanently-installed down hole pressure gauges, placed in the horizontal section, or as close to the Horizontal drain as possible to reduce the necessary pressure correction.

2.3. Use of Differential Pressure Analysis from Gauge Readings

For Reservoirs analysis, pressure monitoring drilling during drilling.

Differential Pressure Analysis between tandem gauges has been found to be an essential precursor to Well Test Analysis in the Rabi field. With this type of analysis, it was possible to:

- Identify and to some degree quantify phase segregation, which can occur even under down hole shut-in devices.
- Identify Shut-in tool leakage.
- Identify periods over which pressure transient analysis can be confidently performed directly on the gauge data use for reservoir analysis and well testing
- Use observed flowing pressure differentials to verify quoted flowing conditions (or even identify cases where gauges are inverted compared to report) during drilling activities
- Correct pressures to sand face, using the insight given into the well fluid distribution with time.
- Provide cross calibration between gauges under actual field conditions.
- Differential Pressure Analysis between bottom hole and tubing head pressure measurements has provided the means to:
- Improve the understanding of well drainage behavior and to identify average Drainage Area depletion rates in a flowing well.
- Confidently assess P1 trends without lengthy periods causing production deferments.
- Enable detection of gas and/or water breakthrough without the requirement for regular testing.

2.4. Permanently Installed Bottom Hole Pressure Gauges

Permanent downhole gauge data are recorded under dynamic changes occurring in the well and the reservoir. Athichanagorn et al., (2002) developed a spline wavelet-based methodology for the preprocessing of pressure data before using it for interpretation purpose. Khong (2001) introduced some important improvements in the wavelet processing methodology for application in oil and gas industry.

Accurate and reliable identification of transient break points are very important for further analysis of the data (Home, 1995). Limitations of the current time-invariant spline wavelet-based approach of break point identification were studied and four alternate algorithms were proposed for improving the accuracy and reliability of break point estimation. The proposed methods were applied to real field data and the results compared to the time-invariant spline wavelet-based approach. The proposed Haar wavelet-based approach did not show any tangible improvement but the other three approaches showed considerable improvement over the spline wavelet-based approach.

The uses of pressure data can be summarized below

[A]. Production practices application

- Checking surface and subsurface equipment
- Special lifting problems

[b]. Well conditions analysis and remedy

- Regular productivity indices data observations
- Interference

[c]. Secondary recovery projects for Producing and injection wells

[d]. Reservoir conditions determination

- Oil-water contacts
- Damaged zones.

Thomas (2002) also deed some work on the ‘‘Analysis of Well Test Data from Permanent Down hole Gauges by Deconvolution”, in His contributions he noted that the accuracy of pressure gauges is significant in well test analysis to the extent that the more sensitive the gauge is, the more accurate the reading.

2.5. Precision Pressure Measurement

An electronic pressure gauge using a silicon crystal sensor was shown to provide predictable response to strain under changing temperature and to provide the precision and accuracy needed for repeatable contact measurements and reliable pressure mapping. The pure silicon crystal has a small mass, a thin unbonded structure, and a temperature sensor for compensation placed in close proximity thereby decreasing the stabilization time required for true pressure recording. Rapid pressure measurement allows shorter, more frequent gradient stops; and consequently, better data. Hannah et al., (2000) after a research on ''Precision Pressure Measurement: The Key to Accurate Fluid-Interface Monitoring'' showed that fluid gradient analysis was found to be a suitable replacement for the dipstick measurement method. According to Hannah et al (2000), in the past, gauge precision limited the accuracy of the gradient contact calculation and suggested that improvements in pressure gauge performance could be made possible by utilizing silicon-crystal technology and this is very important for gauges used in metering of oil and gas (Oriji & Odagme (2015).

The quest for precision in gauge readings have been emphasized by several authors in the life circle of a Well. In this light, Hannah (2000) observed that reducing the full-scale rating of the gauge stretched the sensor's limit to precision levels previously not attained from a gauge. Thirdly, improvement in data quality was achieved by taking concurrent pressure and contact surveys that were previously run separately for other Authors (Brehme et al., 2000). Pressure Gauges has also been used in Liner Running Strings during Liner Cementing Operations (Brehme et al., 2000). Therefore, a precise pressure data could improve reservoir management (Dejam et al., 2018, Hannah et al.,2000). Hence, the importance of this study.

From the ongoing, several works have been carried out on pressure gauge and its performance yet there is the need to determine the most accurate gauges for the Niger Delta because of the peculiarity of its formation in terms of bed thickness and varying formation pressures.

2.5 Non-Linearity in Pressures

Pressure thermal sensitivity. The pressure thermal sensitivity represents the error (psi) that results if the temperature measurement is in error of 1°C.

Maximum hysteresis during the calibration cycle. This test is determined from calibration data.

Calibration check. A calibration check verifies the consistency of the sensor readings when the applied pressures and temperatures are different from those used during the calibration cycle. The calibration check is performed in the laboratory at the time the sensor is evaluated and is essentially a rerun of a master calibration.

Other procedures and tests. Standard procedures are typically used in evaluating pressure transducers to compare different technologies and certify the calibration parameters. The most commonly used standard procedures are as follows:

- Complete master calibration
- Calibration check
- Stability tests: middle term and long term
- Repeatability test
- Resolution test
- Noise or short-term stability test
- Dynamic tests: temperature shock, temperature transient, temperature response time, and pressure shock.

2.6. Differential Pressure Analysis

Principle and Background

The analysis is based upon the difference in pressure measured between tandem pressure gauges (the simplest case), or a combination of pressure differences if more gauges are used during the survey.

The study of these differences can reveal the following problems and has a direct impact on the choice of the data measurements to be used for transient analysis:

1. Phase segregation in the wellbore
2. Fluid interface movements (oil, gas and water)
3. Temperature anomalies affecting the pressure gauge and / or identification of gauges with technical problems, such as:

- Pressure gauges outside of claimed accuracy and resolution specifications
- Gauge drift
- Gauge battery running out
- Other technical or electronic malfunctions

By convention the pressure difference between gauges is calculated so that an increase in the "difference channel" represents an increase in the fluid density between the gauge sensing points, and a decrease represents a

reduction of the fluid density. The “difference channel” behavior will be identical whatever the gauge offset may be (the upper gauge may well read a higher pressure than the lower gauge, possibly due to a gauge problem, but the “difference channel” would have the same identifiable shape).The simple analysis is based upon the study of the pressure and temperature differences between two gauges placed in the test string at different depths (Elshahawi, et al, 2000).
The figure below illustrates schematically what happens at the pressure sensors of two sensing points, if a ‘gas - oil’, ‘oil-water’, ‘gas-water’ or a mixed interface is moving downwards.

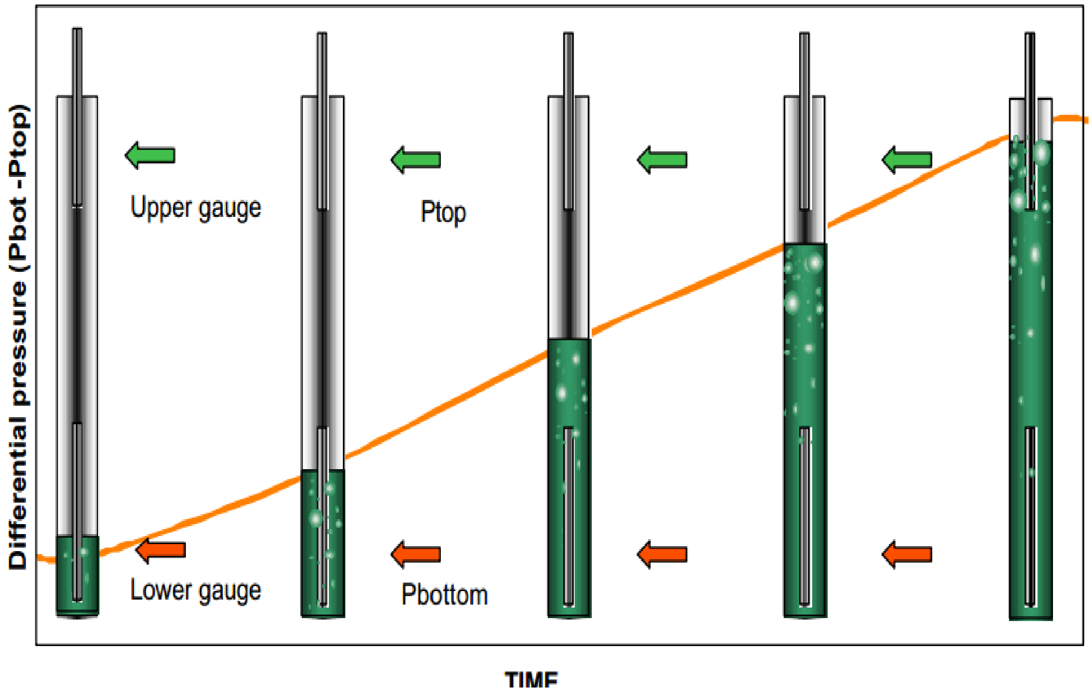

Fig 2.2 The example assumes that any “background” behavior is following a constant transient or is in “pseudo-steady state”. Source. Ecrin 4.03

Once the interface hits the “upper sensor” the pressure at this sensing point remains constant as the interface moves towards the lower pressure point. The pressure at the “lower sensor” declines linearly if the fluid interface movement is constant, and becomes constant again after the interface has moved below the lower pressure point. The difference in pressure between the two sensing points follows the difference in fluid gradient between oil and gas.

III. MATERIALS AND METHODS

Pressure and flow rate data were collected from two wells (well 1 & 2) for two different pressure gauge manufacturing companies (company ABC and DEF) from two oil producing companies X & Y respectively**.** Pressure and rate plots were made and sensitivity analysis was conducted on the gauge response. The results are presented in chapter four of this work.

3.1.1 *Use of Ecrin 4.03 Software for differential pressure analysis and Quality Check Analysis on Gauges.*

The data was used as input into Ecrin 4.03 (sapphire) and differential pressure analysis was done on the data to determine the pressure reading and rate reading, pressure gradient for fluid in the wellbore were calculated and the differential pressures were recorded to know the sensitivity and accuracy of the Pressure gauges. **Figure 3.1** shows the interphase of the software.

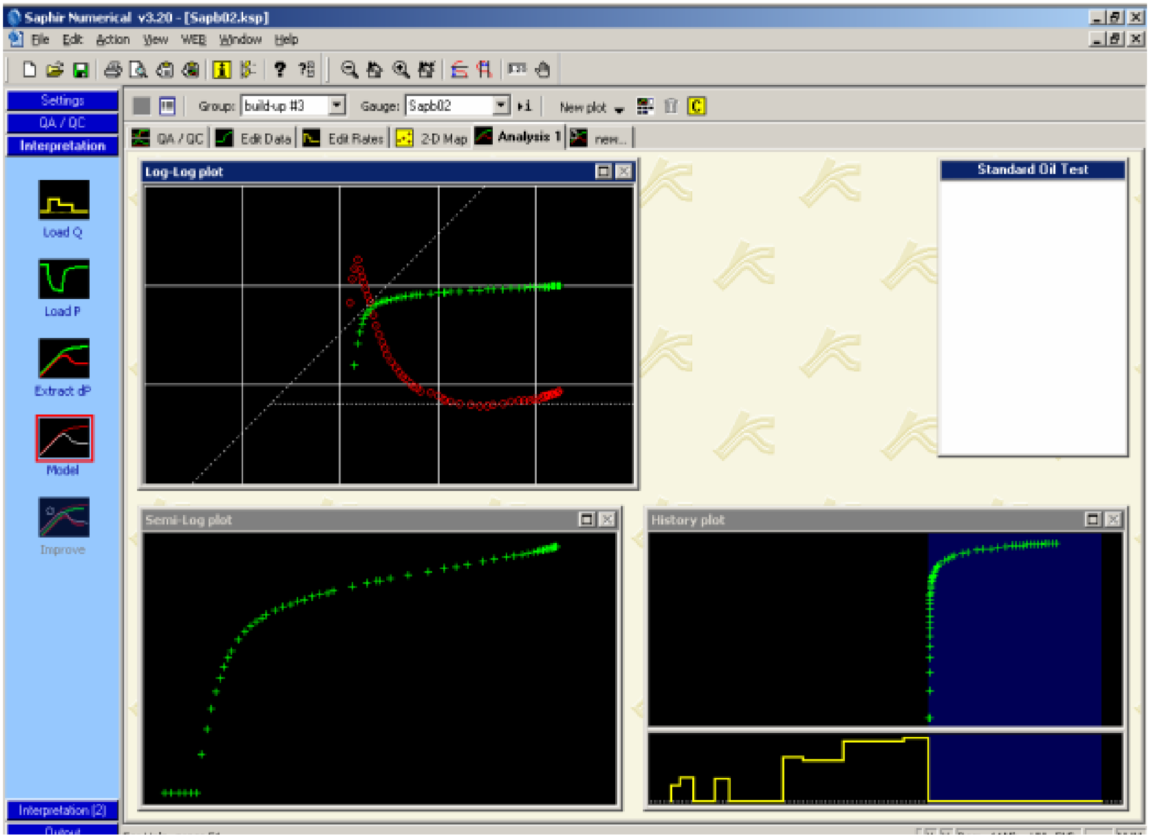

Fig 3.1. Interphase of Ecrin 4.03 (Sapphire) software used for the analysis . Source: Ecrin 4.0

3.3 Study Area

The Niger Delta, is in "South South Zone"of Nigeria , which includes Akwa Ibom State, Bayelsa State, Cross River State, Delta State, Edo State and Rivers State are two different entities. The Niger Delta is an oil producing region in with more than a thousand (1000) oil companies which uses pressure guages in all phases of oil production

Fig 1.1. Map of the Niger delta. Source map data google

IV. RESULTS AND DISCUSSION

Having carried out the differential pressure analyses and the sensitivity on the pressure gauges, the results are presented in **Table 4.1 and 4.2.** The errors were also calculated and tabulated.

Table 4.1. The differential pressure analysis for well 1

S/N	Depth interval (ft) between gauges	Assumed fluid	fluid Gradient (psi/ft)	Calculated Differential pressure dp	differential Pressure Gauge Reading (Psi)	% Error
Well 1	2	Oil	0.278	0.556	0.542	±2.52
	Type of gauge: ABC Gauges Name of Company: Company X Assumed fluid gradient = 0.9 psi/ft.					

Table 4.2. The differential pressure analysis for well 2

S/N	Depth interval (ft) between gauges	Assumed fluid	fluid Gradient (psi/ft)	Calculated Differential pressure dp (psi)	differential Pressure Gauge Reading (Psi)	% Error
Well 1	2	Oil	0.282	0.564	0.5	±11.34
	Type of gauge: DEF Gauges Name of Company: Company Y Assumed fluid gradient = 0.9 psi/ft					

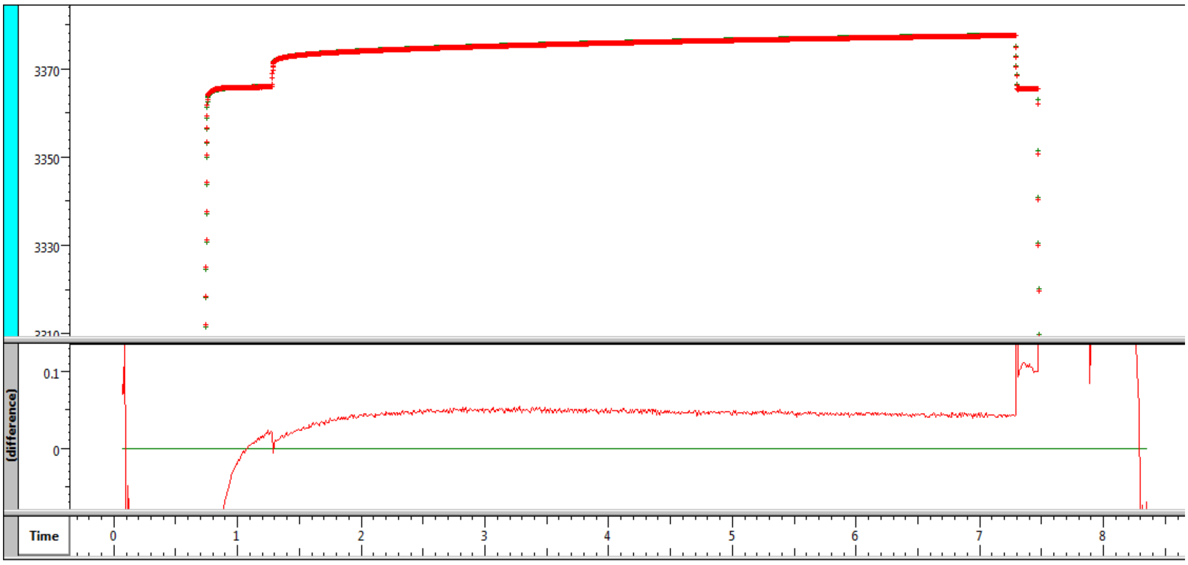

Fig.4.1 Pressure reading for Well 1

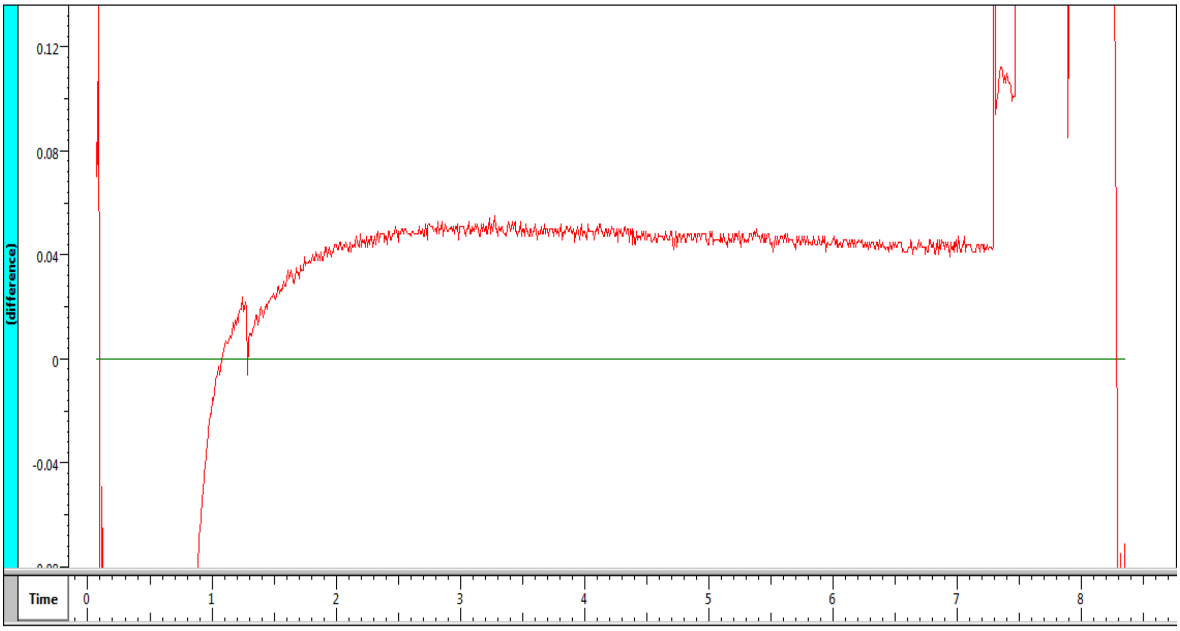

Fig .4 .2 Rate Reading for Well 1

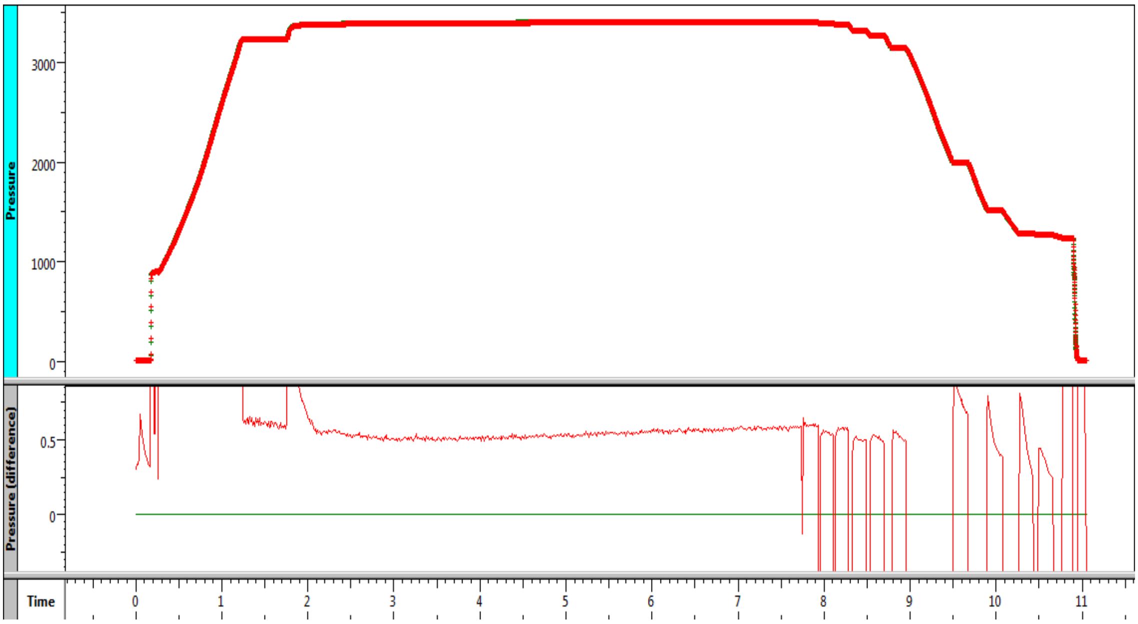

Fig. 4.3. Pressure Readings for well 2

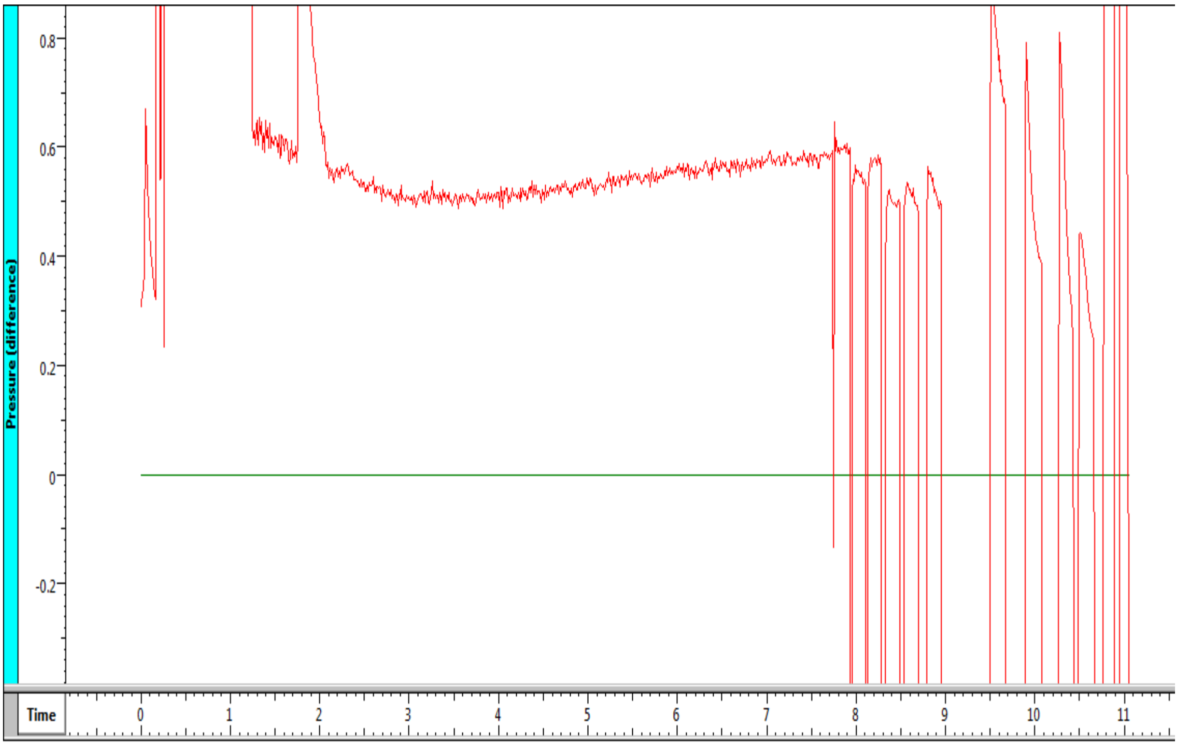

Fig. 4.4. Rate Readings from well 2

V. DISCUSSION

For pressure measurements in well 2, the pressure gauge from company DEF for oil producing company Y was used based on information available to the researcher. From the results presented above, the pressure reading for well 2 had a poor sensitivity which can be seen in the pressure vs. time plot in **Figure 4.3 and 4.4.** The differential pressure reading between the two gauges was measured as **0.5 (psi)** for Well 2 and this indicated a poor degree of accuracy in the pressure gauge reading with a calculated percentage error of ±11.34 % which is too high. Therefore, the pressure gauge from company DEF for oil producing company Y has a poor pressure response. This will present a wrong pressure reading for well testing. Consequently, wrong information of the subsurface pressures and the BHP test will be obtained for this well. On the other hand, pressure gauge from gauge manufacturing company ABC and oil producing company X which was used for pressure measurement for well 1, had a better differential pressure reading between the two gauges of **0.542 (psi)** for

Well 1 with a percentage error of **±2.52%**. Based on this finding, this gauge would most likely produce a better data for well testing than gauge DEF resulting from better resolution and sensitivity.

The findings are in agreement with previous studies. Firstly, Elshahawi, et al, 2000 noted that formation pressures, measured by a wireline pressure tester, which are conventionally used to build mud and reservoir pressure profiles should be measured using highly sensitive gauges. Further studies indicate that such practice would enhance interpretation and prediction of reservoir pressure profile (Dejam et al., 2018, Stewart, 2011, Qasem, et al., 2002). Furthermore, If the measured interval is sufficiently thick, accurate pressure gradients may be established (Elshahawi, et al, 2000,).

Therefore, the resolution of pressure gauge increasingly becomes very important when taking pressure measurement in the thinner the beds and lead to errors in the determination of pressure gradients. because thicker beds have more pressure (Dastjerdi et al. 2019). Further, highly sensitive pressure gauge is required to determine the bottom hole pressures from measured pressure data for better reservoir prediction using Artificial Neural network in wellbore stability in low pressure reservoirs, matured field and well designs (Fekete et al.,2015, Osuman et al., 2015, Odagme et al 2016). Also, it is relevant to use high resolution gauges when gauges are placed far from the perforations owning to downhole restrictions (Dastjerdi et al., 2019, Kuchuk & Biryukov 2014). In application, pressure gradients are helps in identification of permeability barriers, presence of skin, reservoir fluid contacts and the determination of the reservoir fluid density (Elshahawi, et al, 2000, Qasem, et al., 2002)). Therefore, in the Niger Delta which are predominately thin bed and low energy conditions and oxygen deficiency of the Akata formation (Statcher, 1995), high resolution and sensitivity of pressure gauges are inevitable to enhance the degree of accuracy in the data for well testing, improve reservoir management and pressure data used in planning drilling programmes for matured as obtained in the Niger Delta.

VI. CONCLUSION AND RECOMMENDATION

The sensitivity analysis of pressure gauges from two companies (ABC and DEF) for well 1 and 2 from oil producing company X and Y has been conducted and from the results presented, the following conclusions and recommendations can be deduced.

1. The success of a well test analysis depends on the accuracy of the pressure and rate data provided. This work shows that some pressure gauge provides an inaccurate pressure reading which will affect the well test analyses, mislead drilling Engineers if these gauges were to be used during drilling.
2. Based on data analyses from this study, pressure gauge manufacturing company ABC is recommended to be used in the Niger Delta with an error of ±2.52% as against company DEF with an error of ±11.34%. Hence, the resolution and sensitivity of gauge ABC was recommended since this would produce better gauge readings with minimum error.
3. Pressure gauge calibrations should be unnegotiable if they must be used for measurement of pressure data for Well testing and offset drilling data.
4. Finally, multiple pressure point could be taken for thin bed pressure gauge measurement to enhance accuracy.

REFERENCES

[1]. Athichanagorn, S., Horne, R.N., and Kikani, J., (*2002)*, "Processing and interpretation of long-term data acquired from permanent pressure gauges",

[2]. Czichos, Horst; Smith, Leslie, eds. (2011). Springer Handbook of Metrology and Testing (2nd ed.). 1.2.2 Categories of Metrology. ISBN 978-3-642-16640-2. Archived from the original on 2013-07-01.

[3]. Dejam M, Hassan Zadeh H, Chen Z (2018) Semi-analytical solution for pressure transient analysis of a hydraulically fractured vertical well in a bounded dual-porosity reservoir. J Hydrol 565:289–301

[4]. Dastjerdi, A.M, Farab, A.E and Sharif M (2019). 'Possible pitfalls in pressure transient analysis: Effect of adjacent wells ' Journal of Petroleum Exploration and Production Technology (2019) 9:3023–3038 https://doi.org/10.1007/s13202-019-0701-2.

[5]. Elshahawi, H., Samir, M., and Fathy, K. 2000. Correcting for Wettability and Capillary Pressure Effects on Formation Tester Measurements. Presented at the SPE Annual Technical Conference and Exhibition, Dallas, Texas, 1-4 October 2000. SPE-63075-An introduction to the Kalman filter

[6]. Fekete, P., Bruno, L. A., Dosunmu, A., **Odagme, S**., Sanusi, A., & Bowe, E. (2015, August 4). The Effect of Wellbore Stability in Naturally Fractured Reservoirs. Society of Petroleum Engineers. doi:10.2118/178267-MS. www.onepetro.org

[7]. Fekete, P., Ekpedekumo, R., Dosunmu, A., Odagme, S., & Bovwe, E. (2016, August 2). Evaluation of the Methodologies of Analysing Production and Pressure Data of Tight Gas Reservoir. Society of Petroleum Engineers. doi:10.2118/184263-MS. www.onepetro.org.

[8]. Gilly, P. and Horne, R.N. (*1998)*, "Analysis of pressure/flow rate data using the pressure history recovery method", paper SPE 57601

[9]. Hannah (2000) ''Precision Pressure Measurement: 'The Key to Accurate Fluid-Interface Monitoring'.

[10]. Kuchuk F, Biryukov D (2014) Pressure-transient behavior of continuously and discretely fractured reservoirs. SPE Reserv Eval Eng. 17:82–97

[11]. Nomura, M., 2006, "Processing and Interpretation of pressure transient data from permanent downhole gauges". Stanford University Ph.D. thesis.

[12]. Nomura, M. and Horne, R. N., 2009, "Data processing and interpretation of well test data as a non-parametric problem", SPE paper 120511

[13]. Odagme, B. S., Dosunmu, A., Oriji, B. A., & Fekete, P. (2016, August 2). Optimizing Well Design and Delivery for Wellbore Stability Management by Minimizing Subsurface Uncertainties. Society of Petroleum Engineers. doi:10.2118/184319-MS. www.onepetro.org

[14]. Onyekonwu, M.O (2000) 'General Principles of Bottom-Hole Pressure Tests' Chi Ikoko Series

[15]. Oriji A. B and Odagme B. S (2015). Application of Metering Process in Oil and Gas Production in Niger Delta Fields. Indian Journal of Scientific Research and Technology (INDJSRT), Volume 3 Issue 6, December 2015 pp-1- 6. www.indjsrt.org.

[16]. Okpo, E. E., Dosunmu, A., & Odagme, B. S. (2016, August 2). Artificial Neural Network Model for Predicting Wellbore Instability. Society of Petroleum Engineers. doi:10.2118/184371-MS. www.onepetro.org.

[17]. Osuman, L, Dosunmu, A, Odagme B S (2015) Optimizing Completions in Deviated and Extended Reach Wells. International Journal of Engineering and Techniques 1: 2. 54-67. www.ijetr.org

[18]. Stewart, G (2011) Well test design and analysis. PennWell Corporation, Tulsa,

[19]. Stacher, P., 1995. Present understanding of the Niger Delta hydrocarbon habitat, in, Oti, M.N., and Postma, G., eds. Geology of Deltas: Rotterdam, A.A. Balkema, p. 257-267.

[20]. Qasem, F. H., Nashawi, I. S. and Mirt, M. I. 2002. Detection of pressure buildup data dominated by wellbore phase redistribution effects. *J. Petrol. Sci. Eng.*, 34: 109–122.

[21]. Thomas, O., (2002) "The data as the model: Interpreting permanent downhole gauge data without knowing the reservoir model". Stanford University MS thesis. Welch, G. and Bishop G., 2006.

ODAGME, B. S, et. al. "Sensitivity Analysis of Pressure Gauges Used in Niger Delta For Effective Pressure Measurements for Drilling Operations, Reservoir Data Analysis and Well Testing."*American Journal of Engineering Research (AJER)*, vol. 10(5), 2021, pp. 31-42.