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Optimization of Drilling Bit Performance: A Cost-Per-Foot and Breakeven Analysis of Well-A and Well-B at Pan Ocean Oil Corporation Nigeria

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Abstract: *The assessment of drilling bit performance is essential for maximizing drilling process operational effectiveness and cost-efficiency. Using cost per foot and breakeven analysis, this study evaluates drilling bit performance to identify the best bit for fully drilling a well while lowering expenses. Well-A and Well-B of Pan Ocean Oil Corporation Nigeria were the subject of a case study that examined the effectiveness of seven distinct bits that were used to drill each well. With a breakeven rate of 51.51 feet per hour and the best cost per foot performance of $113.45/ft on run 1, Well-A reached a total depth of 13,203 feet. The best performance was shown by the 16"Baker MX-D53DX bit in run 2 in Well-B, which reached a depth of 13,866 feet. It cost $79.88/ft and broke even at78.14 ft/hr. Internet searches, case studies, and online resources were used to collect data. Bit optimization, specifically with the Baker T13 and BakerMX-D53DX, provided significant cost savings and increased penetration rates, according to the results. The significance of choosing an economical bit to maximize drilling efficiency and lower operating costs is emphasized by this study.*

Keywords: breakeven, well, cost, foot, drill bit

INTRODUCTION

Cost reduction and efficiency have become major challenges in the drilling of gas wells in recent years (Kwame, 2024; Kumar et al., 2020). The optimization of drilling parameters plays a significant role in reducing drilling costs, saving time, and ensuring safe operations. Researchers have been working to improve existing techniques through computerized mathematical models (optimization) aimed at determining the ideal combination of parameters to lower drilling costs while maximizing profit in a safer and more efficient environment. As technology advances, it aids in making the most optimal decisions in gas well drilling operations.

Drilling is an essential process widely used in the mining, construction, and oil and gas industries to create holes in various materials. According to Yahiaoui et al. (2013), a drilling bit is a cutting or boring tool used in oil and gas well drilling. One part of the bottom hole assembly that makes contact with the formation and performs the crushing and cutting function is the drilling bit (Bourgoyne et al., 2020; Caenn et al., 2017; Delavar et al., 2023). The bit, which is an integral part of the rig, must be in optimal condition to ensure efficient cutting. It is powered by the drill string or bottom hole motor and comes in different types, including drag bits, roller cone bits, and diamond bits. It is important to note that as a result of constant improvement modern insert bits are routinely used in many areas from top to bottom.

The effectiveness of diamond bits, in particular, varies depending on the type of formation being drilled, such as soft, medium, or hard formations. Bit selection is crucial for efficient drilling, as the right bit can significantly impact performance, cost, and safety. Oloro et al. (2011) studied drilling bit performance at Shell Petroleum Development Company's Opukushi-38 well using cost-per-foot (CPF) and breakeven analysis. Their findings revealed that the Hughes bit, which costs $34.57/ft, was the most cost-effective bit compared to others. CPF is a metric that helps compare the efficiency of different bits and drilling parameters by dividing the total drilling cost by the total footage drilled. Factors influencing CPF include bit cost, rig operating cost, drilling time, trip time, and the footage drilled.

Breakeven analysis, on the other hand, determines the point where the total drilling cost equals the revenue generated, helping assess the economic viability of a well. This analysis is crucial for evaluating the profitability of different drilling strategies. Similarly, optimization strategies for bit selection take into account various factors such as formation type, bit type, and key operational parameters, including:

- **Rate of Penetration (ROP):** Optimizing ROP maximizes footage drilled per unit of time while maintaining bit life and safety (Kuznetcov, 2016).
- **Weight on Bit (WOB):** Adjusting WOB achieves optimal cutting efficiency and minimizes bit wear.
- **Rotational Speed (RPM):** Optimizing RPM ensures efficient chip removal and prevents overheating.
- **Mud Parameters:** Proper mud properties help cool and clean the drill bit while preventing formation damage.

The performance of drilling bits has a significant impact on ROP, overall drilling costs, and the success of drilling operations. Therefore, evaluating bit performance through bit records is essential for improving the design of drilling bits. Manufacturers use these records to enhance their products, thereby optimizing drilling efficiency.

Bit selection and performance evaluation are vital in the oil and gas industry, where high drilling costs and challenging operational conditions make effective bit evaluation especially important (Yahiaoui et al., 2013). A rigorous evaluation process is necessary to determine the best bit for efficient drilling, taking into account factors like bit life, cost, ROP, and formation type. Additionally, studies like those by Oriji et al. (2015) have shown that breakeven analysis can help determine the performance requirements for various bit types to match the cost per foot of existing bits. This is essential for selecting the most cost-effective and efficient bit for specific drilling conditions. In rotary drilling, the bit's condition, the weight used to drill, and the rotational speed all influence how effectively it performs. Drillers aim to select bits that optimize ROP for a given formation, whether it is soft, medium, or hard (Adekunle & Olawale, 2020).
This chapter will review two main types of bits—drag bits and roller cone bits—and examine the grading and assessment process, emphasizing the economic and performance evaluations required for effective bit

selection. As the goal of drilling companies is to maximize profits, bit performance directly influences both drilling costs and profitability. A well-evaluated bit enables the efficient completion of a well, making bit selection a key factor in the success of drilling operations (Eren & Ozbayoglu, 2010; Elkatatny, 2021).

Aim and Objectives of this Project:

1. To correctly select a bit that can stay longer in the formation.
2. To establish cost savings and conduct a performance/economic evaluation of a bit.
3. To evaluate bit performance using cost per foot equations and breakeven calculations.

METHODOLOGY

As earlier complained, the recent trend toward deeper and costlier holes has led to the development of various rock bits which can stay in the hole longer, drill more footage and eliminate expenses. As a result there is a need for bits that can perform to enhance these qualities, ever increasing types of bit have become available, these are the milled tooth bit and the insert bit which are designed to have either sealed or non-sealed bearing. The various design have made the various bits to have different prices, footage drilled, penetration rate, and rotary hour. But all these factors have lost their significance, the only factor considered in drilling or selecting a bit is the cost per foot comparison.

The record data of this project was obtained from "PAN OCEAN OIL NIGERIA" in Ogugu Delta State of Nigeria. The data contain the bit record of wells; WELL A AND WELL B. WELL A has it's co-ordinate to be 228741.20mN, 53878.16nE.OML 98 Delta State Nigeria. It was spudded and was drilled to a depth of 13203ftmd/12912.52ft TVD. The well was drilled and completed to it's total depth using a total of seven (7) bits and KCA Deutag T57 rig cost of $125,000/day with trip of 9hours in a good hole condition and round trip of 18hours. The well was drilled to it's total depth of 13203ft within a period of (2) weeks. WELL B has it's co-ordinate to be 231273.92mN, 368124.97 mE. OML 98 Delta State Nigeria. It was spudded and was drilled to a depth of 13866ftmd/11921.24ft TVD. The well was drilled and completed to using a total of seven (7) bits and KCA Deutag T57 rig cost of $125,000/day with trip of 9hours in a good hole condition and round trip of 18hours. The well was drilled to it's total depth of 13203ft within a period of (2) months.

TABLE 1 Drilling bit data used in Well -A

Bit Run	Bit Size	Bit Make	Bit Type	Depth in (ft)	Depth Out(ft)	Footage Drilled (ft)	Rotation Hour (hrs)	Trip Time (hrs)	AROP (ft/hr)	Bit Cost ($)
1	16”	Baker	T13	237	4100	3163	75	3	51.507	52,00
2.	16”	BAKER	T13	4100	5995	1095	79	4	23.927	32,000
3.	12 ¼”	Reed	MSR61MAIC	5995	7616	1621	92.5	5	17.524	32,680
4	12 ¼”	Hughes Christensen	HCM506ZX	7616	8010	394	14	5	28.143	32,680
5	12 ¼”	Reed	R12A	8010	8966	956	51.13	6	18.697	32,680
6	12 ¼”	Reed	MSR646M	8966	11000	2034	116	7	17.534	65,000
7	8 ½	Reed	DSX713M	11000	13203	2203	105	9	20.981	48,000

TABLE 2 Drilling bit data used in Well-B

Bit Run	Bit Size	Bit Make	Bit Type	Depth in (ft)	Depth Out(ft)	Footage Drilled (Ft)	Rotation Hour (Hrs)	Trip Time (Hrs)	AROP (ft/hr)	Bit Cost ($)
1	16”	Baker	MX-D53DX	318	3600	3282	42	2	78.143	33,000
2.	16”	BAKER	MX-D53DX	2028	6005	3977	70.5	4	56.411	33,000
3.	12 ¼”	Hughes Christensen	HC507	6005	9663	3658	111.7	7	32.748	62,000
4	12 ¼”	Hughes Christensen	MX-CX18DDT	9663	11060	1397	85.3	8	16.377	62,000
5	12 ¼”	Reed	MSR-616	11060	11859	799	49.3	8	16.207	62,000
6	8 ½	Reed	DSR713M	11859	13786	1927	76.1	9	25.322	46,000
7	8 ½	Hughes Christensen	MXL-C09DDT	13786	13866	80	4.1	10	19.512	46,000

EVALUATION OF BIT PERFORMANCE IN WELL – A

COST PER FOOT ANALYSIS OF BITS USED IN WELL -A

The most practical and accepted approach for the IADC to assess the performance of the drilling bit was for
price per foot. By adjusting for this parameter, the relationship between penetration and bit cost at rates. Equation 1 was used to calculate the drilling cost per foot of bit run for the following variables: 1, 16"T13 (Baker), 2, 16 T13 (Baker), 3, 12 ¼" Reed (MIR61MAIC), 4, 121/4 Hughes Christensen, 5, 121/4" Reed, 6, 121/4" Reed, and 7, 81/2"Reed Bit, respectively.

$$C = \frac{B+CR\,(T+t)}{F} \qquad \text{Equation 1}$$

Where C = Cost per foot, B = Bit cost ($), C = Hourly Rig cost ($/hr), T = Trip time (hr), t = Rotating time (hr), and F = Footage drilled (ft)

i. **Drilling cost per foot of bit run1, 16”T13 (Baker)**

B = $32,000, R = $5208.33hr, T = 3 hours, t = 75 hours, and F = 3863 ft

$$C = \frac{32{,}000 + 5{,}208.33\ (3 + 75)}{3863}$$

$$C = \frac{32{,}000 + 5{,}208.33\ (78)}{3863}$$

$$C = \frac{32{,}000 + 5208{:}33\ (78)}{3863}$$

C= $113.45/ft

ii. **Drilling cost per foot of bit run 2, 16 T13 (Baker).**

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B = $ 52,000, C = $ 5208.33hr, T = 4hours, t = 79 hours, and F = 1895ft

$$C = \frac{32,000 + 5,208.33\ (4 + 79)}{1895}$$

$$C = \frac{32,000 + 5,208.33\ (83)}{1895}$$

$$C = \$245.00/ft$$

iii. Drilling cost per foot of bit run 3, 12 ¼" Reed (MIR61MAIC)

B = $32,680, R = $5208.33/hr, T = 92.5hours, t =5 hours, and F = 1621 ft

$$C = \frac{32,680 + 5208.33\ (92.5 + 5)}{1621}$$

$$C = \frac{39,000 + 5208.33(97.5)}{1621}$$

C=$333.43/ft

iv. Drilling cost per foot of bit run 4, $12^{1/4}$ Hughes christensen

B = $32,680, R = $5208.33/hr, T = 5 hours, t =14 hours, and F = 394 ft

$$C = \frac{32,680 + 5208.33\ (14 + 5)}{394}$$

$$C = \frac{32.680 + 5208.33\ (19)}{394}$$

$$C = \frac{32,680 + 98,958.27}{394}$$

$$C = \frac{131638.27}{394}$$

C = $334.11/ft

v. Drilling cost per foot of bit run 5 , $12^{1/4}$" Reed

B = $32,680, R = $5208.33/hr, T = 6 hours, t =51.13 hours, and F = 956 ft

$$C = \frac{32,680 + 5208.33\ (6 + 51.13)}{956}$$

$$C = \frac{32,680 + 5208.33\ (57.13)}{956}$$

$$C = \frac{32,680 + 297,551.893}{956}$$

$$C = \frac{330,231.893}{956}$$

C = $345.43/ft

vi. Drilling cost per foot of bit run 6, $12^{1/4}$" Reed

B = \$65,000, R = \$5208.33/hr, T = 7 hours, t =116 hours, and F = 2034 ft

$$C = \frac{65{,}000 + 5208.33\,(116 + 7)}{2034}$$

$$C = \frac{65{,}000 + 5208.33\,(123)}{2034}$$

$$C = \frac{65{,}000 + 640{,}624.59}{2034}$$

$$C = \frac{705{,}624.59}{2034}$$

C = \$346.91/ft

vii. Drilling cost per foot of bit run 7, 81/2"Reed Bit.

B = \$48,000, R = \$5208.33/hr, T = 9 hours, t =105 hours, and F = 2203 ft

$$C = \frac{48{,}000 + 5208.33\,(9 + 105)}{2203}$$

$$C = \frac{48{,}000 + 5208.33\,(114)}{2203}$$

$$C = \frac{48{,}000 + 593{,}749.62}{2203}$$

$$C = \frac{641{,}749.62}{2203}$$

C = \$291.307/ft

BREAKEVEN CALCULATION OF BITS USED IN WELL A

This approach to bit selection uses an offset well's minimum cost analysis (Majeed, etal., 2019). The process for this the following method is very basic (Rob March 2002): Choose the offset control wells, get bit records from the offset wells. Ascertain the prospect wells' rig costs and select the option that resulted in the lowest cost per foot result using the breakeven calculation formula to identify the optimal bit that will cost the least per foot to be. This investigation employed Equation 2 to compute breakeven on a specified interval for 26" Smith MTB115 Bit, $16^{1/2}$" Bakers T13 Bit, $12^{1/4}$" Reed MSR6CMAIC Bit, $12^{1/4}$" Hughes HXM506ZX Bit, $12^{1/4}$" Reed R12A Bit, $12^{1/4}$" Reed MSR616M Bit, and $8^{1/2}$" Reed DSX713M Bit respectively.

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$$ROPBE = \frac{RR}{(C-(((RR \times T)+B)/F))}$$ Equation 2

Where: ROPBE = Breakeven penetration rate (ft/hr), RR = Hourly rig rate ($/hr), C = Bit cost per foot ($/ft) , T = Trip time (hr), B = Bit cost ($) , and F = Assumed footage drilled for breakeven (ft)

i. **Breakeven calculation for 26" Smith MTB115 Bit.**

RR = $5208.33/hr, C = $113.45/ft, T = 3 hours, B = $32,000, and F = 3863 ft

$$ROPBE = \frac{5208.33}{(113.45 - (((5208.33 \times 3) + 32{,}000)/3{,}863))}$$

$$ROPBE = \frac{5208.33}{(113.45 - ((15{,}624.99 + 32{,}000)/3{,}863))}$$

$$ROPBE = \frac{5208.33}{(113.45 - (47624.99/3{,}863))}$$

$$ROPBE = \frac{5208.33}{(113.45 - 12.328)}$$

$$ROPBE = \frac{5208.33}{101.122}$$

ROPBE = 51.51 ft/hr

ii. **Breakeven calculation for 16$^{1/2}$" Bakers T13 Bit.**

RR = $5208.33/hr, C = $245.0/ft, T = 4 hours, B = $32,000, and F = 1,895 ft

$$ROPBE = \frac{5208.33}{(245.0 - (((5208.33 \times 4) + 32{,}000)/1{,}895))}$$

$$ROPBE = \frac{5208.33}{(245.0 - ((20833.32 + 32{,}000)/1{,}895))}$$

$$ROPBE = \frac{5208.33}{(245.0 - (52{,}833.32/1{,}895))}$$

$$ROPBE = \frac{5208.33}{(245.0 - 27.8803799)}$$

$$ROPBE = \frac{5208.33}{217.1196}$$

ROPBE = 23.99 ft/hr

iii. **Breakeven calculation for 12$^{1/4}$" Reed MSR6CMAIC Bit.**

RR = $5208.33/hr, C = $333.43/ft, T = 5 hours, B = $32,680, and F = 1621 ft

$$ROPBE = \frac{5208.33}{(333.43 - (((5{,}208.33 \times 5) + 32{,}680)/1{,}621))}$$

$$ROPBE = \frac{5208.33}{(333.43 - ((26{,}041.65 + 32{,}680)/1{,}621))}$$

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$$\text{ROPBE} = \frac{5208.33}{(333.43 - (58{,}721.65/1{,}621))}$$

$$\text{ROPBE} = \frac{5208.33}{(333.43 - 36.2255706)}$$

$$\text{ROPBE} = \frac{5208.33}{297.204}$$

ROPBE = 17.52 ft/hr

iv. Breakeven calculation for 12$^{1/4}$" Hughes HXM506ZX Bit.

RR = $5208.33/hr, C = $334.11/ft, T = 5 hours, B = $32,680, and F = 394 ft

$$\text{ROPBE} = \frac{5208.33}{(334.11 - (((5208.33 \times 5) + 32{,}680)/394)}$$

$$\text{ROPBE} = \frac{5208.33}{(334.11 - ((26{,}041.65 + 32{,}680)/394))}$$

$$\text{ROPBE} = \frac{5208.33}{(334.11 - (58721.65/394))}$$

$$\text{ROPBE} = \frac{5208.33}{(334.11 - 149.039721)}$$

$$\text{ROPBE} = \frac{5208.33}{185.070}$$

ROPBE = 28.14 ft/hr

v. Breakeven calculation for 12$^{1/4}$" Reed R12A Bit.

RR = $5208.33/hr, C = $345.43/ft, T = 6 hours, B = $32,680, and F = 956 ft

$$\text{ROPBE} = \frac{5208.33}{(345.43 - (((5208.33 \times 6) + 32{,}680)/956))}$$

$$\text{ROPBE} = \frac{5208.33}{(345.43 - ((31{,}249.98 + 32{,}680)/956))}$$

$$\text{ROPBE} = \frac{5208.33}{(345.43 - (63929.98/956))}$$

$$\text{ROPBE} = \frac{5208.33}{(345.43 - 66.872364)}$$

$$\text{ROPBE} = \frac{5208.33}{278.557636}$$

ROPBE = 18.70 ft/hr

vi. Breakeven calculation for $12^{1/4}$" Reed MSR616M Bit.

RR = \$5208.33/hr, C = \$346.91/ft, T = 7 hours, B = \$65,000, and F = 2,034 ft

$$\text{ROPBE} = \frac{5208.33}{(346.91 - (((5208.33 \times 7) + 65{,}000)/2{,}034))}$$

$$\text{ROPBE} = \frac{5208.33}{(346.91 - ((36458.31 + 65{,}000)/2{,}034))}$$

$$\text{ROPBE} = \frac{5208.33}{(346.91 - (101458.31/2{,}034))}$$

$$\text{ROPBE} = \frac{5208.33}{(346.91 - 49.88117502)}$$

$$\text{ROPBE} = \frac{5208.33}{297.028825}$$

$$\text{ROPBE} = 17.53\text{ft/hr}$$

vii. Breakeven calculation for $8^{1/2}$" Reed DSX713M Bit.

RR = \$5208.33/hr, C = \$291.307/ft, T = 9 hours, B = \$48,000, and F = 2,203 ft

$$\text{ROPBE} = \frac{5208.33}{(291.307 - (((5208.33 \times 9) + 48{,}000)/2{,}203))}$$

$$\text{ROPBE} = \frac{5208.33}{(291.307 - ((46874.97 + 48{,}000)/2{,}203))}$$

$$\text{ROPBE} = \frac{5208.33}{(291.307 - (94874.97/2{,}203))}$$

$$\text{ROPBE} = \frac{5208.33}{(291.307 - 43.0662596)}$$

$$\text{ROPBE} = \frac{5208.33}{248.2407}$$

$$\text{ROPBE} = 20.98\text{ ft/hr}$$

EVALUATION OF BIT PERFORMANCE IN WELL – B

COST PER FOOT ANALYSIS OF BITS USED IN WELL – B

Equation 3 was used to calculate drilling cost per for Well B at drilling cost per foot of bit run of 1, 16" Baker T13 Bit, 2, 16" Baker T13 Bit, 3, $12^{1/4}$" Hughes Christensen Bit, 4, $12^{1/4}$" Hughes Bit, 5, $12^{1/4}$" Reed Bit, 6, $8^{1/2}$" Reed Bit, 7 and , $8^{1/2}$" Hughes Bit respectively.

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$$C = \frac{B + R\,(T + t)}{F} \qquad \text{Equation3}$$

C = Cost per foot ($/ft), B = Bit cost ($), R = Rig cost ($/hr), T = Trip time (hr), t = Rotating time (hr), and F = Footage drilled (ft)

i. Drilling cost per foot of bit run 1, 16" Baker T13 Bit.

B = $33,000, R = $5208.33/hr, T = 2 hours, t =42 hours, and F = 3282 ft

$$C = \frac{33{,}000 + 5208.33(2 + 42)}{3{,}282}$$

$$C = \frac{33{,}000 + 5{,}208.33(44)}{3{,}282}$$

$$C = \frac{33{,}000 + 229{,}166.52}{3{,}282}$$

$$C = \frac{262{,}166.52}{3{,}282}$$

C = $79.88/ft

ii. Drilling cost per foot of bit run 2, 16" Baker T13 Bit.

B = $33,000, R = $5208.33/hr, T = 4 hours, t =70.5 hours, and F = 3,977 ft

$$C = \frac{33{,}000 + 5208.33(4 + 70.5)}{3{,}977}$$

$$C = \frac{33{,}000 + 5{,}208.33(74.5)}{3{,}977}$$

$$C = \frac{33{,}000 + 388{,}020.585}{3{,}977}$$

$$C = \frac{421020.585}{3{,}977}$$

C = $105.86/ft

iii. Drilling cost per foot of bit run 3, $12^{1/4}$" Hughes Christensen Bit.

B = $62,000, R = $5208.33/hr, T = 7 hours, t =111.7 hours, F = 3,658 ft

$$C = \frac{62{,}000 + 5{,}208.33(7 + 111.7)}{3{,}658}$$

$$C = \frac{62{,}000 + 5{,}208.333(118.7)}{3{,}658}$$

$$C = \frac{62{,}000 + 618{,}228.771}{3{,}658}$$

$$C = \frac{680{,}228.771}{3{,}658}$$

C = $185.95/ft

iv. **Drilling cost per foot of bit run 4, 12$^{1/4}$" Hughes Bit.**

B = $62,000, R = $5208.36/hr, T = 8 hours, t =85.3 hours, and F = 1,397 ft

$$C = \frac{62{,}000 + 5{,}208.33(8 + 85.3)}{1{,}397}$$

$$C = \frac{62{,}000 + 5{,}208.33(93.3)}{1{,}397}$$

$$C = \frac{62{,}000 + 485{,}937.189}{1{,}397}$$

$$C = \frac{547{,}937.189}{1{,}397}$$

C = $392.22/ft

v. **Drilling cost per foot of bit run 5, 12$^{1/4}$" Reed Bit.**

B = $62,000, R = $5208.33/hr, T = 8 hours, t =49.3 hours, and F = 799 ft

$$C = \frac{62{,}000 + 5{,}208.33(8 + 49.3)}{799}$$

$$C = \frac{62{,}000 + 5{,}208.33(57.3)}{799}$$

$$C = \frac{62{,}000 + 298{,}437.309}{799}$$

$$C = \frac{360{,}437.309}{799}$$

C = $451.11/ft

vi. **Drilling cost per foot of bit run 6, 8$^{1/2}$" Reed Bit.**

B = $46,000, R = $5208.33/hr, T = 9 hours, t =76.1 hours, and F = 1,927 ft

$$C = \frac{46{,}000 + 5{,}208.33(9 + 76.1)}{1{,}927}$$

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$$C = \frac{46{,}000 + 5{,}208.33(85.1)}{1{,}927}$$

$$C = \frac{46{,}000 + 443{,}228.883}{1{,}927}$$

$$C = \frac{489{,}228.883}{1{,}927}$$

C = $253.88/ft

vii. Drilling cost per foot of bit run 7, $8^{1/2}$" Hughes Bit.

B = $46,000, R = $5208.33/hr, T = 10 hours, t = 4.1 hours, and F = 80ft

$$C = \frac{46{,}000 + 5{,}208.33\ (10 + 4.1)}{80}$$

$$C = \frac{46{,}000 + 5{,}208.33\ (14.1)}{80}$$

$$C = \frac{46{,}000 + 73{,}437.453}{80}$$

$$C = \frac{119{,}437.453}{80}$$

C = $1,492.97.88/ft

3.3.2 Breakeven Calculation of Bits Used in Well – B

Equation 4 was used to calculate breakdown of Well- B for 1, 16" Baker T13 Bit, 2, 16" Baker T13 Bit, 3, $12^{1/4}$" Hughes Christensen Bit, 4, $12^{1/4}$" Hughes Bit, 5, $12^{1/4}$" Reed Bit, 6, $8^{1/2}$" Reed Bit, 7, and $8^{1/2}$" Hughes Bit respectively.

$$ROPBE = \frac{RR}{(C-(((RR \times T)+B)/F))} \qquad \text{(Equation 4)}$$

ROPBE = Breakeven penetration rate (ft/hr), RR = Hourly rig rate ($/hr), C = Bit cost per foot ($/ft), T = Trip time (hr), B = Bit cost ($), and F= Assumed footage drilled for breakeven (ft)

i. Breakeven calculation for run 1,16" Baker Bit.

RR = $5208.33/hr, C = $79.58/ft, T = 2 hours , B = $33,000, F = 3,282 ft

$$ROPBE = \frac{5{,}208.33}{(79.88 - (((5{,}208.33 \times 2) + 33{,}000)/3{,}282))}$$

$$ROPBE = \frac{5{,}208.33}{(79.88 - ((10{,}416.66 + 33{,}000)/3{,}282))}$$

$$ROPBE = \frac{5{,}208.33}{(79.88 - (43{,}416.66/3{,}282))}$$

$$\text{ROPBE} = \frac{5,250}{(79.88 - 13.2287)}$$
$$\text{ROPBE} = \frac{5,208.33}{66.6513}$$
ROPBE = 78.14ft/hr

ii. Breakeven calculation for run 2, 16” Baker Bit.

RR = $5208.33/hr, C = $105.86/ft, T = 4 hours, B = $33,000, and F = 3,977 ft

$$\text{ROPBE} = \frac{5,208.33}{(105.86 - (((5,208.33 \times 4) + 33,000)/3,977))}$$
$$\text{ROPBE} = \frac{5,208.33}{(105.86 - ((20,833.32 + 33,000)/3,977))}$$

$$\text{ROPBE} = \frac{5,208.33}{(105.86 - (53,833.32/3,977))}$$
$$\text{ROPBE} = \frac{5,208.33}{(105.86 - 13.5361629)}$$
$$\text{ROPBE} = \frac{5,208.33}{92.32383706}$$

ROPBE = 56.41ft/hr

iii. Breakeven calculation for run 3, $12^{1/4}$” Hughes Bit.

RR = $5208.33/hr, C = $185.95/ft, T = 7 hours, B = $62,000, and F = 3,658 ft

$$\text{ROPBE} = \frac{5,208.33}{(185.95 - (((5,208.33 \times 7) + 62,000)/3,658))}$$
$$\text{ROPBE} = \frac{5,208.33}{(185.95 - ((36,458.31 + 62,000)/3,658))}$$

$$\text{ROPBE} = \frac{5,208.33}{(185.95 - (98,458.31/3,658))}$$
$$\text{ROPBE} = \frac{5,208.33}{(185.95 - 26.9158857)}$$

$$\text{ROPBE} = \frac{5,208.33}{159.034114}$$

ROPBE = 32.75ft/hr

iv. Breakeven calculation for run 4, $12^{1/4}$” Hughes Bit.

RR = $5208.33/hr, C = $392.22/ft, T = 8 hours, B = $62,000, and F = 1,397 ft

$$\text{ROPBE} = \frac{5,208.33}{(392.22 - (((5,208.33 \times 8) + 62,000)/1,397))}$$

$$\text{ROPBE} = \frac{5{,}208.33}{(392.22 - ((41{,}666.64 + 62{,}000)/1{,}397))}$$

$$\text{ROPBE} = \frac{5{,}208.33}{(392.22 - (103{,}666.64/1{,}397))}$$

$$\text{ROPBE} = \frac{5{,}208.33}{(392.22 - 74.20661417)}$$

$$\text{ROPBE} = \frac{5{,}208.33}{318.0133858}$$

ROPBE = 16.38ft/hr

v. Breakeven calculation for run 5, 12$^{1/4}$" Reed Bit.

RR = \$5208.33/hr, C = \$451.11/ft, T = 8 hours, B = \$62,000, and F = 799 ft

$$\text{ROPBE} = \frac{5{,}208.33}{(451.11 - (((5{,}208.33 \times 8) + 62{,}000)/799))}$$

$$\text{ROPBE} = \frac{5{,}208.33}{(451.11 - ((41{,}666.64 + 62{,}000)/799))}$$

$$\text{ROPBE} = \frac{5{,}208.33}{(451.11 - (103{,}666.64/799))}$$

$$\text{ROPBE} = \frac{5{,}208.33}{(451.11 - 129.745482)}$$

$$\text{ROPBE} = \frac{5{,}208.33}{321.3645181}$$

ROPBE = 16.21ft/hr

vi. Breakeven calculation for run 6,8$^{1/2}$" Reed Bit.

RR = \$5208.36/hr, C = \$253.88/ft, T = 9 hours, B = \$46,000, and F = 1,927 ft

$$\text{ROPBE} = \frac{5{,}208.33}{(253.88 - (((5{,}208.33 \times 9) + 46{,}000)/1{,}927))}$$

$$\text{ROPBE} = \frac{5{,}208.33}{(253.88 - ((46{,}874.97 + 46{,}000)/1{,}927))}$$

$$\text{ROPBE} = \frac{5{,}208.33}{(253.88 - (92{,}874.97/1{,}927))}$$

$$\text{ROPBE} = \frac{5{,}208.33}{(253.88 - 48.1966632)}$$

$$\text{ROPBE} = \frac{5{,}208.33}{205.6833368}$$

ROPBE = 25.34ft/hr

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vii. Breakeven calculation for run 7,8$^{1/2}$" Hughes Bit.

RR = \$5208.36/hr, C = \$1,492.97/ft, T = 10 hours, B = \$46,000, F = 80ft

$$ROPBE = \frac{5,208.33}{(1,492.97 - (((5,208.33 \times 10) + 46,000)/80))}$$

$$ROPBE = \frac{5,208.33}{(1,492.97 - ((52,083.3 + 46,000)/80))}$$

$$ROPBE = \frac{5,208.33}{(1,492.97 - (98,083.3/80))}$$

$$ROPBE = \frac{5,208.33}{(1,492.97 - 1,226.04125)}$$

$$ROPBE = \frac{5,208.33}{266.92875}$$

$ROPBE = 19.51$ft/hr

TABLE 3: Cost per foot and breakeven calculation in Well A

BIT NO	BIT SIZE (INCH)	BIT MAKE	BIT TYPE	COST PER FOOT ($/FT)	BREAKEVEN ANALYSIS (FT/HR)
1	16"	BAKER	T13	113.45	51.50
2	16"	BAKER	T13	245.0	23.98
3	12¼	REED	MSR6 1MAIC	333.43	17.52
4	12$^{1/4}$"	HUGHES CHRISTENSEN	HCM5 06ZX	334.11	28.14
5	12$^{1/4}$"	REED	R12A	345.43	18.70
6	12$^{1/4}$"	REED	MSR 647M	346.91	17.53
7	8¼	REED	DSX 713M	291.31	20.98

TABLE4: Cost Per Foot and Breakeven Calculation in Well B

BIT NO	BIT SIZE (INCH)	BIT MAKE	BIT TYPE	COST PER FOOT ($/FT)	BREAKEVEN ANALYSIS (FT/HR)
1	16"	BAKER	MX-D 53DX	79.88	78.14
2	16"	BAKER	MX-D 53DX	105.86	56.41
3	$12^{1/4}$"	HUGHES CHRISTENSEN	HC507	185.95	32.75
4	$12^{1/4}$"	HUGHES CHRISTENSEN	MX-C X18DDT	392.22	16.38
5	$12^{1/4}$"	REED	MSR-616	451.11/	16.21
6	$8^{1/2}$"	REED	DSR713M	253.88	25.34
7	8¼"	HUGHES CHRISTENSEN	MCL-CO9 DDT	1492.97	19.51

RESULTS AND DISCUSSION

Bit Performance in Well- A

The analysis of the data from well A indicates that two (2) (16" Baker T13) were used to drill the first section, which resulted in 3863 feet of footage at a rotation hour of 75 hours and an average trip time of three hours see Table 1. It had a breakeven penetration rate of 51.50 feet per hour and a cost per foot of $113.45 feet. With a rotation time of 79 hours and an average trip time of 4 hours, the second bit (16" Baker T13) drilled 18951 feet of footage. It had a breakeven penetration rate of 23 to 98 feet per hour and a cost per foot of $245 feet. Four (12.25 Reed but) bits were used to drill the third section of the well. The third bit (12.25" Reed MSR61mAIC) drilled 1621 feet of footage at a rotational time of 92.5 hours and an average trip time of 5 hours. It had a breakeven penetration rate of 17.52 feet per hour and a cost per foot of $333.43 feet. Drilling footage of 394 feet at a rotation time of 14 hours and a trip time of 5 hours was done by the fourth bit (12.25" Hughes ChristensenHCm506ZX). It drilled with a breakeven penetration of 28.14ft/hr and a cost per foot of $334.11ft. Drilling footage of 956 feet at a rotation time of 51:13 hours and an average trip time of 6 hours was the fifth bit (12.25" Reed R12A). With a breakeven penetration rate of 18 to 70 feet per hour and a cost per foot of $345 to 43 feet, the sixth bit (12 to 25" Reed MSR616M) drilled 2,034 feet of footage at a rotation time of 116 hours and an average trip time of 7 hours. The cost of drilling was $346.91 feet per foot, with a breakeven penetration rate of 17.53 feet per hour. With a rotation time of 105 hours and an average trip time of 9 hours, the seventh bit (8.5" Reed DSX713M) drilled 2,203 feet of footage. It had a breakeven penetration rate of 20–98 feet per hour and a cost per foot of $291–31 feet.

Bit Performance in Well -B

Based on the analysis of Well B, two (2) 16" b first bits (16" BakerMX-D53DX) were used to drill the well's first section, resulting in 3282 feet of drilled footage at a rotation time of 42 hours and an average trip time of two hours as shown in Table 2. It drilled at a breakeven penetration rate of 78.14 feet per hour and a cost per foot of $79.58 feet. The second bit (16" Baker MX-D53DX), which had an average trip time of 4 hours and drilled footage of 3977 feet at a rotation time of 70.5 hours. It drilled at a breakeven penetration rate of 56.41 feet per hour, with a cost per foot of $105.86 feet. Four (4) 12.25" bits were used to drill the second well. Drilling 3658 feet of footage at a rotational time of 111.7 hours and an average trip time of 7 hours was the third bit (12.25" Hughes Christensen HC507). It had a breakeven penetration rate of 32.75 feet per hour and a cost per foot of $185.95 feet. The fourth bit, a 12.25" Hughes Christensen MX-CX18DDT, drilled 1397 feet of footage with an average trip time of 8 hours and a rotation duration of 85.3 hours. It drilled at a breakeven penetration rate of 16.38 feet per hour and cost $392.22 feet per foot. Drilling footage of 799 feet at a rotation time of 49.3 hours and an average trip time of 8 hours was the fifth bit (12.25" Reed MSR-616). At a breakeven penetration rate of 16.21 feet per hour, it was drilled at a cost of $45.11/ft. At a rotation time of 76.1 hours and an average trip time of 9 hours, the sixth bit (12.25" Reed DSR713m) drilled footage of 1927 feet. With a breakeven penetration rate of 25.34 feet per hour, it was drilled at a cost of $253.88 per foot. The 8.5" Hughes MxL-CO9DDT sevens bit drilled 80 feet of film at a rotational time of 4.1 hours and an average trip duration of 9 hours. With a breakeven penetration rate of 19.51 feet per hour, it was drilled at a cost of $1493.97 per foot.

According to the bit record from Well A, a cumulative total of seven (7) bits were employed to achieve the ultimate depth of 13,203 feet as shown in Table 3. A variety of bit types were utilized to reach this total depth of 13,203 feet, indicating that the well was drilled in seven (7) distinct sections. The initial section was executed utilizing a (16" Baker T13) bit, covering a footage of 3,863 feet. This particular run yielded optimal performance for drilling that section of the well, characterized by the lowest cost per foot and the highest breakeven penetration rate. The associated cost per foot was determined to be $113.45 per foot, with a breakeven penetration rate of 51.50 feet per hour. For Well B, as indicated by the bit record, a cumulative total of seven (7) drilling bits were deployed to achieve the well's ultimate depth of 13,866 feet, with various types of bits utilized throughout the drilling process, illustrating that the well was completed in seven (7) distinct sections see Table 4 . The initial bit employed was a 16” Baker MX-D53DX, which facilitated drilling up to a total depth of 3,282 feet. This operational run demonstrated optimal performance for drilling within that segment of the well, characterized by the lowest cost per foot and the highest rate of penetration. The economic analysis of this run revealed a cost of $79.88 per foot and a break-even penetration rate of 78.14 feet per hour.

CONCLUSION

The assessment of drill bit efficiency through cost per foot analysis alongside breakeven calculations resulted in an improved evaluation of bit performance. A case study on wells A and B revealed that seven (7) bits were utilized to reach a total depth of 13,203 ft for Well A. In comparison, seven (7) bits were necessary to drill well B to a depth of 13,866 ft. This variance is ascribed to effective bit optimization. The analysis of drilling bits through cost per foot and breakeven calculations offers a superior evaluation of bit performance. Most bits functioned effectively but were costly. Examination showed that Baker T13 and Baker MX-D53DX, which utilized the same bit manufacturer in Well A and Well B respectively, exhibited superior performance owing to their cost and economic feasibility and can be employed for additional Substitute oil Wells.

Recommendation

i. To achieve the best drilling results, drilling engineers ought to assess bit performance through cost per foot comparisons and breakeven analysis for improved bit performance. In performing bit optimization, proper attention must be given to accurately measuring variables like footage drilled, trip time, rotating hours, depth in, depth out, and so on

ii. The evaluation of the bit employed in well A and well B suggests taking into account the 16" Baker T13 bit from well B, which has the lowest cost per foot and the highest breakeven penetration rate for optimizing drilling operation expenses.

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