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Productivity Enhancement by Re-Perforation in Abu-Attifel Oil Field - Libya: A Case Study

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ABSTRACT

The Libyan National Oil Corporation (NOC) announced a strategic plan at the beginning of 2023 to increase the level of oil production to two million barrels per day. Companies operating in the oil sector have, in turn, started implementing NOC's plan to increase recovery rates from the fields they operate. Mellitah Oil and Gas B.V. Company, Libya branch, started developing measures to enhance production in the Abu-Attifel Oil field. The company sought to enhance the productivity of the two wells, A1 and A3, located in the A100 concession, from the upper Nubian Sandstone reservoir using the Re-perforation technique, as the level of production from these two wells had decreased due to scale formation caused by the accompanying water during production and high temperatures, which led to closing some of perforation intervals. In February 2024, the company succeeded in increasing oil production by 976 STB/D in the A1/A100 well and by 557 STB/D in the A3/A100 well, compared to late 2023 levels, which reflecting the efficacy of the Re-perforation technique in mitigating scale-related issues and optimizing reservoir performance.

KEYWORDS: Productivity Enhancement, Re-perforation Technique, Abu Attifel Oil Field, Sandstone Reservoir.

1. INTRODUCTION

The National Oil Corporation (NOC) has been dedicatedly striving to improve oil production rates from the Libyan oil fields. To achieve this target, the NOC devised a strategic plan in February 2023, to reach a production level of two million barrels per day. As a result, companies operating within the oil sector have undertaken various measures to boost their oil recovery rates.

Different stimulation techniques are employed by these companies to enhance oil recovery. These techniques involve hydraulic fracturing, acid jobs, perforation extension, and re-perforation, which is the simplest and most economical option [(1)]. Mellitah Oil & Gas B.V. Company, in which the NOC shares 85% ownership with the Italian Eni [(2)], has initiated the implementation of this strategic plan across the fields under its operation, including the Abu Attifel oil field. This onshore field is located approximately 60 kilometers away from the city of Gallo, situated in the Sirte Basin, which is the largest sedimentary basin in Libya.

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The Abu Attifel oil field was initially discovered back in 1967 in the A100 concession. Since then, the field has played a crucial role in the country's oil production. The field primarily taps into a sandstone reservoir that operates under a water drive mechanism [(3)]. The company executed the re-perforation process in many wells, including wells A1 and A3, which are the focus of the study.

2. RESERVOIR CHARACTERISTICS

The two clastic units are the main reservoirs of the A100 concession, locally known as Lower Nubian Sandstone and Upper Nubian Sandstone, separated by Varicoloured Shale [(4)]. The main petrophysical characteristics of Upper Nubian Sandstone are shown in Table 1.

Table 1: Reservoir Characteristic

Net Pay ft	Av. Phi %	Av. Sw %	Av. Permeability K, md
633	13	22	50

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3. PRODUCTIVITY ENHANCEMENT

One way to enhance productivity is to stimulate the well, as stimulation refers to increasing the production of the well that has been damaged. This damage obstructs the flow of fluids; one of its causes is the blockage of perforations in the well casing. The clogging of the holes in the casing is due to the precipitation of minerals (the formation of scales) [5].

Water is the major source of all scale formation, and when water is produced along with oil and gas - as in the field of Abu Attifel - different types of scale are formed in the reservoir or the production tubing. The scale can deposit in the form of a thick layer in the wellbore tubing, which reduces the production diameter of the tubing, resulting in impaired flow, production equipment failure, emergency shutdown, and increased maintenance cost [6, 7]. High temperature is also a cause of this problem [8], as the Flowing Tubing Head Temperature (FTHT) reaches up to 236O F in the A1/A100 well and 204O F in the A3/A100 well.

This paper aims to identify the extent of the well's response to the re-perforation process as a stimulation technique for removing scale that closes some of the perforation intervals to enhance productivity.

4. A1/A100 Well History

The A1 Well is the first well drilled in the A100 concession. In February 1968, an A1 oil well was drilled and completed. The well targeted the Upper Nubian Sandstone in the perforation intervals (13,998' – 14,024'), achieving a production rate of 1,654 STB/D and 0% WC. In 1973, after several perforation extension and re-perforation operations, the highest production rate of 19,692 STB/D was achieved. However, by 1988, the water-producing layers 13,645'-13,710' and 13,776'-13,890' had to be isolated due to an increased water cut (WC) of 66%, resulting in a significant decline in the oil production rate to 812 STB/D.

According to the data shown in Table 2, the oil production rate during the period from April to November decreased by approximately 785 STB/D Fig.1. The rate of gas production also decreased by approximately 3,000MSCF/D in the same period Fig.2, with an increase in water cut reaching 72% Fig.3.

Table 2: A1Well Routine Tests History

Date	FTHP psi	FTHT Deg F	Qo STB/D	Qg MSCF/D	Qw STB/D	GOR SCF/STB	WC %	Choke Size /64
01.Apr.2023	850	236	1577	4305	2504	2733	61	16
05.May.2023	619	233	1529	3520	N/A	2299	52	46
30.Jun.2023	910	232	1365	4706	2350	3449	63	80
11.Aug.2023	850	233	1243	4002	2435	3220	66	12
21.Nov.2023	750	216	792	1411	2035	1783	72	80

In November 2023, a Production Logging Test (PLT) was conducted. The test results were as follows:

- The most significant contribution intervals were observed at the top (13,345' -13,350'), as the test did not cover to the bottom up to 13,444'.
- Some parts of the perforations showed very minor contributions that could not be quantified.
- Gamma Ray (GR) readings indicated the presence of scale, which might potentially impact production efficiency and further complicate operations

4.1 Well Stimulation Decision

Based on the PLT test results indicating the presence of scale and insufficient contribution from some perforations, along with the reservoir characteristics outlined in Table 1 and the well's history spanning over 55 years, which showcased a positive response to improvement through Re-perforation, the decision was made to re-perforate the intervals specified in Table 3.

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Table 3: Required Re-perforation intervals

Interval No.	From ft	To ft	Height ft	Type of gun/SPF/phase
1	13,350	13,360	10	2" power jet nova gun (6SPF,60°)
2	13,368	13,385	17	

4.2 Well Stimulation Results (Re-Perforation)

After completing the procedure of re-perforating in-under-balance conditions with the requested gun, a routine test was conducted on February 11, 2024, and the results were as shown in Table 4 and Fig.1, 2, 3.

Table 4 : A1/A100 Well Routine Test Results

Date	FTHP psi	FTHT Deg F	Qo STB/D	Qg MSCF/D	Qw STB/D	GOR SCF/STB	WC %	Choke Size /64
11.Feb.2024	928	234	1768	5715	2387	3232	57	52

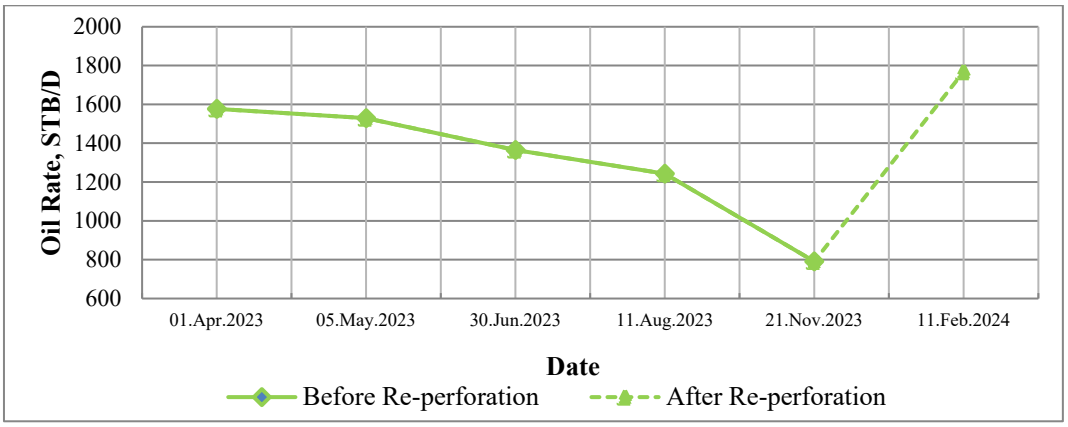


Fig. 1: A1 Well Oil Rate vs. Date

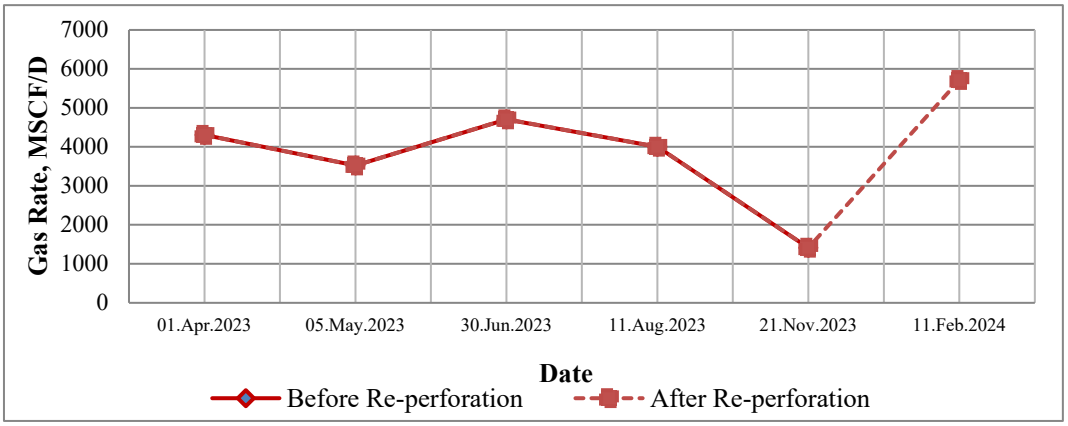


Fig. 2: A1 Well Gas Rate vs. Date

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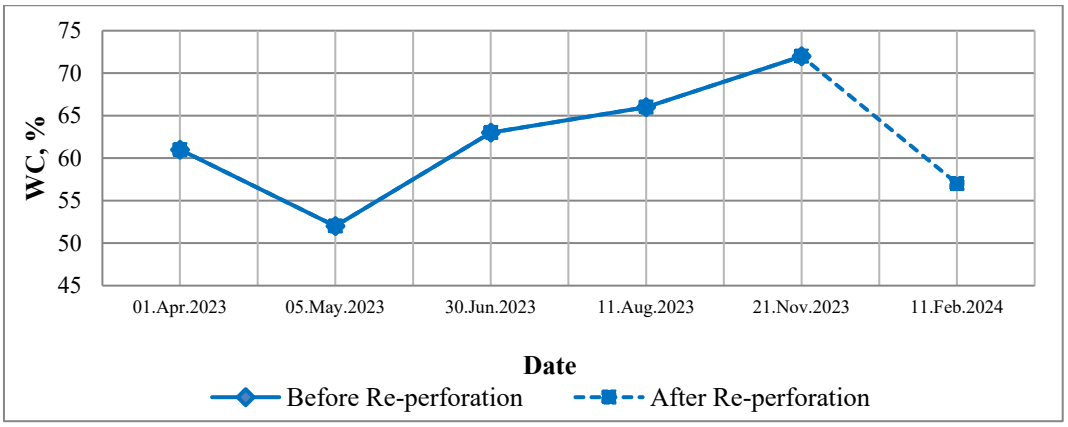


Fig. 3: A1 Well Water Cut vs. Date

5. A3/A100 Well History

The well was drilled and completed in the A100 concession in mid-1969 in the main area of the Upper Nubian Sandstone with perforated intervals (13,814'-14,173') covering a distance of 210 feet. Production commenced in the latter part of the first quarter of 1972, with a production rate of 5,674 STB/D and GOR 1,771MSCF/STB.

As mentioned earlier, the issue of scale formation due to accompanying water and high temperature persists as a common challenge in mature fields. Scale removal jobs were carried out in 1994 and during the years 2002 and 2003. Subsequently, extension perforation and re-perforation procedures were implemented, resulting in an increase in Water Cut.

The history of water cut for well A3 showcases a series of significant increases over the years, with notable spikes occurring in 1998, 2004, and 2007, ultimately peaking at 93% in November 2020. Each time, to address this issue, water shut off (WSO) operations were conducted, the last one was in August 2021, leading to a successful mitigation of the problem. The Top of Cement (TOC) was established at 13,634', resulting in a considerable reduction of the WC percentage to 29%.

With the success of the last operation in 2021, a remarkable 64% reduction in WC was achieved, consequently enhancing oil production from 365 to 1,692 STB/D.

Table 5 presents the results of the routine well test conducted in from March November 2023, while Fig. 4, 5, 6, illustrate the production rates of oil (Qo) and gas (Qg) and WC% plotted against the dates for same period.

Table 5: A3 Well Routine Tests History

Date	FTHP psi	FTHT Deg F	Qo STB/D	Qg MSCF/D	Qw STB/D	GOR SCF/STB	WC %	Choke Size /64
23.Mar.2023	1650	202	1542	2095	524	1533	23	32
27.May.2023	1440	220	1930	3666	557	1901	22	30
14.Agu.2023	1360	221	1866	4067	487	2179	21	10
30.Nov.2023	1050	204	1529	2700	216	1775	13	32

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Also, in Jan 2024, a PLT test was conducted. The test results were: Slightly contributed to the top interval (13,603' -13,610').

5.1 WELL STIMULATION DECISION

Based on the PLT test results that indicated slight contribution from the top interval (13,603' - 13,610') and considering the reservoir characteristics outlined in Table 1, along with the well's history spanning over 55 years, which exhibited a positive response to enhancing productivity through Re-perforation, the decision was made to re-perforate the interval specified in Table 6.

Table 6: Required Re-perforation interval

Interval No.	From ft	To ft	Height ft	Type of gun/SPF/phase
1	13,603	13,610	7	2" power jet nova gun (6SPF,60°)

5.2 WELL STIMULATION RESULTS (RE-PERFORATION)

After completing the procedure of re-perforating in-under-balance conditions with the requested gun, a routine test was conducted on February 18, 2024. The results are detailed in Table 7 and depicted in Fig. 4, 5, 6.

Table 7 : A3 Well Routine Test Results

Date	FTHP psi	FTHT Deg F	Qo STB/D	Qg MSCF/D	Qw STB/D	GOR SCF/STB	WC %	Choke Size /64
18.Feb.2024	770	217	2086	3525	770	1709	27	80

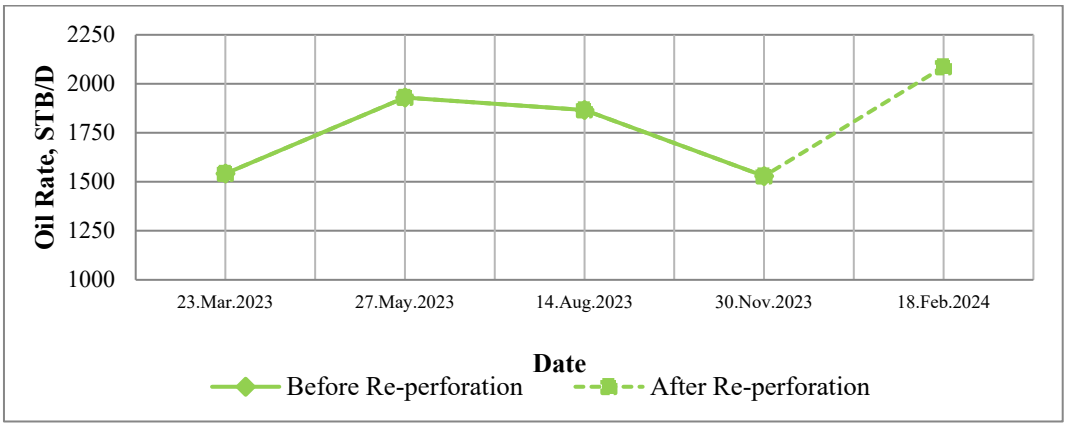


Fig. 4: A3 Well Oil Rate vs. Date

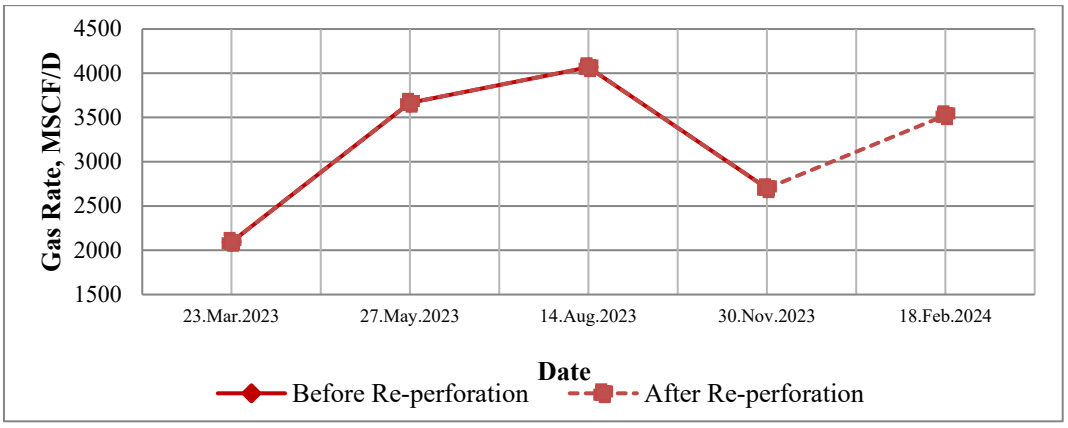


Fig. 5: A3 Well Gas Rate vs. Date

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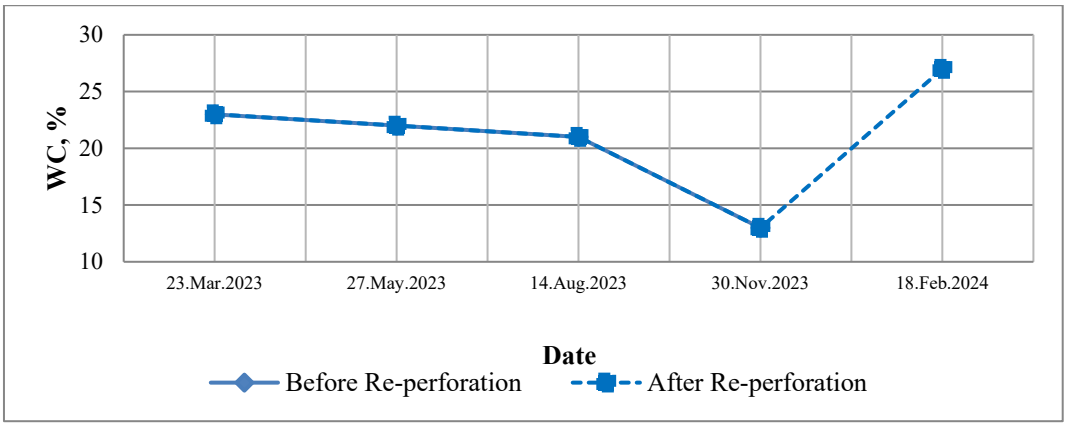


Fig. 6: A3 Well Water Cut vs. Date

6. Discussion and Recommendations

The sandstone reservoir in the A100 concession has demonstrated a notable response to well productivity enhancement techniques such as re-perforating. This has resulted in significant improvements in oil and gas production. Additionally, isolating the water-producing layers has effectively reduced the WC.

However, the historical data from the A1 well reveals a considerable decline in production since May 1973, primarily due to scale formation, which engineers successfully addressed this issue through re-perforation or extending the perforation. Also, the company's reports indicate a successful reduction of the WC to 12% in 2019, either by isolating the water layers or repairing casing patches. However, there has been a concerning increase in the WC reaching 54% in 2022 and 72% by the end of 2023. The decrease by 15% in the WC in 2024 is attributed to the large increase in the oil production rate compared to the water production rate as indicated in the Table 2 and Table 4 after re-perforation process. Therefore, it is recommended to conduct further PLT testing, starting from a depth of 13,444 ft, to isolate the potential water-producing layers or investigate any shifting of the water-oil contact (WOC) by using cased hole saturation tool to check the changing in water saturation.

In the case of well A3, the historical data reveals a series of scale removal jobs conducted between 2001 and 2003, in addition to several perforation extensions and re-perforations were carried out until 2007, where these jobs led to a significant increase in the WC, rising from 25% to 93%, while oil production saw a decline to 365 STB/D. The engineers successfully addressed this issue by implementing several WSO jobs, ultimately reducing the WC to 29% by August 2021. After the last re-perforation job in Feb. 2024, the WC returns to increase by 14%, i.e. from 13% to 27%. This increase is due to the increase in the rate of water production, which is close to the increase in the rate of oil production referred to in the Table 5 and Table7 after re-perforation process. To address this challenge effectively, it is recommended to run reservoir saturation tool RST to monitor the shifting of WOC for closing the perforation intervals that significantly contribute to water production, and conducting a perforation extension process in zones with high oil saturation.

7. CONCLUSION

- Success of the process of enhancing the productivity of wells A1/A100 and A3/A100 by re-perforating in the recommended intervals.
- In February 2024, the oil production rate in the A1/A100 well increased by 976 STB/D (from 792 STB/D to 1,768 STB/D) and in the A3/A100 well by 557 STB/D (from 1,529 STB/D to 2,086 STB/D) compared to November 2023.
- The rate of gas production in Feb.2024 increased by 4304MSCF/D in A1/A100 well and 825 MSCF/D in A3/A100 well i.e. from 1411 MSCF/D to 5715 MSCF/D in A1/A100 well and from 2700 MSCF/D to 3525 MSCF/D in A3/A100 well compared to what it was in late 2023.
- The water cut (WC) increased after Re-perforation by 14% in the A3/A100 well i.e. from 13% to 27%, due to the increased of water rate production and decreased by 15% in A1/A100 well i.e. from 72% to 57%.

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Nomenclature

FTHT: Flowing Tubing Head Temperature

FTHP: Flowing Tubing Head Pressure

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GR: Gamma Ray log

MSCF/D: Thousand Standard Cubic Feet per Day

PLT: Production logging test

Qo: Oil Production Rate

Qg: Gas Production Rate

SPF: Shots per Foot

STB/D: Stock Tank Barrel per Day

TOC: Top of Cement

WC: Water Cut

WSO: Water Shut Off

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