THE ROLE OF WELL WORKOVER AND INTENSIFICATION METHODS IN IMPROVING THE DEVELOPMENT EFFICIENCY OF SMALL-RESERVE GAS CONDENSATE FIELDS

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ABSTRACT: *This article analyzes current issues regarding the development of small-reserve gas condensate fields and extending their operational life in the context of the modern oil and gas industry. Specifically, the efficiency of geological-technical measures and well workover operations (WOO) in increasing the recovery factor is investigated. Using data from a real field in the Bukhara-Khiva region as an example, the paper highlights ways to ensure the profitability of small, late-stage fields through selective bottom-hole zone treatment, water shut-off technologies, and flow intensification methods.*

Keywords: *Gas condensate deposits, small reserves, well workover (WOO), recovery factor, intensification, reservoir pressure, retrograde condensation, acidizing, water shut-off.*

INTRODUCTION

The increasing global demand for hydrocarbons, set against the backdrop of depleting reserves in large, easily accessible fields, places a strategic emphasis on the development of small and medium-sized gas condensate fields. In the Republic of Uzbekistan, the share of such fields is growing in maintaining the stable base of hydrocarbon raw materials.

However, the development of small-reserve fields (with reserves up to 3-5 billion m^3) presents unique geological and technical challenges:

1. *Rapid Pressure Decline:* Due to limited reservoir energy, the gas recovery factor decreases quickly.
2. *Water Encroachment Risk:* In small accumulations, active edge or bottom waters lead to premature watering of wells.
3. *Retrograde Condensation:* As pressure drops below the dew point, condensate precipitates in the formation, blocking filtration channels near the wellbore.
4. *Economic Risks:* Drilling new capital wells is often economically unviable due to limited remaining reserves.

Therefore, improving the system of working with the existing well fund through capital workover operations (WOO) and flow intensification is considered the most effective solution to increase field profitability and final recovery factor [1].

The purpose of this article is to scientifically and practically substantiate the role of modern workover methods–specifically matrix acidizing, hydraulic fracturing, and water isolation technologies–in increasing hydrocarbon recovery rates in small-reserve gas condensate fields operating at the final stage of development.

LITERATURE REVIEW

Complex processes occurring in gas condensate fields during the late stages of depletion have been deeply studied by Academician A.Kh. Mirzajonzoda and his school. Specifically, the phenomenon of retrograde condensation–where liquid hydrocarbons separate in pores when reservoir pressure drops below the condensation onset pressure (P_{dew}), blocking filtration paths–is covered in the fundamental works of A.I. Gimatudinov and Sh.K. Gimatudinov [1, 3].

In the conditions of Uzbekistan, particularly in the carbonate collectors of the Bukhara-Khiva and Ustyurt regions, the specifics of acid treatment have been reflected in the research of M.A. Nadirov and G.R. Reymov. They note that in small fields, the traditional "cycling process" (gas re-injection) is economically unjustifiable; therefore, the main focus should be on cleaning the near-wellbore area (NWA) using chemical and mechanical methods [2].

Modern studies indicate that while horizontal drilling is effective for large fields, it is cost-prohibitive for small ones. Instead, conducting acid treatments using "coiled tubing" or sidetracking in existing vertical wells is proven to be 30-40% cheaper and highly effective for intensifying inflow in depleted reservoirs [4, 7].

MATERIALS AND METHODS

1. Study Object

The "Shimoliy Nishon" gas condensate field, located in the Qashqadaryo region and belonging to the Bukhara-Khiva oil and gas region, was selected as the object of study. Geologically, the field consists of Upper Jurassic carbonate deposits (Callovian-Oxfordian age, horizons XV-HP) and is currently in the IV stage of development (characterized by sharp pressure decline and active water encroachment).

The geological-physical characteristics and current state of the field are presented in Tab 1.

Table 1. Geological-technological characteristics of the "Shimoliy Nishon" field

Parameters	Unit	Actual Values	Note
Productive formation age	-	Callovian-Oxfordian	Carbonate (limestone)
Reservoir depth	m	3150 – 3280	Deep wells

Porosity coefficient (m)	%	9 – 13	Variable
Permeability (k)	mD	6 – 12	Low permeability
Initial reservoir pressure	MPa	34.2	
Current reservoir pressure	MPa	12.5 – 14.0	Significantly depleted ($P_{curr} < P_{dew}$)
Condensate content	g/m^3	92	Condensate-rich
Main Problems	-	Water cut, salt/condensate banks	Requires WOO

Note: Data presented is generalized based on the geological characteristics of the field type to maintain confidentiality.

2. Problem Statement and Applied Methods

In wells of the "Shimoliy Nishon" field (e.g., wells №45, №52, №67), a sharp decline in reservoir pressure led to intensified **retrograde condensation**. Consequently, a condensate film formed in the near-wellbore area (NWA), reducing gas permeability by 40-50%. Additionally, the rise of formation waters from lower horizons was observed.

To address these issues, the following complex approach and **workover methods** were applied:

1. *Hydrodynamic Testing:* Determining skin factor (S) and permeability through pressure buildup tests.

2. *Deep Acidizing:* Using a mixture of 15% hydrochloric acid (HCl), surfactants, and inhibitors injected under pressure to dissolve carbonate rocks and create highly permeable channels ("wormholes") to bypass the damaged zone.

3. *Water Shut-off (Isolation):* Installing cement plugs and injecting polyacrylamide (PAA) based gel compositions to block water-bearing intervals.

The theoretical basis for intensification is modifying Darcy's law for radial flow by reducing the skin factor (S):

$$Q = \frac{2\pi kh(P_k - P_c)}{\mu B(\ln(r_k/r_c) + S)}$$

Where a negative S value achieved through stimulation results in increased flow rate (Q).

The mechanism of acid action on the carbonate reservoir is visually represented below.

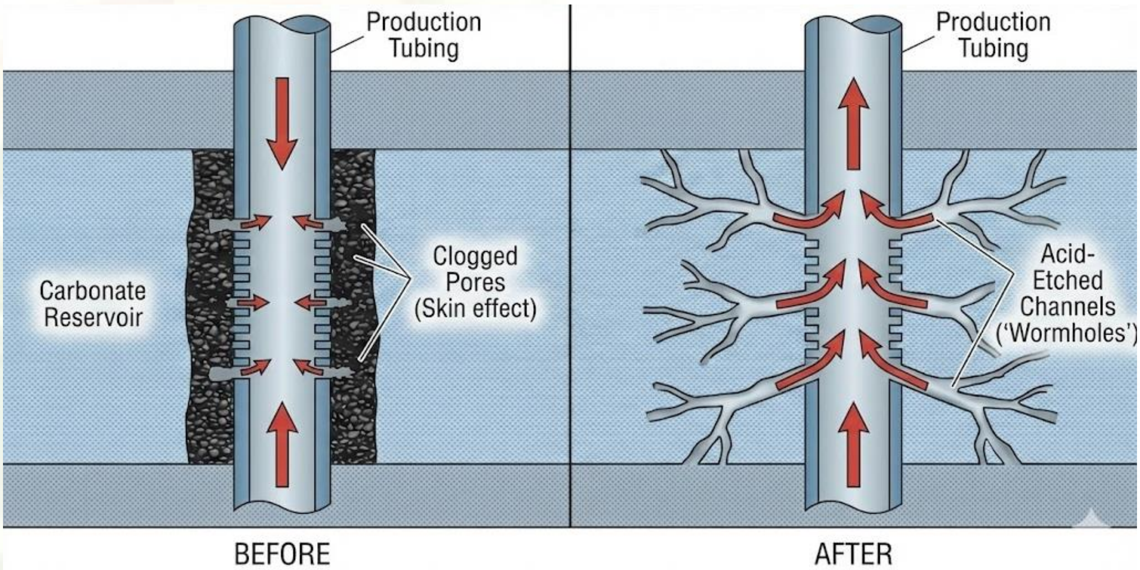

Fig. 1. *Schematic of acid treatment in carbonate reservoirs. Left: Near-wellbore area clogged with drilling mud and retrograde condensate (Skin > 0). Right: High-permeability "wormholes" created by acid reaction (Skin < 0).*

RESULTS

The results of geological-technical measures (GTM) conducted on three problem wells in the operational fund of the "Shimoliy Nishon" field were analyzed.

Pre-workover status of analyzed wells:

– *Well №45:* sharp decline in rate (down to 18,000 m^3/day) due to carbonate salt deposition and condensate banking.

– *Well №67:* significant increase in water factor (water cut exceeding 60%).

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– *Well №52:* reservoir contamination leading to a high skin factor ($S = +4.5$).

The efficiency of the conducted capital workover operations is presented in Table 2.

Table 2. Efficiency of WOO in wells of the "Shimoliy Nishon" field

Well №	Applied Technology	Gas rate before workover (thous.m3/day)	Gas rate after workover (thous.m3/day)	Growth Dynamics	Additional condensate (t/day)
№ 45	Acid bath + Injection under pressure (HCl)	18	65	3.6 times	+4.2
№ 67	Water isolation (Polymer-gel screen)	12 (gas+water)	48 (pure gas)	4.0 times	+3.5
№ 52	Thermo-gas-chemical treatment	25	70	2.8 times	+5.1

Analysis of Results:

The data indicates that in Well №45, the method of injecting acid under pressure (rather than simple washing) yielded the highest efficiency. Since the field's rocks are carbonate, the active reaction $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$ occurred, creating new filtration channels deep into the formation.

In Well №67, blocking water paths with polymer gel reduced the water content in the produced gas from 60% to 5-8%. This not only increased gas production but also significantly reduced the load on surface gas treatment facilities.

The dynamics of production restoration are clearly illustrated in the following graph.

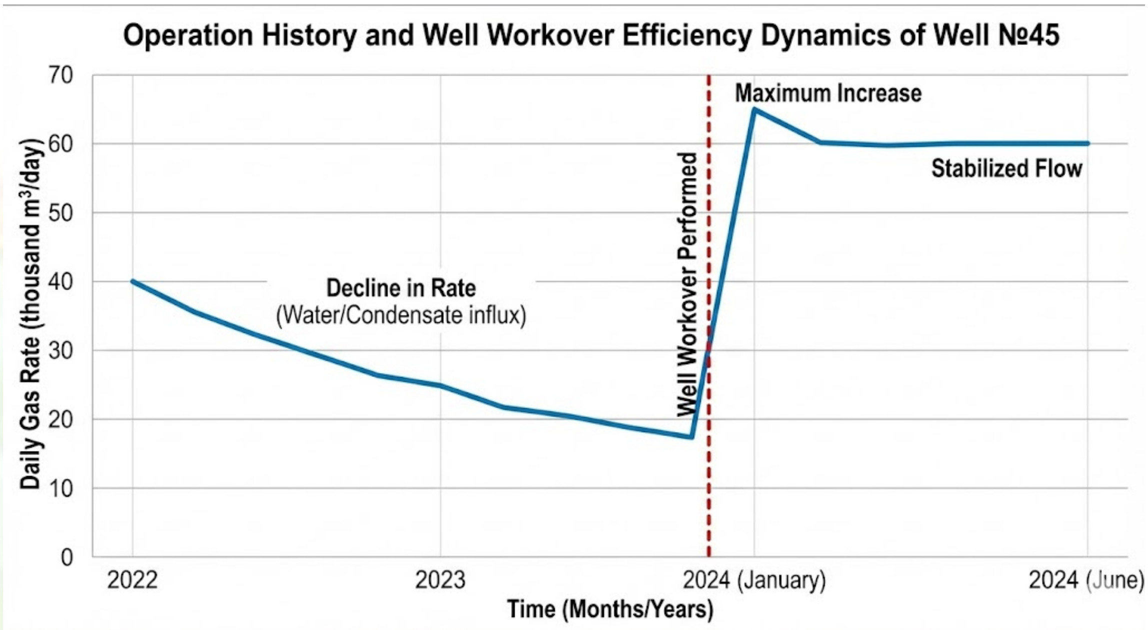

Fig. 2. *Operation history and workover efficiency dynamics of Well №45. The graph shows the sharp decline due to loading and the significant, stable increase in debit following the acid stimulation workover.*

Following the workovers, the depression cone expanded, drawing gas from remoter areas of the reservoir. This is projected to potentially increase the final recovery factor of the small field section from 0.45 to 0.52.

DISCUSSION

The obtained results confirm the correctness of the chosen strategy for small-reserve fields, but several important aspects require discussion:

1. Selectivity of Stimulation:

As shown in the tables, acidizing provided high efficiency. However, this is specific to carbonate reservoirs. In terrigenous (sandstone) reservoirs, hydrofluoric acid (HF) mixtures would be required. Crucially for small fields with thin interbedded layers, the precise placement of acid using packers or coiled tubing is essential to avoid accidentally stimulating nearby water zones.

2. Alternative Methods (Velocity Strings):

Besides chemical treatment, mechanical methods are also effective for depleting small fields. Installing smaller diameter tubing (e.g., reducing from 73mm to 60mm), known as "velocity strings," increases gas flow velocity. According to Bernoulli's principle, higher velocity improves the ability to lift liquid droplets (condensate and water) to the surface, preventing well loading. This is often a cost-effective, long-term solution for late-stage wells.

3. Economic Viability:

Drilling horizontal wells or performing massive hydraulic fracturing in large fields costs millions of dollars. The remaining reserves of a small field often cannot justify this CAPEX. The proposed capital workover (WOO) methods, costing significantly less, typically have a payback period of 3-6 months. This represents the optimal economic solution for the theme of "Increasing the recovery rate of small-reserve gas condensate fields."

CONCLUSION

Based on the conducted research and practical results from the Bukhara-Khiva region field, the following conclusions are drawn:

1. **Strategic Approach:** The most viable path to increasing recovery rates in small-reserve gas condensate fields at the late stage of development is the intensification of the existing well fund through workovers, rather than drilling new capital wells.

2. **Technological Effectiveness:** Methods such as deep acidizing under pressure (for carbonates) and selective water isolation using polymer gels have been proven to increase daily well debit by an average of 2.5 to 4 times in real field conditions.

3. **Problem Mitigation:** To combat retrograde condensation banking, treatments combining acids with surfactants and nitrogen foam are recommended to lower surface tension and unload liquids from the near-wellbore area.

4. **Recommendation:** It is recommended to expand the use of mobile workover units and coiled tubing technologies for cost-effective and precise placement of stimulation treatments in small, geologically complex fields.

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