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Completion Configuration and Drawdown Regimes to Maximize Oil Recovery from Low-Permeability Reservoirs Without Hydraulic Fracturing

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Abstract: The development of low-permeability (tight) reservoirs, which constitute one of the key elements of the modern global energy system, has historically relied primarily on hydraulic fracturing technologies. At the same time, increasing pressure from economic constraints, growing logistical complexity, and stricter environmental requirements are creating a demand for technological solutions capable of minimizing or completely eliminating the use of hydraulic fracturing. Under these conditions, the aim of the study is to formulate a scientifically grounded concept and conduct a comprehensive analysis of a synergetic approach to the development of low-permeability reservoirs without the use of hydraulic fracturing, based on the integration of advanced well completion configurations with optimized production strategies. The methodological framework of the work is interdisciplinary in nature and includes a systematized review of publications, content analysis of specialized reports by leading international organizations (IEA, OPEC, McKinsey), as well as a detailed investigation of representative case studies (Midland Basin, Sakura). The results obtained indicate that effective replacement of hydraulic fracturing is possible only with the joint optimization of the hardware component (geometry, architecture of wellbores) and the software component (dynamics and operating modes). It is demonstrated that multilateral wells (MLW) of the Fishbone type provide a higher increase in the net present value (NPV) of the project compared with the concept of extra-long horizontal wells (ERW). It is shown that the use of aggressive drawdown management strategies (reducing Pwf, min to the range

of 500–800 psia) makes it possible to increase the ultimate recoverable resource (КИН, EUR) by up to three times relative to conservative regimes. In addition, it is established that optimized cyclic EOR schemes (water–CO_2–polymer) with a mandatory soaking phase can provide an efficiency increase of up to 300% compared with continuous injection protocols. Based on the analysis, it is substantiated that the integrated configuration (MLW + smart completion + aggressive drawdown management + cyclic EOR) represents both a technologically feasible and economically competitive alternative to traditional hydraulic-fracturing-oriented approaches. The conclusions obtained are of practical significance for petroleum engineers, research teams, and top management of oil and gas companies focused on reducing CAPEX and decreasing the environmental footprint in the industrial development of unconventional hydrocarbon resources.

Keywords: low-permeability reservoirs, maximization of oil recovery, without hydraulic fracturing, completion configuration, multilateral wells, Fishbone, drawdown management, cyclic methods, EOR, smart wells.

Introduction

In the context of the radical transformation of the global energy system, which, according to estimates by the International Energy Agency (IEA), is accompanied by a simultaneous increase in electricity demand and heightened volatility in hydrocarbon markets [1, 2], the development of unconventional reserves, primarily low-permeability (tight) reservoirs, is becoming not merely a technological option but an element of long-term energy security [3]. According to OPEC reports for 2022, to meet the forecast demand and offset natural production decline, the cumulative volume of global investments in the oil industry up to 2045 must reach 12,1 trillion USD [5]. A significant share of this capital will be directed to enhanced oil recovery (EOR) technologies; at the same time, according to market forecasts for 2022–2027, the EOR segment targeting low-permeability and shale formations is expected to demonstrate a compound annual growth rate (CAGR) of 8.28% during 2022-2027 [6].

Over the past decades, the practice of developing low-permeability reservoirs has effectively formed a monopolistic technological paradigm based on the use of hydraulic fracturing (HF) [7]. HF has been regarded as a virtually irreplaceable tool for creating artificial conductivity in reservoirs with initially low permeability [9]. However, under current conditions the industry is increasingly confronted with a set of constraints that call into question the universality and unquestioned dominance of this technology.

First, the influence of economic factors is intensifying. Analytical materials from Deloitte and McKinsey document the transition of the industry to the paradigm of disciplined capital allocation, which implies prioritizing capital efficiency and strict control of operating expenditures (OPEX) [10]. The focus of companies is shifting from extensive production growth at any cost to the optimization of project profitability. Against this backdrop, HF, characterized by high capital intensity (CAPEX), substantial resource consumption, and a complex logistical configuration (water supply, proppant, chemical additives, mobilization of HF fleets), comes into direct contradiction with the new economic logic of the industry.

Second, geopolitical risks and the vulnerability of supply chains act as limiting factors. According to McKinsey analytics, trends of resource nationalism are strengthening and the fragility of global logistics and supply contours is increasing [12]. The growing dependence on imported equipment, proppant, and specialized chemical additives is transforming into a risk of disruption to the continuity of field operations, which, in turn, stimulates the search for technological solutions with lower dependence on external suppliers and international market conditions.

Third, environmental and regulatory constraints are coming to the forefront. In industry reviews by SPE Grand Challenges [4], water management and the range of environmental issues associated with the use of HF are highlighted as key challenges for the further development of the oil and gas sector. This is reflected in the tightening of regulatory oversight, more stringent requirements for environmental reporting, and an increase in the social cost of projects employing HF.

The combination of these factors forms a pronounced scientific and technological gap: there is a need to create economically competitive and environmentally sustainable methods for developing low-permeability reservoirs without the use of HF. The existing body of research, including studies devoted to analyzing the influence of geological and technological parameters on the oil recovery factor (ORF), as a rule, considers well completion configurations and production regimes separately, within isolated problem statements. To date, there is no comprehensive study in which the synergistic interaction of advanced non-HF completion configurations and dynamically optimized production regimes is analyzed as a single integrated development system.

The author's hypothesis is that an integral approach combining targeted expansion of the geometric drainage area (for example, through multi-lateral well architectures) with advanced dynamic management of filtration flows (control of reservoir drawdown and cyclic EOR approaches) can provide an oil recovery factor in low-permeability reservoirs that is economically comparable to, or exceeds, the results of conventional HF-based schemes, while simultaneously significantly reducing operational risks and the overall environmental footprint.

The aim of the study is to provide a scientific justification and analysis of the technological and economic feasibility of development strategies for low-permeability reservoirs without HF by synthesizing and systematizing data on the effectiveness of alternative completion configurations and optimized production regimes.

The scientific novelty is based on the fact that the study for the first time formulates a comprehensive synergistic model for the development of low-permeability reservoirs, in which the stochastic nature of reservoir stimulation by HF is replaced by deterministic control of the geometry of the drainage contour and production regimes.

Materials and methods

The methodological architecture of the study has a distinctly interdisciplinary character and is based on the integration of three mutually complementary analytical approaches, which makes it possible to ensure maximum completeness and depth in addressing the formulated research task.

As the primary stage, a structured review was carried out of peer-reviewed scientific and engineering publications indexed in the leading international bibliographic databases Scopus, Web of Science, OnePetro, and Springer. The analysis was focused on identifying, typologizing, and comparatively assessing the effectiveness of technological solutions alternative to hydraulic fracturing (GRP), including multilateral drilling, smart well completion systems, as well as unconventional variants of enhanced oil recovery (EOR) methods, in particular cyclic waterflooding schemes.

For the empirical verification of the theoretical framework and assessment of its applicability under real field conditions, a detailed examination of representative case studies was conducted. This approach made it possible to extract and systematize factual data on the oil recovery factor (ORF), the net present value (NPV) of projects, as well as on key operational parameters (KOP) characterizing the industrial implementation of the technological solutions under consideration.

In parallel, a content analysis of strategic and industry reporting was performed, aimed at identifying macroeconomic, geopolitical, and technological drivers that determine the investment climate and priority directions of research and development (R&D). The analysis included reports by leading global sectoral organizations and consulting firms (IEA, OPEC, McKinsey, Deloitte), which made it possible to link the technological conclusions of the study with the current and projected context of industry development.

Practical and empirical basis (case studies).

Case 1 (geometry): the Sakura project, within which a comparative analysis was carried out of multilateral wells of the MLW Fishbone type and conventional horizontal wells.

Case 2 (production regime): a project in the Midland Basin focused on examining the impact of various drawdown management strategies on the final recoverable reserves (EUR).

Case 3 (EOR regime): a project in Nigeria dedicated to optimizing the parameters of the cyclic application of EOR methods.

Results and discussion

Analysis indicates that abandonment of hydraulic fracturing implies not merely a technological modification, but a fundamental change of the conceptual framework: from artificial increase of reservoir conductivity by means of hydraulic fracturing to maximization of the contact area with the productive interval through complication of the trajectory and geometry of the wellbore. This section considers precisely the hardware aspect of this approach [28, 30].

Multilateral well (MLW) technology [13] and its

Fishbone type modification represent a qualitative departure from the single wellbore paradigm. Instead of forming one or several planes of hydraulic fractures, MLW creates a three-dimensionally branched system of drainage channels capable of covering small scale geological heterogeneities and isolated pockets of residual oil.

The practical feasibility and efficiency of this solution were demonstrated in the Sakura case study [13]. Within this project a multilateral well with five laterals was designed and numerically simulated, after which its techno economic indicators were compared with the parameters of two conventional horizontal wells required to drain a part of the reservoir of comparable area.

The comparison results were unambiguous:

Increase in recovery factor: the MLW Fishbone configuration provided a higher oil recovery factor (higher oil recovery) due to more complete involvement of the reservoir in production [13].

Cost reduction: despite the increased complexity of drilling and completion, the total operating costs in the operation of a single multilateral well were lower than the aggregate costs of drilling and subsequent operation of two separate horizontal wells.

Economic efficiency: the net present value (NPV) of the project with one MLW exceeded the total NPV of the two horizontal wells that would have had to be drilled in order to achieve comparable drainage coverage [13].

Thus the Sakura case clearly demonstrates the fundamental difference between the two approaches. Hydraulic fracturing is oriented toward solving the problem of increasing conductivity, forming a stochastic fracture network whose efficiency decreases significantly under high lithological and filtration capacity heterogeneity of the reservoir [7]. Multilateral wells, by contrast, address the problem of geometric coverage, creating a deterministic drainage system. In a heterogeneous reservoir, where hydraulic fracturing may bypass local sweet spots or initiate early breakthrough of bottom and edge waters, the MLW configuration (with the five bore architecture in the Sakura case) in fact diversifies geological risk, providing guaranteed contact with several segments of the reservoir and more stable drainage over the entire target volume.

Below, Table 1 presents a comparative analysis of the efficiency of MLW Fishbone and horizontal wells (according to the Sakura case study data).

Table 1. Comparative analysis of the efficiency of MLW Fishbone and horizontal wells (based on the Sakura case study) (compiled by the author based on [13]).

Parameter	**Well type**	**Number of wellbores**	**Relative CAPEX (estimate)**	**Oil recovery factor**	**Net present value (NPV)**
Base case 1	Horizontal	1	1.0x	Low	1.0y
Base case 2	Horizontal (2 wells)	2 (from 2 wells)	2.0x	Medium	2.0y
MLW scenario	Fishbone (Sakura)	5 (from 1 well)	1.5x	High	> 2.0y

An alternative strategy for increasing the wellbore contact area with the productive interval is the drilling of ultra-long horizontal wellbores (ERW) with lengths of 2–3 miles or more. This engineering approach, often described by the longer–faster–cheaper formula [29], likewise pursues the objective of maximizing the length of the drained reservoir section. However, when moving to such wellbore length scales, fundamental constraints of both physical and economic nature begin to dominate, which reduces the ultimate effectiveness of this strategy.

An analysis of drilling statistics in the Permian Basin based on Rystad Energy data demonstrated a productivity degradation per foot of 10–20% for 3-mile wellbores compared with 2-mile wellbores [29]. From a technological standpoint, this is associated with increasing hydrodynamic frictional pressure losses as the horizontal section length increases, which leads to a reduction in drawdown at the toe (toe) of the well. As a result, the distal, most remote part of the ultra-long wellbore effectively operates in a muted mode and contributes only insignificantly to the total production.

The results of numerical modeling confirm that the simple extensive principle that longer is better is a suboptimal solution [22]. For given geological and technical conditions, there exists a finite optimal length of the horizontal wellbore, beyond which the incremental increase in cumulative production becomes marginal. Thus, when modeling the development of areas with small remaining reserves, the optimal wellbore length was about 80 m, whereas for areas with medium remaining reserves it was about 200 m (Fig. 1). Further extension of the wellbore beyond these values had practically no effect on the increase in integrated production.

A fundamentally important conclusion follows from this: multibranch MLW architecture of the Fishbone type [13] represents a more advanced engineering solution compared with the concept of a single ultra-long ERW wellbore [29]. Instead of attempting to drill one suboptimal wellbore with a length of about 15 000 ft and inevitably encountering constraints caused by frictional losses [29], MLW technology makes it possible to construct from a single surface location several horizontal wellbores of optimal length (for example, about 200 m each). In this way, the physical limitations inherent to ultra-long horizontal wellbores are effectively bypassed, and reservoir drainage becomes more uniform and efficient at comparable scales of contact with the reservoir rock.

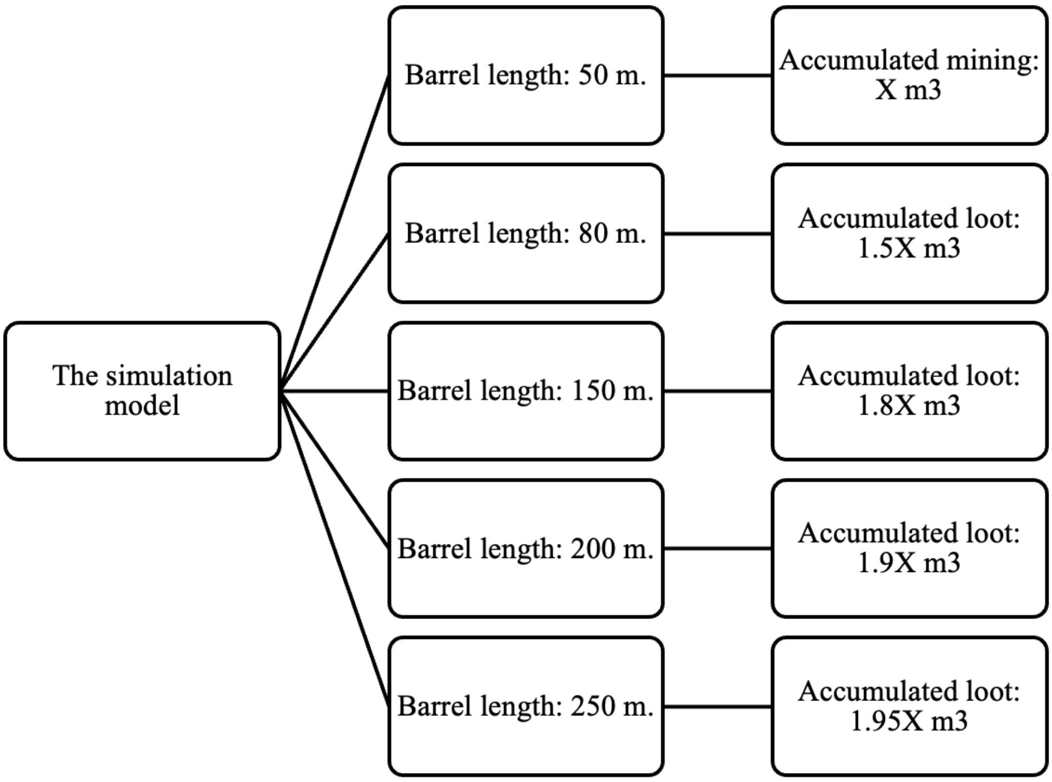

Fig. 1. Dependence of accumulated production on the length of the horizontal shaft (compiled by the author based on [13, 22, 29]).

Modeling reveals a pronounced nonlinear relationship between horizontal wellbore length and the oil recovery factor, demonstrating the existence of a technologically optimal length (in the present case on the order of 200 m), upon reaching which further extension of the wellbore leads to such a minor increase in production that it no longer offsets the increasing capital expenditures for drilling [22].

The abandonment of hydraulic fracturing as the basic tool for staged reservoir stimulation raises a fundamental question: how can controlled inflow distribution be ensured along an extended horizontal or multilateral wellbore in the absence of traditional hydraulic fracturing segmentation? The key to solving this problem lies in the use of integrated and smart completion systems.

Study [15] describes an integrated completion concept that enables the formation of segmentation in an open hole without performing hydraulic fracturing. The technology is based on a run-in secondary completion string that includes open-hole packers and controlled sliding sleeves. This configuration, tested at temperatures up to 180 °C and differential pressures up to 60 MPa, provides the capability for selective opening and closing of individual wellbore intervals, thereby implementing segmented control of inflow or fluid injection [15].

The next stage of development is the equipping of these segments with smart elements, namely inflow control devices (ICD) and autonomous inflow control devices (AICD) [16]. These solutions allow, in a passive mode (ICD) or autonomously active mode (AICD), a response to changes in the phase composition of the fluid, automatically restricting, in particular, water or gas inflow during their early breakthrough into the well.

The integration of such systems is a necessary condition for realizing the potential of multilateral wells (MLW). A multilateral well [13] with five laterals inevitably operates under conditions of geological heterogeneity: individual laterals intersect intervals with different permeability and different distances from the oil–water contact. In the absence of smart completion, a lateral that intersects a high-permeability zone or experiences early water breakthrough begins to dominate the inflow and effectively suppresses the productivity of the entire well, reducing the total drawdown on the reservoir. The application of smart completion [15] makes it possible to promptly isolate the problematic lateral or segment while maintaining and optimizing production from the remaining laterals. In this way, the well is transformed from a passive drainage element into an actively managed reservoir asset (Fig. 2).

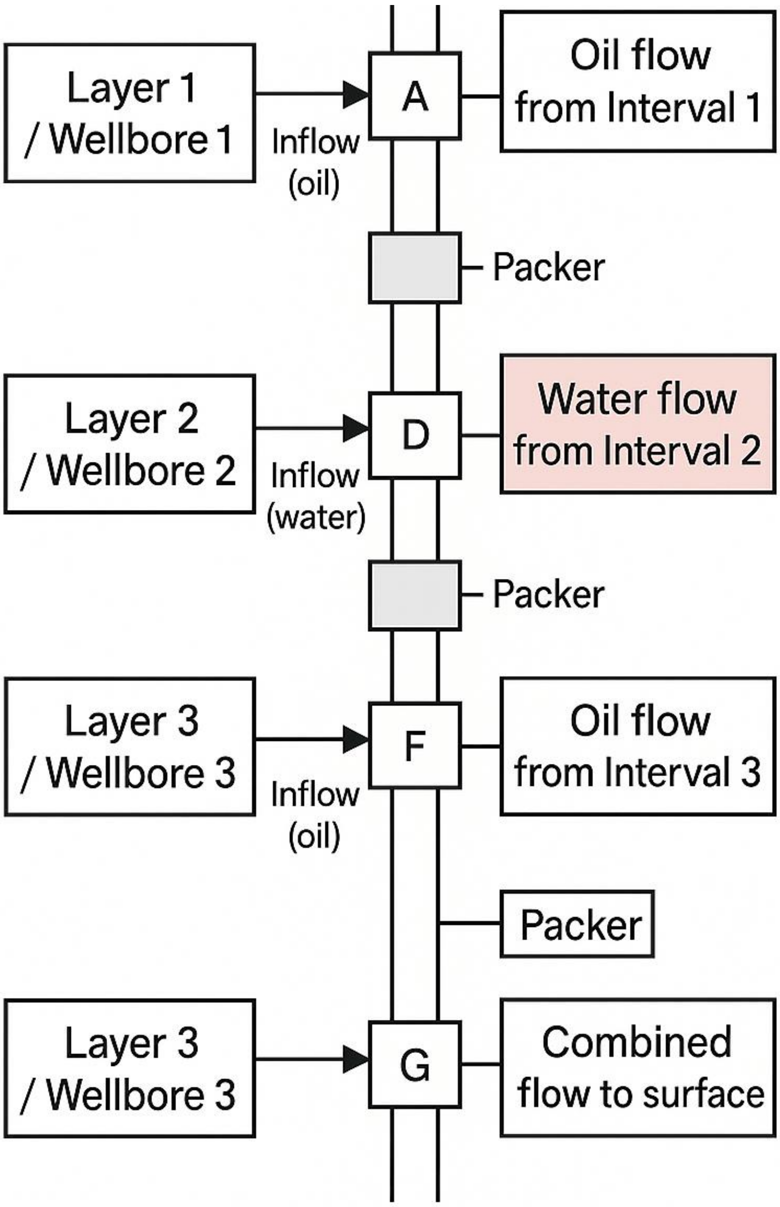

Fig. 2. Conceptual diagram of an integrated "smart" completion (non-HF) (compiled by the author based on [13, 15, 16]).

An intelligent open-hole completion scheme based on a combination of packers and autonomous inflow control devices (AICD) provides separately adjustable inflow from individual intervals without hydraulic fracturing. With this approach, problematic interval 2, prone to early water breakthrough, can be isolated in an autonomous mode [15].

The presence of a high-tech hardware component (MLW in combination with intelligent completions) represents only a necessary, but by no means sufficient, condition for development efficiency. Under low-permeability reservoir conditions, the determining factor becomes the software component, that is, the selected well operating mode. Its fundamental task is to compensate for the high capillary pressure and extremely low filtration rates inherent in this type of reservoirs [8, 20].

The main operational dilemma is formulated as the question of how intensively the well should be produced, that is, what magnitude of bottomhole drawdown is advisable to create. The intuitively clear, cautious approach assumes minimization of production rate (maintaining elevated bottomhole pressure) in order to reduce the risk of water or gas breakthrough. However, for low-permeability systems such a strategy contradicts their actual physical characteristics.

A representative study performed for the Midland Basin is particularly illustrative [23], in which the impact of four drawdown management options on the final oil recovery factor (EUR — Estimated Ultimate Recovery) was investigated. Strategies differing in the magnitude of the minimum maintained bottomhole pressure (Pwf, min) were considered:

– Base case: Pwf, min = 2300 psia

– Conservative: Pwf, min = 1000 psia

– Moderate: Pwf, min = 800 psia

– Aggressive: Pwf, min = 500 psia

The obtained results (Table 2) turned out to be, at first glance, counterintuitive. In the model for Wolfcamp B, the aggressive scenario with Pwf, min = 500 psia provided a forecast EUR at the level of 1960 thousand barrels (MBO), whereas the base mode with Pwf, min = 2300 psia yielded only about 670 MBO [23]. Thus, a reduction in bottomhole pressure led to an almost threefold increase in ultimate recovery.

Table 2. Impact of the drawdown management strategy on the final recovery factor (EUR) (Midland Basin case) (compiled by the author based on [23]).

Strategy	Min. bottomhole pressure (Pwf,min)	EUR (MBO) - Scenario 1 (Wolfcamp B)	EUR (MBO) - Scenario 2 (Wolfcamp A)
Base	2300 psia	670	133
Conservative	1000 psia	1680	681
Moderate	800 psia	1823	1346
Aggressive	500 psia	1960	681 (model anomaly)

This phenomenon is interpreted in terms of filtration physics in low-permeability reservoirs [20]. The inflow from the matrix is governed not only by Darcy's law, but also by the presence of a threshold pressure. If the applied drawdown (the difference between reservoir pressure and bottomhole pressure) is lower than this threshold, the oil is essentially unable to overcome capillary forces and escape from the micropores. The conservative regime [23] results in an excessively small drawdown: the matrix volume remains essentially non-activated, and up to 70% of the geologically available oil remains in the reservoir. In contrast, an aggressive strategy with a reduced Pwf,min generates a drawdown sufficient to overcome the threshold pressure and initiate effective matrix drainage.

A comparison of the expected ultimate oil recovery under various scenarios of drawdown control at the wellbore demonstrates a clear advantage of the most aggressive regime (reduction of Pwf, min to 500 psia) [23]. However, as the primary oil recovery factor is depleted (including cases where aggressive drawdown is applied), it becomes necessary to switch to EOR methods. In this context, conventional waterflooding in low-permeability reservoirs proves to be practically ineffective [18, 31]: the injected water predominantly flows through high-permeability channels of minimum hydrodynamic resistance, bypassing the low-permeability matrix and failing to provide its effective drainage.

As an alternative approach, a cyclic development method is used [17]. In contrast to continuous displacement schemes, this approach essentially represents a periodic reservoir treatment with alternating stages of stimulation and system response.

A representative example in this context is a case study for a field in Nigeria [25], where a combined cyclic injection process of a Water–CO2–Polymer system was thoroughly optimized for the development of heavy oil in a low-permeability reservoir. As a result of the analysis, three dominant oil recovery mechanisms were identified: reduction of oil viscosity due to dissolution of CO2 in the oil; formation of so-called foamy oil; swelling of the oil, leading to an increase in its volume and, accordingly, its mobility [25].

Parametric optimization of the process led to the following configuration: injection pressure of 2000 psia, soaking period of 6 days, and withdrawal rate of 3.7172 psi/min. With this combination of parameters, an oil recovery factor of 49.89% was achieved. Comparison with traditional continuous CO2 injection schemes showed that the obtained oil recovery factor is approximately three times higher (by 300%) than the oil recovery typical of classical continuous CO2 displacement processes (9–11%) [25, 28].

This result clearly demonstrates the fundamental difference in the physics of the ongoing processes. Continuous injection in a quasi-stationary (static) mode, as a rule, forms a dominant high-conductivity channel and leads to accelerated breakthrough of the agent with minimal involvement of the matrix in filtration [33]. In contrast, the cyclic mode (dynamic mode) comprises three sequentially implemented phases: Injection (pressure increase), Soaking, and Production.

For low-permeability reservoirs, the Soaking phase is decisive. It is at this stage that the system is provided with a time interval (in the considered case [25] — 6 days) required for diffusive penetration and capillary imbibition of the working agent (CO_2, water) into the low-permeability pore matrix. During this time, the agent dissolves in the oil, reduces its viscosity, induces swelling, and thereby mobilizes the previously immobile hydrocarbon phase. The subsequent Production phase essentially implements the very aggressive drawdown [23] that ensures the extraction of the already treated, mobilized oil from the matrix into the flow, increasing the total oil recovery factor [19, 21].

The efficiency of the optimized cyclic EOR implemented with a soaking phase exceeds by more than a factor of three the performance of traditional continuous-injection schemes due to the involvement of additional displacement mechanisms activated precisely during the pause between cycles [25].

The comprehensive analysis performed demonstrates that none of the approaches considered can be regarded as a universal solution. For highly efficient development of low-permeability reservoirs without hydraulic fracturing, what is fundamentally important is not the choice of a single correct method, but the formation of an integrated development architecture based on the synergistic combination of several technological tools.

The integrated synergistic model of non-HF development (Fig. 3), proposed within the framework of this study, can be presented as follows.

Step 1 (Hardware): Design of a multilateral well (MLW) of the Fishbone type [13]. The main objective of this stage is to maximize the geometric contact of the system of wellbores with the productive interval and, as a consequence, spatial diversification and partial leveling of geological risks.

Step 2 (Hardware+): Equipping the completion assembly with an integrated system with longitudinal segmentation (packers, sleeves) and AICD devices [15, 16, 24]. The purpose of this step is to ensure controllability and targeted inflow control for each individual wellbore or segment, which creates the technical basis for subsequent adaptive operation.

Step 3 (Software — Phase 1): Putting the well into operation in an aggressive drawdown mode (for example, at Pwf, min 500–800 psia) [23]. The task of this stage is to maximize the primary oil recovery factor by overcoming the threshold filtration pressure in the reservoir matrix and initiating inflow from poorly drained zones.

Step 4 (Software — Phase 2): As primary production declines, switching the system to cyclic EOR mode (for example, a Water–CO_2–Polymer sequence) [25]. The purpose of this step is to mobilize the residual oil retained in the matrix by repeatedly exposing it to alternating agents with different physicochemical mechanisms of action.

Step 5 (Synergy): Use of intelligent completion for selective implementation of Step 4 [14]. This makes it possible to organize asynchronous cycles in individual wellbores or segments, individualizing the cycle parameters (injection pressure, duration of soaking phases and active impact phases) for each local reservoir segment, which ensures its targeted optimization and realizes the full potential of cyclic EOR [25].

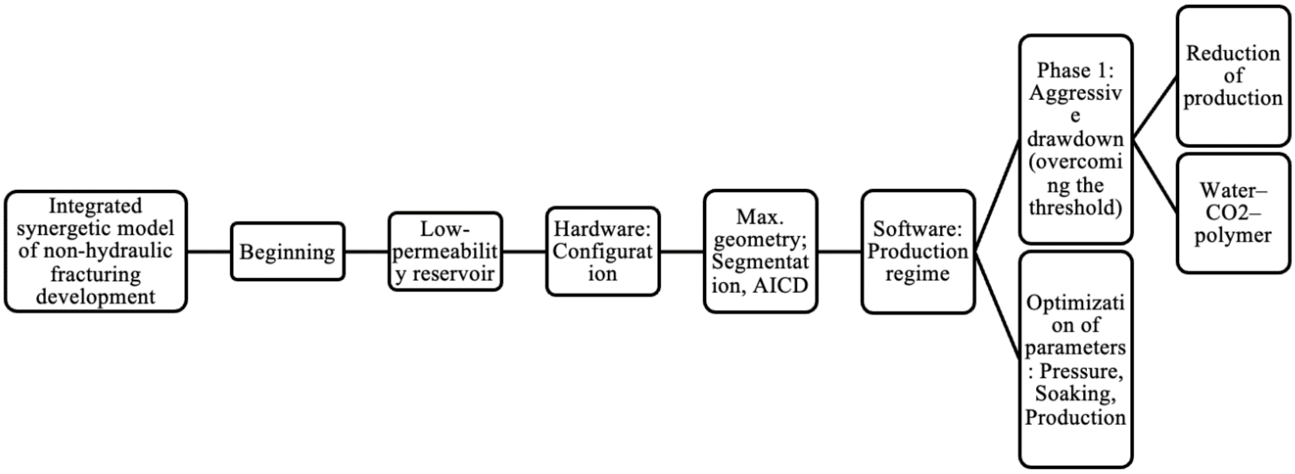

Fig. 3. Integrated synergetic model of non-fracturing development (compiled by the author based on [25, 30, 32, 34]).

The author's synergistic model is considered as a single framework integrating advanced well equipment configurations (Hardware) and controlled dynamic production regimes (Software), which makes it possible to maximize the oil recovery factor under conditions of abandoning hydraulic fracturing (HF).

The proposed development architecture is specifically aimed at overcoming the key barriers that constrain industry-wide implementation of non-HF approaches.

Technological barriers. The Grand Challenges primarily include complex geological structure and ultra-low reservoir permeability. The MLW concept [13] provides more effective adaptation to geological heterogeneity and uncertainty compared with stochastic HF, whereas the proposed well operating regimes are purposefully designed around the specifics of filtration processes in low-permeability rocks and account for the corresponding inflow physics [23, 33].

Economic barriers. The modern paradigm of disciplined capital [11] requires technological solutions with a stable and predictable economic profile. The Sakura case [13] demonstrates that application of MLW provides higher NPV compared with drilling several separate wells, while abandoning HF further reduces both operating and capital expenditures (OPEX and CAPEX) [26, 27].

Geopolitical risks and supply chain risks. The McKinsey report [13] emphasizes the vulnerability of the industry to disruptions in global supply chains. In this context, the proposed development strategy proves to be significantly less dependent on complex and risky logistics chains associated with the supply of proppant, guar, and specialized HF fleets.

Environmental barriers. Transition to development without HF [4, 31, 32] fundamentally reduces fresh water consumption and decreases chemical impact on the formation, which meets increasingly stringent environmental requirements and reduces the overall environmental footprint of the project.

Conclusion

The analysis performed makes it possible to formulate a set of fundamental provisions that confirm the technological and economic viability of the concept of developing low-permeability reservoirs without the use of hydraulic fracturing.

First, hydraulic fracturing should not be regarded as the only acceptable stimulation tool. Increasing economic constraints within the framework of a disciplined capital policy, rising logistical uncertainty, and stricter environmental requirements generate a persistent demand for alternative technological approaches and stimulate the transition to new paradigms of development system design.

Second, achieving high efficiency is possible solely through the integration of Hardware and Software. It is impossible to maximize the oil recovery factor in low-permeability reservoirs without hydraulic fracturing by relying only on completion design improvement or only on operating regime control. A critical condition for success is the consistency between the deterministic geometry of the drainage system and advanced strategies of dynamic reservoir energy management.

From the standpoint of drainage geometry, priority should be given to optimization rather than extreme maximization. As a Hardware solution, multilateral wells (MLW) of the Fishbone type demonstrate superiority in net present value (NPV) and reservoir sweep compared with the extensive practice of drilling extra-long horizontal wellbores (ERW), which are characterized by a productivity ceiling and rate degradation when further increasing wellbore length.

In terms of inflow control, a transition to intelligent completions is required. For effective control of the complex hydrodynamic system of MLW and minimization of the risk of premature water and/or gas breakthrough, the completion design must possess smart completion functionality, including segmenting packers and inflow control devices (ICD/AICD) that provide distributed control of filtration flows.

As for operating regimes, aggressive drawdown and cyclic exposure play a key role. As Software, two fundamentally different regimes should be employed: (1) aggressive reduction of bottomhole pressure (500–800 psia) at the early stage of development, which allows a multiple, approximately threefold, increase in primary oil recovery factor, and cyclic EOR processes with an optimized soaking phase at the subsequent secondary stage, demonstrating up to 300% efficiency gain compared with continuous injection.

The working hypothesis formulated in the introduction has received empirical verification. The presented case studies and the analysis of technological trend evolution indicate that the integrated non-hydraulic-fracturing strategy (MLW + Smart Completion + Aggressive Drawdown + Cyclic EOR) is not only a technically feasible solution but also an economically competitive alternative to traditional approaches.

The practical significance of the study lies in offering operating companies a scientifically grounded roadmap for simultaneously reducing CAPEX, OPEX, operational risks, and environmental footprint in the development of unconventional hydrocarbon resources.

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