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Review of the Technical and Economic Evaluation of the Use of Means of Simultaneous Independent Operation for Solving Technical Problems

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Abstract

In the context of developing multilayer deposits in Turkmenistan, the technical and economic evaluation of technique used in simultaneous and independent operation represents an important area of work. Most of the oil and gas fields both in our country and abroad are multi-layered. At the same time, several productive layers are located layer by layer one above the other. From the point of view of rational development, the development of such deposits by independent grids of wells drilled for each individual reservoir is the most preferable. However, the experience of oilfield development shows that more than half of all capital investments are spent on drilling wells. Therefore, the development of multilayer deposits by independent well grids for each formation requires huge capital expenditures and is not always economically and technologically justified. In this regard, when developing multi-layer deposits, several productive formations are often combined into one operational facility, which makes it possible to shorten the time of field development, reduce capital investments for drilling wells and field development, etc. At the same time, simultaneous development of several formations by one object is possible only with the same physico-chemical properties of oils in the combined formations, if the inflow of oil and gas is sufficient from each formation at an acceptable bottom-hole pressure in the well, with close values of reservoir pressure in the combined formations, excluding oil flows between the formations, and close values of reservoir waterlogging. If the above conditions are not met, then multidimensional deposits are developed using the method of simultaneous and independent operation (hereinafter referred to as SIO) with one well. Depending on the specific geological and technical conditions for the development of deposits, technical and operational characteristics of wells, one of the currently available SIO schemes is used. Mandatory requirements for all SIO schemes are the possibility of separate development and commissioning of each reservoir, measurement of oil flow rates of each reservoir separately, as well as separate measurement of each reservoir for waterlogging, gas content and examination of each reservoir for oil and gas inflow. When deciding on the use of the SIO method, the degree of depletion of reserves, the proximity of the oil content contour to wells, the presence of resins and paraffin in the extracted oils, the thickness of the productive layers and the impermeable interlayers separating them, the condition of the production column of wells, etc.

Productive horizons have different capacities from one to several tens of meters; their operation is carried out from the bottom up according to the traditional scheme. Such a traditional scheme of operation of multilayer deposits provides for the development of a grid of vertical wells for each operational facility, which leads to an increase in capital costs for drilling wells

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and a decrease in the profitability of the products obtained. Accordingly, in the production of hydrocarbons, the main cost item is the construction of new production wells. It is necessary to solve the problem of reducing construction costs almost immediately with the introduction of wells into drilling. The simplest way is to combine several oil-saturated horizons into several development facilities. Simultaneous and independent operation (SIO) and dual water injection operation (DIO) can be applied to regulate the zone development by layers (uniform exploration of layers, intensification of one of the layers). In these cases, the application of SIO and DIO methods aims to increase the current oil production. Savings in this case are generated by increasing the fluid oil production, both from intensifying development and preventing premature well flooding.

The goal and objective of this scientific review are the technical and economic evaluation of the application of simultaneous and independent operation means and incorporation of productive horizons to increase hydrocarbon production during the development of deposits in the initial and late stages of operation. The economic efficiency of such regulation of production is determined by comparing the technical and economic indicators of the zone's development without regulation, calculated considering the actual ratio of technological and economic indicators with the actual technical and economic indicators. Incorporating productive horizons can play a significant role in increasing current oil production, and in some cases, enhancing the oil recovery of the incorporated zone, through the most effective utilization of previously drilled wells on the field. One of the key current technological indicators of incorporation is the additional well production rate, i.e. the increase in current production achieved through the implemented measures. The practical significance of this work lies in the technical and economic evaluation of a more efficient and sustainable oil and gas production technology developed in Turkmenistan, leading to increased production and reduced capital investments at the early and late stages of field development.

Keywords: Oil Recovery; Economic Efficiency; Productive Formation; Injection; Extraction; Reserves Recovery; Incorporation

Introduction

Separated by impermeable clay layers, oil-saturated reservoirs of multilayer deposits, depending on their geological and physical characteristics and reserve ratios, are developed either by an independent well pattern for each layer or by a single common well pattern simultaneously on all or several layers combined into one operational zone.

Consolidating productive layers into operational zones significantly reduces the footage and duration of field drilling, saving material resources for field development. However, multiple completions usually deteriorates the development conditions of each individual layer, complicating the control and regulation of the operation process. In these cases, the method of simultaneous and independent operation is applied, which allows the differentiated impact on the layers developed jointly by one well pattern. Simultaneous and independent operation is a means to provide optimal conditions for the recovery of oil reserves from each layer while economically operating jointly, thereby increasing the economic efficiency of their development [1]. Technological efficiency refers to the increase in recovery rates and the oil recovery coefficient of each layer of a multilayer reservoir by regulating the exploitation process. This involves controlling the movement of oil-water and gas-oil contacts and the extent of reservoir coverage by displacement according to thickness. Simultaneous and independent operation, both in domestic and international practices, is carried out by equipping wells with special technique for layer isolation or using specialized well designs for this purpose. The increase in the current well production rate is the difference between the well production rate after the implementation of a particular measure and the production rate before the measure is implemented. The additional well production rate serves as the initial indicator for determining the additional oil production over the evaluation period the economic effect [2,3].

Materials and Research Methods

The use of SIO and DIO technique to solve specific technological challenges should undergo special technical and economic evaluation. A particular problem here is to select a comparison basis and determine the initial data for calculating economic indicators (capital investments and operating costs).

This group of problems is associated with the possibility of simultaneously using production and injection wells for various technological purposes (intra-well gas lift, thermal water production with simultaneous oil heating, implementing an operation-injection-production scheme in a single well).

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When using SIO and DIO technique for these purposes, the following sources of savings can be identified [4,5]:

Regarding Capital Investments: Implementing intra-well gas lift eliminates the need for drilling wells to gas horizons for high-pressure gas extraction, reduces the requirement for laying gas pipelines to supply gas to production wells and the construction of gas distribution devices, as well as reduces the need for gas lift technique at wellheads.

Regarding Operating Costs: Intra-well gas lift eliminates expenses related to gas extraction, transportation to production wells, and maintenance of the gas distribution network. These sources of savings should be taken into account when determining the economic impact of intra-well gas lift.

The application of downhole technique for simultaneous production of thermal water and oil to heat gas lift pipes is a promising method of operation. However, establishing the economic benefits of this method at the current stage of development poses certain difficulties. This issue should be considered in conjunction with other questions regarding the organization of reservoir temperature maintenance [6].

The Main Types of Technical Tasks

Technique designed for simultaneous separate production of oil and gas and separate water injection, including parallel or concentric production tubing, isolating packer, circulation valve, and bottomhole control devices, can be used to solve a range of technological challenges aimed at improving the technical and economic performance of liquid lifting, both in normal and challenging operating conditions [7].

This technique can solve technological tasks related to optimizing the use of reservoir energy, expanding gas energy, deep thermal water heat energy, etc. These tasks may include methods for lifting liquid from wells, separate oil and water production from a watered layer, conducting hydrodynamic reservoir studies, and exclusion of flooded layers from production. As an example, cases of using SIO technique in the oilfield practice can be considered. SIO technique is applied to utilize natural sources of compressed gas for lifting liquid from the oil reservoir using intra-well gas lift (IWGL). For IWGL implementation, a single flow column, a packer to isolate the upper reservoir from the annular space, an inter-layer isolation packer, and a bottomhole choke are commonly used, through which a specified volume of gas extracted directly from the gas reservoir is introduced into the flow column. When selecting the IWGL process scheme, geological conditions and technological parameters of field development shall be considered. IWGL is implemented in fields in Western Siberia, Turkmenistan, Saratov, and Volgograd regions: The SIO technique scheme "gas production from the gas reservoir - oil production using IWGL" is used for combined oil and gas production from respective reservoirs in a single well. In this method of well operation, two parallel production tubings are installed to separately transport gas and oil to the surface through independent channels. In some cases, the annular space is used as a channel for oil (or gas) extraction. As with all SIO technique schemes utilizing IWGL, two packers are installed in the well: an upper, isolating packer and a lower, inter-layer packer separating the reservoirs from each other [8].

SIO technique can also be used for injecting water from a high-pressure aquifer into an oil reservoir directly in the wellbore, known as intra-well water injection (IWWI), to maintain reservoir pressure. Forced intra-well water pumping from one reservoir to another is achieved using an electric centrifugal or jet pump. The downhole technique of a well-intended for IWWI includes production tubing, a crossflow coupling, and an inter-layer packer. Experimental IWWI installations have been used in Western Siberia. There have been cases of isolating a flooded reservoir by setting packers in wells (water shutoff). When perforating several production zones with a common filter and if one of the zones is fully blocked with watered, isolating it from production and separating it from other zones in the well can be achieved using packer equipment. In the wellbore, one or two production tubings and an isolating packer are installed, which is set in place (packed off) when the reservoir isolation is necessary.

With a single-row scheme, one or two packers are used, depending on the number of productive layers. The most effective method of isolating reservoirs with packers is achieved sequentially from bottom to top [9,10]. There are also other cases of using SIO technique in the operation of multilayer reservoirs in practice.

Results

Determining Economic Indicators

The use of SIO and DIO technique to solve specific technological challenges should undergo special technical and economic evaluation. The fundamental economic evaluation of the feasibility of using SIO and DIO technique in these cases is conducted in accordance with the "Basic Principles for Determining the Economic Efficiency of New Technique Implemented in the National Economy." A particular problem here is to select a comparison basis and determine the initial data for calculating economic indicators (capital investments and operating costs).

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This group of problems is associated with the possibility of simultaneously using production and injection wells for various technological purposes (intra-well gas lift, thermal water production with simultaneous oil heating, implementing an operation-injection-production scheme in a single well).

When using SIO and DIO technique for these purposes, the following sources of savings in capital investments can be identified [11]: Implementing intra-well gas lift eliminates the need for drilling wells to gas horizons for high-pressure gas extraction, eliminates the requirement for laying gas pipelines to supply gas to production wells and the construction of gas distribution devices, eliminates the need for gas lift equipment at wellheads.

Regarding Operating Costs: Intra-well gas lift eliminates expenses related to gas extraction, transportation to production wells, and maintenance of the gas distribution network. These sources of savings should be taken into account when determining the economic impact of intra-well gas lift. The application of downhole technique for simultaneous production of thermal water and oil to heat tubing is a promising method of operation. However, establishing the economic benefits of this method at the current stage of development poses certain difficulties. This issue should be considered in conjunction with other questions regarding the organization of reservoir temperature maintenance. The use of technique in the recovery-injection scheme can nearly always be economically justified because this scheme inherently combines two different functions - production and injection - in a single well. The source of capital investment savings from the application of this technique scheme is the exclusion of drilling one well (production or injection) and its downhole equipment [12-14].

The savings in operating costs are due to the reduction in the total depreciation of wells for oil production and water injection. When considering specific issues related to determining the economic efficiency of using SIO and DIO for solving this group of tasks, operating costs may be amended and augmented taking into account the specific conditions of oil field development.

Determining the Economic Efficiency of Incorporating Formations

The inclusion of overlying horizons, while not typically widespread, can significantly enhance current oil production, optimize the use of drilled wells at the field, and maximize oil reserves recovery. The economic outcome of implementing SIO and DIO typically involves increased well productivity and additional oil production, resulting in savings in both operational and capital costs. Capital cost savings are realized by reallocating funds earmarked for drilling upper formations or densifying well patterns on these formations (layers) as per the development plan. The reduction in operating costs from incorporating formations through SIO and DIO stems from the relative decrease in the cost of oil production per well group participating in the process compared to the cost of oil production without implementing SIO and DIO (without incorporation), considering the expected changes in the oil production process [15].

The annual economic impact of employing SIO and DIO for incorporating productive formations is determined by the savings in the mentioned costs using formula (1).

$$Э=\left(C_1+EK_1\right)Q_1+\left(C_3+EK_3\right)\Delta Q-\left(C_2+EK_2\right)Q_2 \quad (1)$$

Where C_1 and C_2 represent the cost of producing 1 ton of oil without and with the application of SIO respectively; K_1 and K_2 represent the specific capital investments without and with the application of SIO respectively; C_3 and K_3 represent the respective cost and specific capital investment for the deposit (group of deposits) closing the industry development plan; Q_1 and Q_2 represent the annual oil production without and with the application of SIO respectively; ΔQ represents the additional oil production; E represents the normative coefficient of economic efficiency (0.15).

The validity of using this formula for calculating the annual economic effect can be explained by the following circumstances. The incorporation of upper productive horizons is typically carried out on already developed oil fields, with the aim of increasing the flow rates of the drilled wells. Practical experience also indicates that incorporation occurs in wells with low flow rates, considering it as a reserve for flow rate enhancement. Involvement usually targets productive reservoirs, which independent development is inefficient. Considering the above, incorporation through SIO and DIO technologies should be considered as measures aimed at improving the utilization of existing production assets [16].

It’s crucial to focus on the specifics of determining the initial data for calculating the economic effect of applying SIO and DIO technique to incorporate upper productive horizons. The net cost of oil production without SIO and DIO technique (C_1) serves as the baseline in the economic effect calculation formula and reflects the economic state for the period preceding the technique application, or for the period when the technique is used, but excluding additional costs associated with operating wells equipped with SIO and DIO, as well as variable costs related to additional oil production from SIO (energy for fluid lifting, oil gathering and transfer, oil preparation) [17,18].

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Costs associated with operating wells equipped with SIO and DIO differ from regular wells due to additional expenses for depreciating specialized equipment and current repairs. These additional costs, when added to the variable costs associated with producing additional oil, determine the net cost (C_2) in the economic effect calculation formula.

$$\Delta P = (Pr_{.oil}-C_2)Q_2-(Pr_{.oil}-C_1)Q_1 \quad (2)$$

Where ΔP represents the additional profit obtained from the application of SIO and DIO, in thousand manats; C_1 and C_2 represent the respective cost of oil production without and with the application of SIO, in manats per ton; Q_2 represents the commercial oil production with the application of SIO, in thousand tons; Q_1 represents the commercial oil production without the application of SIO, in thousand tons; $Pr._{oil}$ represents the wholesale price of 1 ton of oil in manats per ton.

Additional specific capital investments in well technique with SIO and DIO consist of the cost of specialized technique (SIO and DIO), expenses for additional wellhead equipment, and are determined based on standard prices. The cost of installing underground equipment includes capital investments. An additional indicator of the economic efficiency of applying SIO and DIO is the increase in profit from additional oil production (economic benefit). This indicator is determined based on the company's current oil prices, the cost of producing additional oil per ton, and the quantity obtained in the current year.

$$\Delta P = (Pr_{.oil}-C) \quad (3)$$

C is a net cost of additional oil production, manats per ton.

The payback period of additional capital investments is also determined. The payback period is determined by reducing the cost of additional oil production. Incorporating zones for water injection increases the volume of water injection and contributes to the most complete extraction of oil from the involved zones. The source of savings in this case is the reduction in the net cost of injected water into the involved reservoirs. The net cost of water injection will consist of expenses for water intake and pumping, transfer to the central pumping station, which pumps water into injection wells (cost of seawater transfer), and variable costs for injection [19-21].

As the baseline cost in determining the economic effect, the cost of injection prior to the zones incorporation or the estimated cost without injection into the involved reservoirs is accepted. The latter is determined by the total expenses on injection in the conditions of involving reservoirs, excluding variable costs for additional injection into the involved reservoirs.

Conclusions

The economic effect of the introduction of for simultaneous and independent operation technology was achieved mainly by reducing the cost of drilling additional wells, as well as due to a second additional elevator, which in turn reduces payback periods and reduces operating costs. However, the expediency of using SIO at each specific field, block, horizon, deposit, etc. should be determined only on the basis of in-depth economic analysis. The interest of mining enterprises in drilling wells when introducing simultaneous and independent operation is associated with the following efficiency factors:

- Increase in production rates in order to accelerate the development of the field without increasing the oil recovery coefficient;
- Increase in flow rates without reducing the service life of wells due to gas or water breakthrough through depression funnels;
- Loosening of the grid for the placement of wells in a new field and, accordingly, the number of required production wells;
- Wiring of directional shafts from old wells in depleted fields in order to avoid sealing the grid with new wells;
- The effectiveness of the implementation of the SIO;
- Reduction of drilling volumes by using the trunk of a single well;
- Simultaneous operation of facilities with different reservoir characteristics and properties of oils;
- Increasing the profitability of individual wells by connecting other development facilities or layers of different properties of the same development facility.

The use of technique in the recovery-injection scheme can nearly always be economically justified because this scheme inherently combines two different functions - production and injection - in a single well. The source of capital investment savings from the application of this technique scheme is the exclusion of drilling one well (production or injection) and its downhole equipment.

The savings in operating costs are due to the reduction in the total depreciation of wells for hydrocarbons production and water injection. With this method of water injection, reservoir pressure is maintained while production is simultaneously conducted. When considering specific issues related to determining the economic efficiency of using SIO and DIO for solving this group of tasks, operating costs may be amended and augmented taking into account the specific conditions of oil and gas field development.

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The optimal operating mode of each reservoir within one well pattern may be performed with the technique for simultaneous and independent operation (SIO) or dual injection operation (DIO), which will lead to savings by reducing the number of wells drilled on the field and the technique installation, as well as a reduction in operational costs. Involvement of productive reservoirs leads to an increase in current hydrocarbon production and an increase in the oil and gas recovery factor of the involved zone. By implementing the technology of simultaneous and independent operation of multiple reservoirs, cost savings on drilling and development time, an increase in the oil recovery factor of the reservoirs and their economic efficiency, are determined by introducing this method into production. Based on the conducted pilot works, the economic efficiency indicators of 4 wells, on average over 1 year, compared to conventional wells, amounted to a total profit of 143,252.2 thousand manats, and the self-sufficiency of the expenses for the work performed was 0.56 years. The proposed new technology of oil production by simultaneous and independent operation of multiple reservoirs, in full implementation and development on the field, will create the possibility of achieving economically advantageous and more advanced technical and technological level in the future compared to other applied methods in this area.

The results of the technical and economic evaluation lead to the conclusion that the proposed new technology of oil production by simultaneous and independent operation of multiple reservoirs, in full implementation and development on the field, will create the possibility of achieving economically advantageous and more advanced technical and technological level in the future compared to other applied methods in this area.

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