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EVALUATION OF THE PROCESS OF OIL PRODUCTION BASED ON THE METHOD OF HYPERBOLIC DISTRIBUTIONS

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As one of the methods for intensifying oil production, the method of forced fluid withdrawal is increasingly being used. At the same time, the volumes of carrying out this technological process on a large scale require an assessment of the effectiveness of this method not for individual wells, but an approach to assessing its success as a whole for all production wells in the area under consideration.

The choice of wells for boosting in practice often leads to numerous changes in individual elements of the system, but, in general, it does not have a significant impact on the overall well performance. Carrying out such activities is often associated with a random selection of wells, which, as a rule, is not enough to achieve the desired effect.

Basically, the process under consideration is dynamic and subject to changes over time, both random and purposeful. In this regard, this method requires rapid assessments. The proposed technique is based on the use of the hyperbolic function method [1-3] and the theory of Markov chains [4, 5].

Keywords: water cut, fluid, dynamics, well, forcing, process control

Materials and methods

When conducting forced fluid withdrawal (FFW) - success is assessed not only by forced wells, where production increased, but also the performance of surrounding wells did not deteriorate, an example is the amount of associated water withdrawn, which affects the water cut, as well as the amount of energy costs consumed for the development of a given area. An example of one of the sections X of an oil field (69 wells) isolated from adjacent sections by rows of water injection wells.

The graph is a hyperbolic law (Zipf-Pareto law), which well describes a number of processes, and the manifestation of this law in economics and physics, also related to human life and natural factors [6, 7, 8]. The Zipf-Pareto law is called the "rank law" or the 80/20 law, which leads, in particular, the interaction of two opposing processes, for example, growth and limitation [9-14].

In order for the process to correspond to the evaluation of the Zipf-Pareto law, two approaches are used: frequency approach, which corresponds to the proposed formula below

$$n(x) = \frac{A}{x^{1-\alpha}}$$

where α is a characteristic indicator that determines the speed, convergence; $n(x)$ - distribution of the number of elements depending on the parameters x .

As well as the rank approach, which corresponds to the formula

$$x = \frac{A}{r^{1+\alpha}}$$

where - r is the rank of the corresponding x value, i.e. the number in the descending ordered sequence of the x value.

And the hyperbolic dependence formula, which is rectified in coordinates

$$\lg x = \lg A - (1 + \alpha) \lg r$$

A characteristic feature of the processes of hyperbolic dependence is the presence of "beginning" and "end" in them, moreover, the beginning determines the process itself.

With the help of rank correlation, the distribution of oil and water production rates by wells of the developed area of the X field was studied. The distribution was assessed before and after the FFW at 19 wells in this area.

By straightening the hyperbolic dependence, the initial data [2] were estimated in the coordinates $\lg QH$, $\lg QB$ and $\lg r$, where QH , QB are monthly flow rates (oil and water) for wells, as well as their corresponding ranks.

Results

The results obtained are shown in Fig. 1, which shows that well flow rates are well straightened in allometric coordinates for oil and water. Moreover, two sections and the transition between them are very clearly distinguished, one of which is flat, on which high-rate wells are concentrated, and the second is steep low-rate wells.

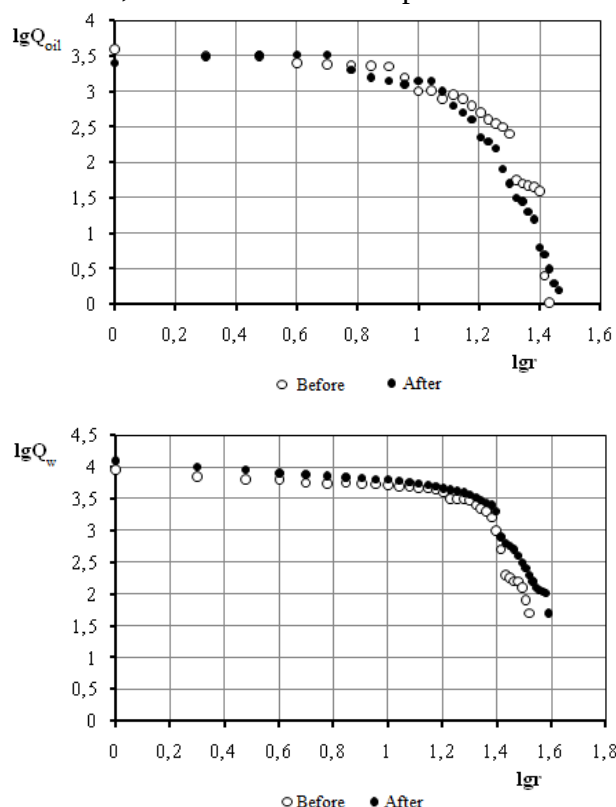


Fig.1.

An analysis of the results of the intervention in a number of wells in the area under consideration before and after the FFW showed that the comparison of the distributions of well flow rates by oil as a result of forcing had al-

most no effect, that is, the oil flow rates depending on their respective ranks in allometric coordinates before and after the intervention almost duplicated those or straight lines. At the same time, an increase in fluid production led to a change in well flow rates and a redistribution of water, which was reflected in independent straight lines lying higher along the ordinate parallel to those obtained before the FFW.

According to the Zipf-Pareto law, the distribution of oil and water production rates before and after forcing

The analysis of the obtained results showed that forcing had practically no effect on oil production, but mainly led to an increase in water withdrawal in the whole area. Comparing the values for these periods before and after the FFW extractions, for this area of the reservoir, it was revealed that oil production decreased slightly with an increase in water production by 40%.

The result obtained for the area under consideration, which combined high- and low-rate wells in allometric coordinates, showed that in the process of forcing there were changes in the ranks and movements of the positions of individual wells of their corresponding rates, both within the straightened sections, and the presence of movements from high-rate in oil and water to low-rate and vice versa. For example, the area where the FFW was performed, wells No. 2377 and 450 oil production rate increased, and wells. 648 and 444 oil production rates dropped sharply and became flooded. However, despite the measures taken, the main part of the wells remained unchanged in the same sections of the straight lines, even despite the change in the values of flow rates before the increase in production, and the corresponding ranks. The wells not affected by forcing generally reacted slightly, remained within the straight lines.

Confirmation

In the area under consideration, all wells were eventually divided into four groups: I - wells with high production rates for oil and water, - wells with high production rates for oil and low production rates for oil, - wells with

low production rates for oil and water. The results of the total production of the site and the assessment of the share of the contribution of each of the groups are shown in Table 1.

Distribution of each of the groups in the total production of the share of the contribution by area

Table 1

Shown	% well of the total	% of total production before FFW	% of total production after FFW	% of total production before FFW	% of total production after FFW	% wells in gr with FFW
I group	20	58	69	49	45	60
II group	10	29	23	6	5	25
III group	15	9	4	32	32	45
IV group	55	4	4	13	18	40

From Table 1, about 90% of oil and 50% of water are produced by wells of groups I and II, and these groups make up only 30% of the total number of wells in the area. The remaining 70% of wells, respectively, produce only about 10% of oil and 50% of water.

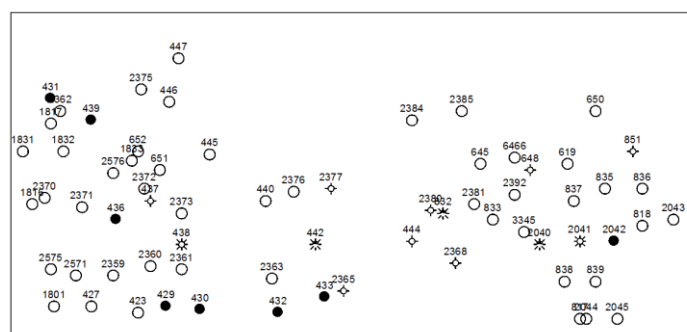
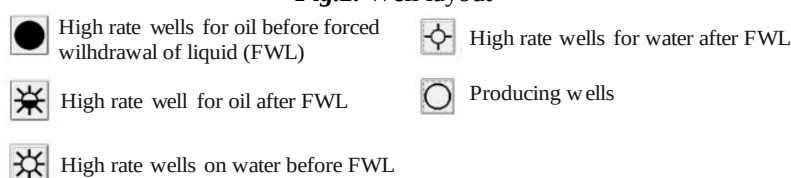


Fig.2. Well layout



If compared by groups of redistribution of oil and water withdrawals, then as a result of forcing, according to the data, there is a relative increase in oil production in group I due to groups II and III, as well as a relative increase in water production in group IV due to groups I and II.

The results of the comparison, and even taking into account the general negative measures taken by the FFW in the area under consideration, indicate that an increase in fluid withdrawal improved the productivity of the group of wells in the total amount of oil production in the area. That is, the use of FFW in

this group gave a positive result. The group of wells that combined low-water cut is explained by a decrease in the share of production in these areas, a low percentage of forcing and a decrease in flow rates of wells No. 2044 and 422 after the intervention in the surrounding wells.

In groups III and IV, the forcing results were unsatisfactory, and even with an increase in fluid withdrawal, the overall production performance of the entire area worsened.

Comparing the results of the forcing with the data of highly productive wells, it can be seen (Fig.2) that even though rows of water injection wells are located on both sides, wells

with high flow rates are grouped at the same border of the strip-like area. Based on these results, a conclusion is made about its low efficiency along the upper and activity along the lower boundary of the flooding process in the area. It also confirms the unsatisfactory results of the FFW for wells that are located along the upper boundary. If we consider the assessment of the success of forcing, then the typical results are those obtained in the part of the area where wells 648, 852, 2045, 818, etc. are located.

Although 2040 and 2042 were considered the most productive among the rest. However, with a total increase in water production in this zone by 25%, oil production decreased by 30%, which indicates that the choice of an object for forcing fluid withdrawal was unsuccessful. In the production system, forecasts of current changes and assessments of the area under consideration were also carried out using the apparatus of the theory of Markov processes. Let us dwell briefly on the theoretical prerequisites necessary for further research [7-9].

Let $x(t)$ be a random process that at different times t took values s from some set. The set S is called the state space, the specific value s from the set S that the random process $x(t)$ takes at time t is called the state of the process at time t . A characteristic of a process is the conditional probability that the state of the process in

$$P\left\{x(t) \in \frac{G}{x(\delta)}, \delta \leq \tau\right\}$$

the set $G \in S$ belongs to the time t if the trajectory of the process up to the time $r \leq t$ is known. For a Markov process, this probability depends only on the state of the process at the current time τ , i.e.

$$P\left\{x(t) \in \frac{G}{x(\delta)}, \delta \leq \tau\right\} = P\left\{x(t) \in \frac{G}{x(\tau)}\right\}$$

If the set T_x and S are finite, then $x(t)$ is said to be discrete in the state space S_n at time T_x in this case, the random process $x(t)$ was considered in a discrete series of fixed points $t_1, t_2, \dots, t_n$, and the values $x(t)$ form a random sequence $x_i = x(t_i)$, $i = 1, 2, \dots, n$. If the structure of the random process $x(t)$ is such that the

probability that $x_{m+1} = S_m = 1$, given all the previous values of x_i , depends only on x_m and does not depend on all, i.e.

That is, they say that the random process $x(t)$ has the Markov property. Markov chains are discrete random processes that have the Markov property.

An ergodic chain is a chain whose states form one ergodic set, or, equivalently, a chain in which one can get from any state to any other. For an ergodic Markov chain, the existence of a vector of stationary probabilities π is proved, which is the limit value of the probabilities $x(t)$ as $t \rightarrow \infty$

$$\pi = (\pi_1, \pi_2, \dots, \pi_n), \lim_{t \rightarrow \infty} P_{ij}^{(t)} = \pi_j \quad (j = 1, 2, \dots, n)$$

For π , there are the following restrictions

$$0 \leq \pi_j \leq 1, \sum \pi_j = 1, \pi = \pi P$$

From the last formula, knowing the matrix P , we can find the vector π . The system of equations for finding the values of π has the following form:

$$\begin{aligned} \pi_1 P_{11} + \pi_2 P_{21} + \dots + \pi_n P_{n1} &= \pi_1 \\ \pi_1 P_{12} + \pi_2 P_{22} + \dots + \pi_n P_{n2} &= \pi_2 \\ \pi_1 P_{1n} + \pi_2 P_{2n} + \dots + \pi_n P_{nn} &= \pi_n \\ \sum_{i=1}^n \pi_i &= 1 \end{aligned}$$

The vector π in oilfield problems is interpreted as a long-term forecast of the distribution density of wells in groups distinguished by the value of one or another indicator (flow rate, water cut, etc.). As an apparatus for estimating well interventions, this method can be applied by evaluating the vector π before and after the event. Consider the evaluation procedure on our example.

To analyze all wells, the entire range of water flow rates was divided into 4 groups: Group I - with flow rates up to 1000 m³/month, Group II - from 1000 to 3000 m³/month, Group III - from 3000 to 5000 m³/month months and IV - more than 5000 m³/month. The relative change in the number of wells (referred to the total number) in the groups was also observed before and after forcing.

Analyzing current performance, predicting the behavior of the system, the future is of

some interest. In a specific case, for a comparative assessment of the expected water yield, such a forecast is important in conditions without forcing and with forcing.

For groups, a forecast is made by finding the values of the final probability vectors of well distribution (π) [4]. Based on the comparison of values, estimations were carried out before and after the FFW, moreover, the probabilities of well distribution are interpreted as the number of wells in certain groups. However, if forced selection was not carried out, then the distribution of wells by groups would be as follows: 38% of wells would be in group I, 15% in group II, 22% in III, and 25% in IV. As a result of the event, the distribution changes somewhat, namely, 41, 12, 15 and 32 percent according to the distributed order of the groups. That is, in groups I and II, they are low-rate, here there is practically no redistribution of wells. But there is also a slight transition (7% of wells) from group III to the highest-yielding group IV.

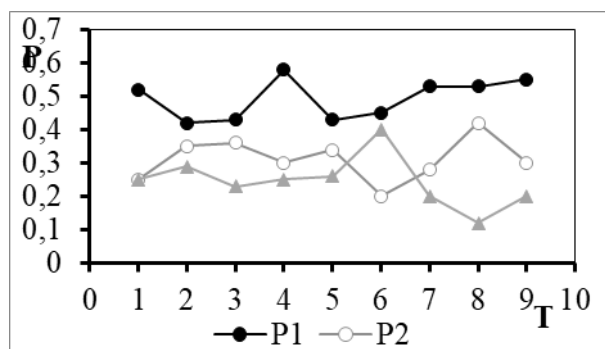


Fig 3. Dynamics of the relative number of wells in groups according to the nature of the change in water production

Let's consider Fig. 3, which shows the change in the relative number of wells in groups identified according to the principle: the first group - wells that did not change water flow rates, the second group - wells that reduced flow rates, and the third - an increase. As can be seen from the figure, no changes are observed in group I. Basically, the redistribution occurs due to the transition from the group of wells that have reduced to the groups that have increased the flow rates of wells. As a result, the obtained predictive values for the distribu-

tion of the relative number of wells, before and after the FFW, respectively, are equal to π before=(0.43; 0.32; 0.25) and after=(0.45; 0.10; 0.45), which is in agreement with the above.

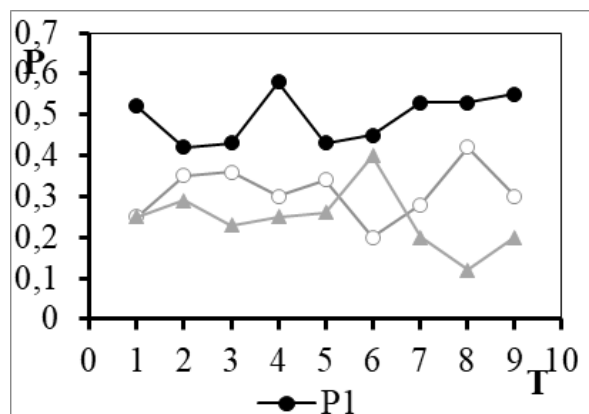


Fig. 4. Change in the relative number of wells in water production groups

In the process, the impact of forcing on the operation of surrounding wells was also separately considered, and 4 groups were identified according to the values of water flow rates. Here, the first group included wells with monthly flow rates up to 500 m³, the second-from 500 to 3000 m³, the third-from 3000 to 5000 m³ and the fourth-over 5000 m³. As can be seen, Figure 4 shows the dynamics of changes in the relative number of wells in these groups. According to the obtained forecast data, the distribution of wells before forcing would be as follows: in group I-20%, in group II-25%, in III-35% and in IV-20%. As a result of the increase in fluid withdrawal, the number of wells in the first lowest-yield group increased to 36%, in the medium-yield groups II and III groups it decreased to 15 and 17 percent, and in the IV-high-yield group, exactly 22% remained almost unchanged. Based on the analysis, it can be concluded that forcing to some extent contributes to the partial withdrawal of water from neighbouring wells, where low and medium rate wells are observed at work.

Conclusions

In general, evaluating the results of the FFW on the change in the nature of the wells in the area under consideration, the following can be noted:

for high-yield wells (oil and water), forcing contributed to a proportional increase in

both water and oil withdrawals, which, as a result, did not affect their water cut;

in high- and low-rate wells with an increase in fluid withdrawal, an increase in high water withdrawal was observed without a corresponding increase in oil production;

a number of wells reduced their water flow rates due to the redistribution of water yield located in the forcing zones during the event;

in general, the activities carried out on the site led to an increase in water withdrawal and did not give the expected effect of increasing oil production, which, in turn, can only be explained by the random nature of the selection of wells.

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HİPERBOLİK PAYLAŞMA ÜSULU ƏSASINDA NEFTVERMƏ PROSESİNİN QIYMƏTLƏNDİRİLMƏSİ

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Məqalədə, geoloji və texniki tədbirlərin səmərəliliyinin qlobal qiymətləndirilməsinin metodoloji əsasları nəzərdən keçirilmişdir. Bu məqsədlə müxtəlif yataqlar üzrə geoloji və mədən məlumatları təhlil edilmiş və quyu debitlərinin əksəriyyətinin Zipf-Pareto qanununa əsasən, paylandığı göstərilmişdir. Müxtəlif geoloji və texniki fəaliyyətlərin səmərəliliyi fəaliyyətlərdən əvvəl və sonra paylanma qanunlarını müqayisə etməklə qiymətləndirilmişdir.

Açar sözlər: sulaşma, maye, dinamika, quyu, sürətlə maye çıxarılması, proseslərin tənzimlənməsi

ОЦЕНКА ПРОЦЕССА НЕФТЕДОБЫЧИ НА ОСНОВЕ ПРИМЕНЕНИЯ МЕТОДА ГИПЕРБОЛИЧЕСКИХ РАСПРЕДЕЛЕНИЙ

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В статье были рассмотрены методические основы глобальной оценки эффективности геолого-технических мероприятий. С этой целью были проанализированы геолого-промысловые данные по различным месторождениям и показано, что большинство дебитов скважин подчиняются распределению Ципфа-Парето.

Эффективность различных геолого-технических мероприятий оценивалась с помощью сравнения законов распределения до и после проведения мероприятий.

Ключевые слова: обводненность, жидкость, динамика, скважина, форсирование, регулирование процесса