ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

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ИЗВЕСТИЯ	N E W S
НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК РЕСПУБЛИКИ КАЗАХСТАН Казахский национальный исследовательский технический университет им. К. И. Сатпаева	OF THE ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN Kazakh national research technical university named after K. I. Satpayev

ГЕОЛОГИЯ ЖӘНЕ ТЕХНИКАЛЫҚ ҒЫЛЫМДАР СЕРИЯСЫ

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СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

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SERIES OF GEOLOGY AND TECHNICAL SCIENCES

4 (430)

ШІЛДЕ – ТАМЫЗ 2018 ж.
ИЮЛЬ – АВГУСТ 2018 г.
JULY – AUGUST 2018

ЖУРНАЛ 1940 ЖЫЛДАН ШЫҒА БАСТАҒАН
ЖУРНАЛ ИЗДАЕТСЯ С 1940 г.
THE JOURNAL WAS FOUNDED IN 1940.

ЖЫЛЫНА 6 РЕТ ШЫҒАДЫ
ВЫХОДИТ 6 РАЗ В ГОД
PUBLISHED 6 TIMES A YEAR

 АЛМАТЫ, ҚР ҰҒА   АЛМАТЫ, НАН РК   ALMATY, NAS RK

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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

UDC 622.276.3

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DECISION-MAKING FOR CHOOSING OF GEOLOGICAL AND ENGINEERING OPERATIONS: CURRENT STATUS AND PROSPECTS

Abstract. It is commonly known that great care is given to upgrading of the efficiency due to implementing of various new technologies and GTM during development of oil fields. Widespread introduction of GTM as well as enhanced oil recovery (EOR) and elaboration of their technologies raise the issues of relevant choice of the best methods ensuring proper technical and economical efficiency in particular conditions. Despite of the profound interest of the researches to the given question, major problems arise currently anyway at comparative evaluation of various types of GTM regarding particular conditions. The issue of upgrading of efficiency of GTM based on the integrated geological and physical and technological information is currently challenging and deserves relevant consideration. Deep analysis of the conditions for applying of various GTM using advanced techniques and corresponding software allows in its turn to give guidance to current possibilities in order to upgrade efficiency of field deposit. For many years the research focused on upgrading of the efficiency of field deposits had been conducted in various scientific and industrial organizations. The analysis of choosing and implementing of GTM at different deposits is of great interest. Review and analysis of up-to-date condition of problem of GTA choosing are illustrated in the article. Examples of application and performance evaluation of GTM are shown at different deposits. Development and upgrading of the analysis methods as well as forecasting of indicators and decision-making have been observed over the recent years. Their implementation allowed upgrading the efficiency of conducted geological and technical operations. As a result of conducted operations the researchers solved the issue of creating of integrated methodology and its mathematic, scheduled and information application for evaluating of efficiency and optimal scheduling of geological and technical operations at field deposits; structure of automated system of decision support and algorithm of its functioning have been created; by transforming the indicators characterizing the formation into the relevant factors, the equations (linear and multiplicative) were made expressing the dependence of the efficiency indicators of GTM from the formed factors; by variants calculation and analysis of comparative efficiency of any GTM in different conditions the directions were shown and the results of making decisions for choosing of the best GTM were obtained.

Key words: geological and technical measure (GTM), field development, decision-making, crude oil production, oil recovery.

Introduction. During operation of oil field well works are reported to be carried out for adjusting of its development and maintenance of crude oil production level. This range of works is called as geological and technical measures (GTM), owing to which oil producing companies provide achieving of the required indicators of field development. It goes without saying there is an operational need for assessing of methods and efficiency criteria of GTM.

It is commonly known that great care is given to upgrading of the efficiency due to implementing of various new technologies and GTM during development of oil fields. Widespread introduction of GTM as well as enhanced oil recovery (EOR) and elaboration of their technologies raises the issues of relevant choice of the best methods ensuring proper technical and economical efficiency in particular conditions. Despite of profound interest of the researches to the given issue, major problems arise currently anyway at

comparative evaluation of various types of GTM regarding particular conditions. It is linked with the lack of research allowing to give prognosis evaluation of the efficiency of GTM for those reasons where it was not applied for whatever reason. State of the art of analysis techniques of information and decision-making allows to achieve this goal upon availability of integrated geological and physical and technological information. At the same time the experience of implementing of different GTM at various fields confirms its great importance for increasing of oil production index as well as provides importance for the investigation of the paths of using to the fullest extent of potential opportunities of the available information, despite of the fact that we have to face its uncertainty both statistical and non-statistical kind very frequently. The specified data demands applying of the methods allowing to build the relevant forecasting models of efficiency indicators and making decisions within the multicriteriality conditions based on the sort of available information.

Accordingly, the issue for the upgrading of the efficiency of GTM based on the integrated geological and physical and technological information is currently challenging and deserves relevant consideration. Deep analysis of the conditions for applying of various GTM using advanced techniques and corresponding software allows in its turn to give guidance to current possibilities in order to upgrade efficiency of field deposit. For many years the research focused on upgrading of the efficiency of field deposits had been conducted in various scientific and industrial organizations. The analysis of choosing and implementing of GTM at different deposits is of great interest.

Summary of the research related to geological and technical measures. Various types of GTM are currently used at oil deposits. They are as follows: bottom hole treatment (BTH), hydraulic fracturing of formation (HFF), extended reach drilling as well as other methods of oil well stimulation and advanced recovery methods (ARM) of geological horizons [1-3].

Various methods for calculation of the efficiency of applied GTM are offered currently [4]. In general all the measures conducted on the wells can be divided into the different types according to impact: technological, maintenance, ARM and oil production intensification, BTH.

According to the literature analysis different models are used for problem solving of oil production forecasting in order to choose the most efficient GTM. Estimated figures are defined by existing trends of oil production and efficiency of scheduled GTM. Recent research including upgrading of the existing approaches to the assessment of efficiency of GTM make possible wide implementation of new systems of programming, automation of automation process of engineering efficiency of the applied methods of the enhanced oil recovery. This includes the development of software complex EOR–Office representing modern tool designated for automation of the whole complex of tasks for experts engaged in enhanced oil recovery [5, 6]. One of the main approaches to the assessment of technological efficiency of various GTM in oil production is extrapolation. The core of extrapolation methods for the assessment of technological efficiency of various GTM consists in building of oil production base level. For this purpose actual oil production during conducting of GTM is comparing with projection data obtained during extrapolation of background. Herewith even minor mistakes in building of base oil production level as noted by experts lead to inadequate matching and planning of effective GTM [7]. In practical terms the real efficiency of GTM is assumed to assess by the methods of characteristics of water-oil displacement, i.e. by watering curves – connections of type $V_н = f (V_ж)$ and by curves of oil production variation – connections of type $V_н = f (t)$: here $V_н$ and $V_ж$ – are accumulated selections of oil and liquid; t –time. According to [7] the cumulative effect can be divided into the effect conditioned by changing of oil displacement nature and effect related to liquid drainage intensification. Additional quantity of produced water is calculated. Cumulative effect of GTM is defined by oil production rate decline curves – connections of type $V_н = f (t)$.

Currently the tens of different types of displacement characteristics [8, 9] are calculated and one of the problems is a choice of such displacement characteristic which was coordinated in the best way with production history of the object and ensured the most precise extrapolation when forecasting [10]. For example work [11] shows some issues related to choosing of the most precise methods of assessment of GTM as well as connections are given for reflecting of possible cases of differentiation of technological benefit of enhanced oil recovery method. According to the author's opinion forecasting of the effect (i.e. calculation of the estimated effect) of GTM based on the extrapolation curves of actual and base oil production using methods of characteristics cannot be always reliable. The author thinks that such circumstance appears due to the following reasons. According to his opinion, despite of the fact that

duration of the effect from applying of some types of GTM (for example, HFF) vary between 5-7 years, the using of watering curves for relatively long-ranged forecasts can be reliable only in case of high watering, exceeding 50-70% as a rule. In case of lower watering (at early stages) the duration of the forecast shall not increase 3-6 months. However many types of GTM are conducted in non-aqueous or less water-producing wells.

It is also noted in the work that upon availability of representative information on declining oil production after conducting of GTM (at least 4-6 points) the reliable extrapolation of displacement characteristics is possible. In such conditions the applying of forecasting methods can be viable, which are based on using of oil production decline ratios. In case if the information of oil uptake is not representative the ratios of declining of uptakes by the other wells are possible with more extended operational period after GTM. Based on the above the upgrading of the methods of displacement characteristics currently appears on the agenda and is quite up-to-date [12]. According to work [13] the object of the forecast is wells, bushes, areas, (well fields), shop, horizon, oil and gas production enterprise and etc., forecast intervals - month, quarter, year. Based on the kind and sequence of planned measures there is a possibility of conducting of multiple-path calculations which in its turn demands corresponding software using modern mathematical apparatus. According to this work [13] considers technology of calculations of forecast indicators implemented in integral software complex (ISC) «Baspro-analytic» (developed by CJSC «Analytical center SibINKor») and applied in practice of indicators analysis of oil deposits of the Nizhnevartovsky district. Two programmable modules are supposed to use for task solving: «Baspro-characteristics» – ensures calculation of base production under existing development system and assessment of impact from conducted GTM; «Baspro-forecast» – estimates anticipated oil production including intended effect from estimated GTM.

Diagrams showing the process of calculation of baseline of oil production as well as its forecasting option are illustrated in the work. Classification of indexes of technological efficiency of GTM conducting is shown. Efficiency of various GTM is installed according to the geological structure of the Ershovoe field. As the authors note, the given principle was used to the fullest extent for making of GTM and forecasting of technological performance data of the development of the Ershovoe oil field effected by CJSC «Tyumen Oil Company». The estimate indicators for the assessment of GTM effect are defined in accordance with «Guidance for the assessment of technological efficiency of applying of enhanced oil recovery methods». The methods applied in the program are based on defining of displacement characteristics approximating in the best way the actual data of oil production history. Approximation is carried out in the setting of user-defined interval and belonging to history interval. Approximation error is estimated «in the least-squared sense». The effect in «Baspro-characteristics» is automatically divided into two constituents: oil production effect and intensification effect. Effect from volume reduction of produced water is calculated alongside with two main effects. If characteristic of base production was already calculated and kept in the base of «anticipated production», «Baspro-characteristics» allows to calculate effect comparing this data and actual production [14].

Development of the mathematical modeling techniques and state-of-the-art instruments of computer science enables defining of technological efficiency of GTM for concerned oil and gas object by two possible ways, considers the author of harmonized calculation methods of the efficiency of GTM [9]: by ongoing multidimensional deterministic filtration model; small parameter random and statistical model on the basis of data of production history.

In the first instance creating of geological and filtration models of the object is required and presence of the relevant software describing processes in place. This approach demands relatively big time and funds costs.

In the second instance the assessment of technological efficiency is performed without involving filtration model of the object. The second approach does not demand big time and funds costs and can be used when using efficiency of GTM.

The methods provide confidence estimate of the initial data, theoretical assumptions, testing of the proposed methods as well as manual to software application. This allows increasing quality and confidence of the made decisions. Other authors [10] conduct analysis of currently used methodological issues on assessment of technological efficiency of GTM as well as provide the results of numerical experiments on the assessment of efficiency of GTM using software application "BASPRO-Characteristics" (methods

SibNIINP) at actual data (a range of areas of the Samotlorskoe field) and at the model characteristics estimated on idealized three-dimensional hydrodynamic model.

On the basis of three-dimensional hydrodynamic calculations of model and real sections of oil formations they conducted experimental calculations using software applications «Tempest MORE (Roxar) and Eclipse (Schlumberger), which results were compared with engineering design by the following methods of assessment of technological efficiency of GTM: methods of All-Union RDE of Oil [8, 15], SibNIINP [16], Kazakova A.A. [7, 8, 17] and Shakhverdieva A. Kh. [18]. Such approach to applying of hydrodynamic models enables testing methods of assessment of technological efficiency at «synthetic» development indicators obtained in the modeling process by individual wells. Resulting from data analysis and decision support of GTM by experts from Tyumen [19] the concept of corporate knowledge bases of Tyumen Oil Company was offered designated for keeping, development, using of the experience and empirical knowledge of the experts of the company engaged in geological and technical operations (GTM) [11]. The organization of work with knowledge basis is based on Internet using. The content of the knowledge basis is structured as pairs "GTM – situation under which the operation was conducted". Mathematical tool of hypergraphs is used for formalizing of representation of the situations, development of the algorithms of the situational analysis (methods of common situational approach) and search.

Situational method (situational models in corporate knowledge basis) is based on searching and using of analogies known from the real experience of the professional activity. The reality of the experience for the engineer can be more important than the results of mathematical modeling. Combination of both approaches where situations – analogues will be used for choosing of the estimated parameters of GTM can be of great interest.

Work [5] describes building of database of GTM by wells recommended for production as well as corresponding criteria for GTM choosing. According to this work building of GTM database by wells by each formation the following criteria shall be chosen: current oil-filled thickness is at most 2 m; formation is not left out or by current fund non-recovery well; formation without coagulation with perforated formation or non-recovery well (this criteria may not be taken into account); in radius of at least 500 m there are no wells by the current fund working on the given formation; bed shaliness is less than 6% (this criteria may not be considered, if the application of EOR (filter cake dissolving) is estimated; the formation permeability is over 0.07 μm^2. Forecasting flowrates are calculated by all considered formations. Allocation of chosen wells is checked according to the maps of current oil-filled thicknesses. The chosen wells are incorporated into GTM base as recommended for rendering to oil production. According to the authors` opinion the offered criteria enable performing choice of wells for building of the computer-based database with the following verification by the compiled maps which is more effective in case of big scope of information than manual well locations selection. This database building order for the development of GTM was applied upon the drawing-up recommendations by Abdrakhmanovskaya, Tchishminskaya and Eastern – Suleevskaya areas in the Romashkinkoe field [20].

Article [21] considers problem solving of creating of data base of GTM by wells recommended for production using method of fuzzy sets on the example of formation «а» of the horizon Д$_1$ of the Eastern - Suleevskaya area of the Romashkinskoe field. Fuzzy set is here an object belonging to which can be judged only with certain volume of concern. Problem solving of well locations selection for recommendation for producing for each formation reduces to defining for all wells of membership functions to multitude «well recommended for rendering for production». Presence of many criteria, frequently contradictory, offers difficulties in choosing of the best solution [22]. In this regard the authors reduce the solution of multicriterion problem to one-criterion using fuzzy set theory, considering this criterion as practicability measure of conducting of provided GTM, that in their view allows effecting fast ranging of possible options of decision by degree of practicability and form the most favorite operation schedule.

The author [23] offers the following concept under assessment of efficiency of measures for increasing of oil production and final oil recovery.

To determine the efficiency of any additional technical measure on increasing of current production and final oil recovery two design options of development of oil deposit (production facility) shall be estimated: without additional action (base option); with additional measure. Regular and precise satisfactory information on the operation of producers and injectors (their flowrates of oil and liquid, water injection

and bottom-hole pressure) on the concerned production facilities [23, 24] is required in order to determine confidently of the initial recoverable reserves of oil and liquid actually brought into production, and their changes .

The analysis of the completed operations indicates that most of the authors consider that performance evaluation of application of methods of enhanced oil recovery (EOR) and performing forecasting for new deposit areas building of geological and filtration models is required for updating of geological conditions of distributing of current reserves of oil. In this regard methodological approach is considered relating to the development and implementation of enterprise software products, oriented at mass user and designated for operation of geological and filtration to tasks of enhanced oil recovery of formations.

Operational solving of production tasks by the authors program products was used – three-dimensional enterprise information system (TDEIS), developed by the employees of RDE of mathematics and mechanics named after N.G. Tchebotareva and LLC "Vensis" under active participation of experts of industrial organizations [25].

The concept of ongoing model is used within the scope of this system. Ongoing system is understood as a single computer technology representing assembly of digital integrated geological, geophysical, hydrodynamic information (database), 3D geological and filtration models and software tools of building and viewing of models, issuing of reporting graphical and tabular material. Description of the basic functions of programmable modules is given in the work. The estimated group consists of three modules designated for building of geological, filtration models and GTM model. Module of building of geological model is working in the presence of database by the initial indicators, filtration model modeling module (Fluid) functions under condition of built geological model (Geo), module for assessment and forecasting of efficiency of GTM uses the results of geological and filtration model for work.

In such a way almost all field-geological information is covered. Classes of oil-field tasks are detailed. Due to GTM the estimated group of software modules consists of GTM module performing two functions: assessment of efficiency of GTM application; analysis of efficiency of GTM in the different geological and industrial conditions.

The review stated above represents profound interest of the researchers to the issue of assessment of efficiency of GTM, development of scientifically-based methodological approaches, analysis and choosing of the best options of the decisions and therefore confirms importance and applicability of decision-making on upgrading of efficiency of GTM.

As you can see from the above mentioned brief survey large number of studies has been performed, related to the assessment of technological efficiency as a separate type of GTM as well as the relevant guidance documents was developed.

This research as well as the results of GTM conducted in several districts allow to solve a number of tasks under their generalization responding several questions in particular predictive estimates of the relative efficiency of the different types of GTM on the concerned specified object, as well as determining of the object which is best suited for certain type of GTM.

Solving of these issues becomes difficult by the lack of the approach concluding in careful statistical analysis of integrated geological and geophysical and technological information, models expressing connection of efficiency indicators of any type of GTM with parameters describing the discovered object (formation). Moreover, in a number of cases the decision-making on choosing of GTM becomes very difficult by the lack or insufficient information.

Modern level of development of mathematical methods and informational technologies as well as the results of their successful using at various stages of the research works enable solving the assigned tasks in the conditions of limited information.

As you can see from the review this circumstance was considered in a number of works related to the efficiency of certain types of GTM.

All known methods for defining of technological and economical efficiency of applying of GTM are based on the comparing of certain dependencies based as a result of its implementing with base. For example, when assessing of the efficiency of the watering actual displacement correspondences are used using this method and without it. At the same time it is obvious that the main task concludes in correct approximation of the natural base process operation without using of GTM [8, 18, 26, 27].

In view of presented information alongside with the development of effective methods of evaluation of technological and economical efficiency of GTM the development of new approaches acquires particular importance enabling to give technological and economical assessment to not only one particular GTM in the certain conditions but comparative efficiency of any GTM in different physical and geological and technical and geological conditions.

This allows performing reasonable matching for these or those GTM wellbores, deposits and their technologies.

Resulting from which work [26] offers calculation system of performance indicators of GTM on the basis of data of technological, physical and geological and commercial characteristics characterizing conditions of conducting of any GTM. Accordingly we performed the research pursuant to slightly simplified and upgraded option of a system [26]. According to the stated diagram the condition of the wells, equipment, history of conversion, the technology of conducting of GTM is characterized by technological features; physical and geological indicators – condition and features of oil deposit, namely: porosity, permeability, hydrocarbon saturation, productivity of deposits and etc.; commercial – deposit development system, current and cumulative oil production before and after conducting of GTM, characteristics of well interaction and etc.

In such a way the chosen technological, physical and geological and commercial indicators generate information collection allowing characterizing the involved facility, technology of conduction of GTM and their impact to the results of conducted measures.

Analysis and assessment of impact of geological and technological characteristics of the object to the efficiency indicators of GTM. As a result from the analysis of the research accumulated to the present time large number of different GTM is used for upgrading the efficiency of the development of oil fields and intensification of oil production. Efficiency of their using depends on reasonable combination of large number of physical and geological, technological and industrial indicators characterizing in an integrated manner the conditions of conducting of any GTM. In practical terms, as a rule, for particular deposits choosing of GTM, their parameters as well as their technological and economical assessment, is performed in geological services of oil and gas production department on the ground of gained experience. However very often despite of experience and knowledge of geological services of oil and gas production department the choice of sites, GTM and their technology is conducted not always properly to certain geological and technological development terms. In practice there is no single approach using which we can give correct technological and economical assessment to not only separately taken GTM in certain conditions but also give predictive estimate of comparative efficiency in various physical and geological and technical and technological conditions.

Owing to recent development of the methods considering marked circumstances, there is a possibility to decide the assigned tasks on the higher level. It is intended here possibility of creating different models as well as the relevant programs based on the integrated geological and geophysical and technical and technological information and allowing making the most grounded technological decisions.

In order to create such models, data of geological and technical measures are used which is conducted on the facilities of different deposits of Kazakhstan [26, 28, 37]. The following factors serve as indicators which impact the efficiency of geological and technical measure: total thickness of formation, m (x_1), oil-filled thickness, m (x_2), uncovered oil-filled thickness, m (x_3), net sand coefficient (x_4), porosity unit fraction (x_5), permeability, K_p*10^{-3} μm^2 (x_6), oil viscosity, mPa*s (formation condition) (x_7), oil density t/m^3 (x_8), gas content, m^3/t (x_9), initial oil saturation, unit fraction (x_{10}), formation temperature, T^{0}C (x_{11}), wax content in oil, % (x_{12}), sulfur content in oil, % (x_{13}), oil flowrate to geological and technical measure, t/day (x_{14}), liquid flowrate to geological and technical measure, t/day (x_{15}), watering to geological and technical measure, % (x_{16}). The following factors serve as indicators of geological and technical measure: duration of the effect, day. (Y_1), additional oil production, t. (Y_2), incremental oil rate, t (Y_3), oil flowrate after geological and technical measure, t/day (Y_4), watering after geological and technical measure, % (Y_5).

Thus, initial data consist of 16 indicators and 5 efficiency indicators by each type of GTM. Further according to works [30, 32, 41], transforming of initial data is conducted in order to reduce a number of input variables.

Then correlation analysis enables installing dependencies of indicators of GTM from the marked factors and before going to correlation analysis, there is a need to ensure in dependency of data to normal

law of distributions which is one of the requirements. There are many different criteria for verifying of the given condition. Verification for normality is a binding procedure within conducting of measurements, control, tests, processing according to the Russian GOST. There are different criteria, but we used criteria of Shapiro-Wilk [29, 37].

The criterion of Shapiro-Wilk is based on relation of optimum linear unbiased estimate to its common estimate by the method of maximum likelihood. Statistics of criterion is as follows:

$$W = \frac{1}{s^2} \left[\sum_{i=1}^{n} a_{n-i+1} \cdot (x_{n-i+1} - x_i) \right]^2 , \tag{1}$$

where $s^2 = \sum_{i=1}^{n} (x_i - \bar{x})^2, \bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$

Numerator is the square of estimate of root-mean-square deviation of Lloyd [30]. Critical statistical values $W(\alpha)$ were defined according to literature data, for example, [29]. If $W < W(\alpha)$, null hypothesis normality of distribution deviates on the level of significance α.

The conducted calculations give opportunity to ground application of data at correlation analysis.

In order to build the dependencies of the selected criteria from the influential factors data of conditions and results of GTM were subjected to the correlation analysis. Moreover the data were subjected to the statistical processing by two ways using the program of linear regression.

1. Dependencies of the efficiency indicators from geological and technological factors by their natural values:

$$Y = a_0 + \sum_{i=1}^{9} a_i x_i \tag{2}$$

2. All the data were preliminary logarithmed, the linear dependency was made in a such way that using exponentiation transformed into multiplicative with further specification by successive approximation:

$$Y = a_0 x_1^{b_1} \cdot x_2^{b_2} \dots x_9^{b_9} \tag{3}$$

Each equation represented the dependency of any efficiency indicator from the chosen factors. Such equations were made for each type of GTM.

After receiving of regression equations the degree of correspondence of calculated values of the efficiency indicators were installed for different GTM by actual equations. The quantitative assessment of degree of conformity is defined by identical measure according to the formula given in work [31], which values shall be changed within $0 \leq I = 1$:

$$I = \frac{1}{1 + \frac{\sum_{i=1}^{N}(Y_{pacu\ i} - Y)^2}{\sum_{i=1}^{N}(Y_{pacu\ i} - \bar{Y})^2}} \tag{4}$$

When using integrated geological and geophysical and technical and technological information for taking of the most grounded technological decision depending on type of GTM that type of regression equation having large identity measure is chosen.

Decision-making at choosing of GTM. Results of calculations by received models are used when making decisions for choosing the best GTM for the considered conditions. This was made using efficiency indicators of GTM, adopted as criteria in such a way that the desired solution was satisfied to conditions of 5 criteria. As it is shown from the review different authors used various criteria for choosing of GTM. The whole process can be presented as a system which simplified diagram is represented on figure. When solving multicriteria tasks the difficulties arise due to the simultaneous satisfying of all the criteria, i.e. it is required to take decisions in the conditions of uncertainty.

Recently various methods are used for solving of such tasks, such as method of combining of criteria into one, generalized method of «the least concessions», positions of fuzzy set theory engineered by L.Zade. Classification of uncertainties given in works [2, 17] enables estimating the situation and choosing the best method for decision-making. Further when making decisions the method called "the least concessions" [32, 37] was used.

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│  Stages for choosing │
└─────────────────────┘
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┌─────────────────────┐
│    Receiving of      │
│    information       │
└─────────────────────┘
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| Gathering of data, installation of factors (independent variables) and indicators of GTM | Processing, systematization and assessment of data |

Analysis of information

| Building of a model | Calculations by model, testing of model on the data of certain deposit (forecast) |

Decision making
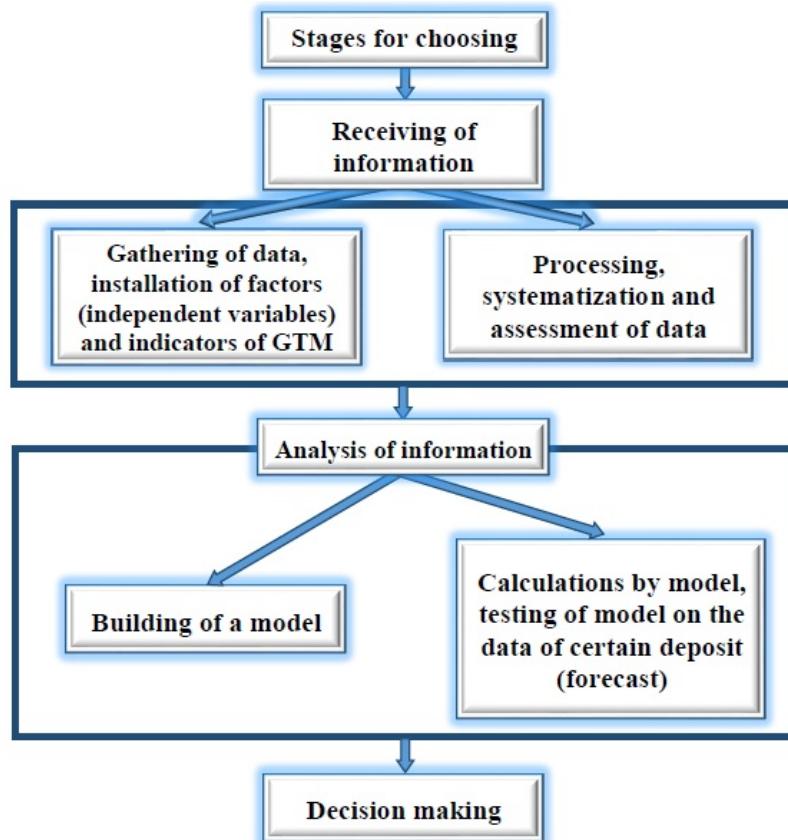
Simplified diagram for system of choosing of GTM.

When using the given method the decision of multicriteria task reduces to successive maximization (minimization) of private criteria and choosing of values of concessions. Besides qualitative analysis of the relative importance of private criteria is made first and they are numbered in order of decreasing of the importance. Then the value of the permissible reduction of the value of first importance criterion is designated and the second importance criterion is maximized provided that the value of the first criterion should not differ from maximum by more than the value of installed reduction. The recession value is redesignated but according to the second criterion and the maximum value of the third importance crite-rion is found provided that the values of the first two criteria should not differ from the previously found maximum values by more than values of the corresponding recessions. Further all the other partial criteria are used. The resulting strategies are consired optimal.

Recently the problems of management and decision-making have increasingly attracted the attention of researchers – oil industry workers. A.A. Koltun in his work [39]. Choosing of geological and technical measures uses the data of the development history (base curve method), which does not enable conside-ring hydrodynamic processes and interference of wells to the fullest extent thereby reducing the reliability of the obtained decisions. However wide development of the hydrodynamic modeling as a mean for choosing of geological and technical measures laid the groundwork for automation of their choosing [33].

The work by A. Cottini-Loureiro and M. Araujo [33, 34] using efficiency maps was suggested for choosing of well pad distribution patterns but time expenditures for building of efficiency maps drastically depend on dimension of the hydrodynamic models and is a process demanding to computing resources. When setting into operation of new wells changing of dynamics of existing wells occurs which does not allow to analyzed method to consider interference of wells in time and employ high requirements to com-puting resources.

Owing to close location of wells their arrangement diagram as shown in work by G. Santellani and B.Hansen [35], leads to difficulties of consideration of their interference it should also be noted that applying of the method stated in the given work force to stop using reputable existing well pad distribution pattern.

The issues of building of informational decision-making support system are considered in a number of studies when using type of geological and technical measure on the oil well for enhancing of its performance. In some of them choosing of options for performing of the certain type of measure is conducting according to the stages of the system analysis of problem situations, [36]. Describing of work of informational system is given on the example of the main software module in the given work allowing to calculate economical efficiency of the geological and technical measure such as formation fracturing [36]. Main stages of decision-making are described when choosing of GTM type. Therewith the process for choosing of wells for conducting of the certain type of GTM undergo the following stages: analysis of the situation (identification of need for conducting of GTM for the certain well); defining of goals (estimating of parameters, on which changing GTM shall be directed); producing of decisions and analysis of alternatives (building of the list of possible types of GTM for achieving of the estimated goals, assessment of their efficiency); implementation of the decision (conducting of GTM); assessment of the results (monitoring of condition of the well after conducting of GTM, analysis of the results). The proposed informational system consists of several software modules by the number of types of GTM [36]. According to the authors` opinion such indicator as achieving of estimated incremental oil rate shall not be considered as a single criterion for assessment of the efficiency of conducting of geological and technical measures. It goes without saying that the more complete analysis requires performing additional analysis of such indicators as quantity of oil, recovered additionally due to conducting of GTM as well as duration of the effect from the measure. The results of analysis of the efficiency of GTM for the period of 2011-2014 are given in the article using the mentioned approach.

Considering significant number of fields developed by LLC «LUKOIL-PERM», all of them are conditionally divided into the groups by geographic principle [38]. The information of the conducted geological and technical measures conducted in 2011-2014 on the wells by the groups of wells for increasing of well efficiency such as hydraulic fracturing of formation, acid treatment, radial drilling, repeated and additional perforations are shown in the stated work.

As follows from the presented data the repeated and (or) additional perforation is conducted more often at the wells of deposits of all the groups, excluding the northern group. The authors note that the most common type of impact is hydraulic fracturing on the wells of the northern group of wells.

In such a way, the research in this direction shows the opportunity of assessment of the comparative efficiency and decision-making when choosing of GTM in various conditions.

Conclusion. Practice of the applying of GTM shows that their implementation appears ineffective. Thus conducting of comparative analysis for the assessment of the efficiency of their using is of great interest not only in conditions of their conducting but in the conditions where they were not conducted. Such assessment shall be based on the relevant models expressing the dependence of indicators of efficiency from the indicators characterizing geological and physical conditions of using any measure in the considered or similar conditions of the other field.

The models obtained for such purpose allow forecasting of the indicators of the efficiency of any type of GTM in new geological and physical conditions. In this regard the systems and design models were used for the purpose of forecasting of indicators for the conditions different from those where GTM were used. The results of the calculations were used when making decisions for choosing of the best GTM for considered conditions. This was performed using efficiency indicators of GTM taken as criteria of GTM adopted as criteria in such a way that the decision would satisfy all the adopted criteria.

Thus, development and upgrading of methods of the analysis, forecasting of the indicators and decision-making which implementation allowed to increase the efficiency of conducted geological and technical measures have been watched recently. As a result of conducted works the researchers solved the task of creating of comprehensive methodology and its mathematical, software and information application for assessment of the efficiency and optimal planning of geological and technical measures on the oil fields; the structure of the automated system of decision support and algorithm of its functioning have been developed; by transforming the indicators characterizing the formation into the relevant factors, the equations (linear and multiplicative) were made expressing the dependence of the efficiency indicators of GTM from the formed factors; by variants calculation and analysis of comparative efficiency of any GTM in different conditions the directions were shown and the results of making decisions for choosing of the best GTM were obtained.

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ҚАЗІРГІ ЗАМАНҒЫ ЖАҒДАЙЫ ЖӘНЕ ЖЕТІСТІКТЕРІ: ГЕОЛОГО-ТЕХНИКАЛЫҚ ШАРАЛАРДЫ ТАҢДАУ БОЙЫНША ШЕШІМНІҢ ҚАБЫЛДАНУЫ

Аннотация. Мұнай кенорындарын игеру кезінде ГТШ және әртүрлі жаңа технологияларды қолдану есебінен тиімділікті арттыруға көп көңіл бөлінеді. Нақты жағдайда қажетті технолого-экономикалық тиімділікті қамтамасыз етуде, ең жақсы әдісті дұрыс таңдауда, олардың технологияларын дамуы және МАӘ, сонымен қатар ГТШ кеңінен қолдануда көптеген сұрақтар қойылады. Мұндай сұрақтарға зерттеушілердің үлкен қызығушылықтарымен қатар, қазіргі таңда нақты жағдайда әртүрлі ГТШ түрлерін салыстырмалы бағалау кезінде маңызды қиыншылықтар туындайды. Қазіргі таңда кешенді геолого-физикалық және технологиялық ақпараттар негізінде ГТШ тиімділіктерін арттыру мәселелері актуалды және сәйкесінше шешім қабылдануға ие болады. Кенорынды игерудің тиімділігін арттыру мақсатында алдымен бар мүмкіндікті дұрыс реттеу сәйкесінше дұрыс бағыттауға мүмкіндігі бар бағдарламаларды және қазіргі таңдағы әдістерді қолданумен әртүрлі ГТШ қолдану жағдайы мұқият талдау жасауға мүмкіндік береді. Көп жылдар бойы зерттеулер әртүрлі ғылыми және өндірістік ұйымдарда, кенорында игерудің тиімділігін арттыруға бағытталып жүргізілді. Әртүрлі кенорында ГТШ енгізу және таңдау тәжірибелерін талдау қызығушылықты тудырады. Мақалада ГТШ таңдаудың қазіргі таңдағы жағдайын талдау және жинақтар келтіріледі. Әртүрлі кенорындарда ГТШ тиімділіктерін бағалау және қолдану мысалдары көрсетілген. Соңғы жылдары өткізілген геолого-техникалық шаралардың тиімділігін арттыру реализациясы, шешімдер қабылдану және көрсеткіштер болжамдары, талдау әдістерін жетілдіру және дамуы байқалады. Мұнай кенорындарында геолого-техникалық шараларын тиімді жоспарлау және тиімділікті бағалау үшін кешенді әдістерді құру және олардың математикалық, бағдарламалық және ақпараттық қамтамасыз ету тапсырмалары зерттеушілердің жүргізілген жұмыстары нәтижелерінде шешілген; шешімді қабылдауды қолдаудың және оның алгоритмінің жұмыс істеуінің автоматтандырылған жүйелер құрылымы игерілген; қалыптасқан факторлардан ГТШ тиімділігінің көрсеткіштерін көрсететін, сәйкесінше факторларға қабатты сипаттайтын, қайта құру белгілері жолымен (сызықты және мультипликативтік) теңдеулер құрастырылды; ең жақсы таңдау бойынша шешім қабылдау нәтижелері алынды және нұсқалық есептеулер жолымен және салыстырмалы тиімділікті талдау әртүрлі жағдайдағы сол немесе өзге ГТШ жолдары көрсетілген.

Түйін сөздер: геолого-техникалық шаралар (ГТШ), кенорынды игеру, шешім қабылдануы, мұнайды өндіру, мұнайбергіштік.

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ПРИНЯТИЕ РЕШЕНИЙ ПО ВЫБОРУ ГЕОЛОГО-ТЕХНИЧЕСКИХ МЕРОПРИЯТИЙ: СОВРЕМЕННОЕ СОСТОЯНИЕ И ПЕРСПЕКТИВЫ

Аннотация. Как известно, повышению эффективности за счет применения различных новых технологий и ГТМ уделяется большое внимание при разработке нефтяных месторождений. Широкое внедрение ГТМ, а также е МУН и развитие их технологий ставит вопросы адекватного выбора наилучших методов, обеспечивающих должную технолого-экономическую эффективность в конкретных условиях. Несмотря на большой интерес исследователей к данному вопросу, все же в настоящее время серьезные затруднения возникают при сравнительной оценке различных видов ГТМ применительно к конкретным условиям. Проблема повышения эффективности ГТМ на основе комплексной геолого-физической и технологической информации в настоящее время является актуальной и заслуживает соответствующего внимания. Тщательный анализ условий применения различных ГТМ с использованием современных методов и соответствующего программного обеспечения позволит в свою очередь правильно сориентировать имеющиеся возможности с целью повышения эффективности разработки месторождения. На протяжении многих лет исследования, направленные на повышение эффективности разработки месторождений, проводились в различных научных и производственных организациях. Представляет интерес анализ опыта выбора и внедрения ГТМ на различных месторождениях. В статье приводится обзор и анализ современного состояния проблемы выбора ГТМ. Показаны примеры применения и оценки эффективности ГТМ на различных месторождениях. В последние годы наблюдается развитие и совершенствование методов анализа, прогнозирования показателей и принятия решений, реализация которых позволила повысить эффективность проводимых геолого-технических мероприятий. В результате проведенных работ исследователями решена задача создания комплексной методики и ее математического, программного и информационного обеспечения для оценки эффективности и оптимального планирования геолого-технических мероприятий на нефтяных месторождениях; разработана структура автоматизированной системы поддержки принятия решения и алгоритм ее функционирования; путем преобразования признаков, характеризующих пласт, в соответствующие факторы, построены уравнения (линейное и мультипликативное), выражающие зависимость показателей эффективности ГТМ от сформированных факторов; путем вариантных расчетов и анализа сравнительной эффективности того или иного ГТМ в различных условиях показаны пути и получены результаты принятия решений по выбору наилучшего ГТМ.

Ключевые слова: геолого-техническое мероприятие (ГТМ), разработка месторождений, принятие решений, добыча нефти, нефтеотдача.

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