ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ
КАЗАХСТАН
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N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
Satbayev University

SERIES

OF GEOLOGY AND TECHNICAL SCIENCES

5 (455)

SEPTEMBER – OCTOBER 2022

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).

The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.

Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*

Periodicity: 6 times a year.

Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19

http://www.geolog-technical.kz/index.php/en/

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS *of the National Academy of Sciences of the Republic of Kazakhstan*
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
https://doi.org/10.32014/2518-170X.220

UDC *553.98*: 550.34.012

I. Isa[1], L.T. Kurmangaziyeva[2], M.K. Urazgaliyeva[3*], A.A. Kubasheva[3], A.G. Kassanova[4]

[1] L.N. Gumilyov Eurasian National University, Astana, Kazakhstan;
[2] Kh.Dosmukhamedov Atyrau University, Atyrau, Kazakhstan;
[3] S.Utebayev Atyrau Oil and Gas University, Atyrau, Kazakhstan;
[4] Atyrau Engineering Humanitarian Institute, Atyrau, Kazakhstan.
E-mail: *mira_090578@mail.ru*

DEVELOPMENT OF A MATHEMATICAL MODEL OF THE OIL RESERVOIR KENKIYAK FIELD ON THE BASIS OF ITS GEOLOGICAL MODELS

Abstract. In the processes of development, production and transportation of high-viscosity oils, such as the Kenkiyak fields, there are certain problems associated with the composition and solidification of raw materials at a certain temperature. In this regard, in order to increase the efficiency of the above processes, it is necessary to select appropriate technologies that provide optimal temperature conditions. At present, one of the most effective methods for solving these issues is the use of mathematical modeling to search for, determine the optimal parameters of oil development and production processes based on modern computer and information technology tools. Therefore, in order to effectively solve the problems of development and production of high-viscosity oils, the issues of constructing mathematical models of oil deposits, taking into account their geological and petrophysical characteristics, are an urgent task of oil science and practice.

To study the geological models of the studied reservoirs of the Kenkiyak oil field and to develop its mathematical model, methods of system analysis are used. These methods make it possible to apply a set of interrelated methods of geological exploration and determination of oil reserves, as well as methods of forecasting and mathematical statistics in the development of models of the studied horizons of the Kenkiyak field.

Based on the results of the study of 4 geological models of the selected main plateaus of the Kenkiyak field, a mathematical model was developed for it, which allows taking into account the dynamics of the movement of the oil mixture during the development and production of high-viscosity oil. The proposed mathematical model is based on the heat-producing model and includes mass and energy conservation equations, as well as mass and oil saturation limitation equations.

The results of the study can be used to determine: the permeability of oil reservoirs; oil reserves; optimal temperature conditions and to optimize other parameters of oil production processes.

Key words: Geological model, mathematical model, oil reservoir, heat-producing model, oil saturation, relative permeability.

И. Иса[1], Л.Т. Курмангазиева[2], М.К. Уразгалиева[3*], A.A. Kubasheva[3], А.Г. Касанова[4]

[1] Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан;
[2] Х. Досмухамедов атындағы Атырау университеті, Атырау, Қазақстан;
[3]С. Өтебаев атындағы Атырау мұнай және газ университеті, Атырау, Казақстан;
[4]Атырау инженерлік гуманитарлық институты, Атырау, Казақстан.
E-mail: *mira_090578@mail.ru*

КЕНҚИЯҚ КЕНОРНЫ МҰНАЙ ҚОЙНАУЫНЫҢ МАТЕМАТИКАЛЫҚ МОДЕЛІН ОНЫҢ ГЕОЛОГИЯЛЫҚ МОДЕЛДЕРІ НЕГІЗІНДЕ ҚҰРУ

Аннотация. Кенқияқ кен орындары сияқты тұтқырлығы жоғары мұнайларды игеру, өндіру және тасымалдау процестерінде белгілі бір температурада шикізаттың құрамы мен қатаюына байланысты мәселелер туындайды. Сондықтан жоғарыда аталған процестердің тиімділігін арттыру үшін оңтайлы температуралық жағдайларды қамтамасыз ететін сәйкес технологияларды таңдау қажет болады. Қазіргі уақытта осы мәселелерді шешудің тиімді әдістерінің бірі қазіргі заманғы компьютерлік және ақпараттық технология құралдары негізінде мұнайды игеру мен өндірудің оңтайлы параметрлерін іздеу, анықтау үшін математикалық модельдеуді қолдану болып табылады. Сондықтан тұтқырлығы жоғары мұнайларды игеру және өндіру мәселелерін тиімді шешу үшін олардың геологиялық және петрофизикалық ерекшеліктерін ескере отырып, мұнай кен орындарының математикалық модельдерін құру мәселелері мұнай ғылымы мен практикасының *өзекті міндеті* болып табылады.

Кеңқияқ мұнай кен орнының зерттелген қабаттарының геологиялық модельдерін зерттеу және оның математикалық моделін жасау үшін жүйелік талдау тәсілдері қолданылады. Бұл тәсілдер Кеңқияқ кен орнының зерттелетін горизонттарының модельдерін жасақтауда геологиялық барлау мен мұнай қорын анықтаудың, сондай-ақ болжау және математикалық статистика әдістерінің өзара байланысты әдістерінің кешенін қолдануға мүмкіндік береді.

Кеңқияқ кен орнының таңдалған негізгі коллекторларының 4 геологиялық моделін зерттеу нәтижелері бойынша ол үшін тұтқырлығы жоғары мұнай қоспасын игеру және өндіру кезінде мұнай қоспасының қозғалыс динамикасын есепке алуға мүмкіндік беретін математикалық модель ұсынылды. Ұсынылған математикалық модель жылу шығаратын модельге негізделген және масса мен энергияны сақтау теңдеулерін, сонымен қатар масса мен мұнайға қанығуды шектеу теңдеулерін қамтиды.

Зерттеу нәтижелерін практикада келесілерді анықтауда қолданылуы мүмкін: мұнай қабаттарының өткізгіштігін; мұнай қорын; оптималды температуралық режидерді және мұнай өндіру процестерінің басқа параметрлерін оптимизациялауда.

Түйін сөздер: геологиялық модель, математикалық модель, мұнай қабаты, жылу шығаратын модель, мұнайға қанықтық, салыстырмалы өткізгіштік.

И. Иса[1], Л.Т. Курмангазиева[2], М.К. Уразгалиева[3*], А.А. Кубашева[3], А.Г. Касанова[4]

[1] Евразийский национальный университет имени Л.Н. Гумилев, Астана, Казахстан;
[2] Атырауский университет имени Х. Досмухамедова, Атырау, Казахстан;
[3]Атырауский университет нефти и газа им. С. Утебаева, Атырау, Казахстан;
[4]Атырауский инженерно-гуманитарный институт, Атырау, Казахстан.
E-mail: *mira_090578@mail.ru*

РАЗРАБОТКА МАТЕМАТИЧЕСКОЙ МОДЕЛИ НЕФТЯНОЙ ЗАЛЕЖИ МЕСТОРОЖДЕНИЯ КЕНКИЯК НА ОСНОВЕ ЕГО ГЕОЛОГИЧЕСКИХ МОДЕЛЕЙ

Аннотация. В процессах разработки, добычи и транспортировки высоковязких нефтей, таких как месторождений Кенкияк, возникают определенные проблемы, связанные с составом и застыванием сырья при

определенной температуре. В этой связи для повышения эффективности перечисленных процессов необходимо выбрать соответствующие технологии, обеспечивающие оптимальные температурные режимы. В настоящее время одним из наиболее эффективных методов решения этих вопросов является применение метода математического моделирования для поиска, определения оптимальных параметроыв пролцессов разработки и добычи нефти на базе современных средств компьютерных, информационных технологий. Поэтому для эффективного решения проблем разработки и добычи высоковязких нефтей вопросы построения математических моделей нефтяных залежей с учетом их геологических, петрофизических характеристик являются *актуальной задачей* нефтяной науки и практики.

Для исследования геологических моделей исследуемых пластов нефтяного месторождения Кенкияк и для разработки его математической модели используются методы системного анализа. Эти методы позволяют применить комплекс взаимосвязанных методов геологической разведки и определения запаса нефти, а также методов прогнозирования и математической статистики в процессах разработки моделей исследуемых горизонтов месторождения Кенкияк.

В работе на основе результатов исследования 4-х геологических моделей, выбранных основных платов месторождения Кенкияк, разработана для него математическая модель, позволяющая учитывать динамику движения нефтяной смеси при разработке и добыче высоковязкой нефти. Предложенная математическая модель основана на теплодобывающей модели и включает уравнения сохранения массы и энергии, а также уравнения ограничения массы и нефтенасыщенности.

Результаты исследования могут быть использованы для определения: проницаемости нефтяных пластов; запасов нефти; оптимального температурного режима и для оптимизации других параметров процессов добычи нефти.

Ключевые слова. геологическая модель, математическая модель, нефтяная залежь, теплодобывающая модель, нефтенасыщенность, относительная проницаемость.

Introduction. The challenges of developing mathematical models of oil reservoirs with high-viscosity oil allowing to forecast and determine the optimal scheme and technology of oil fields development is one of the current objectives of oil science and practice (Лысенко и др, 2018: 5-247-02321-8, Gladkikh et all 2018: 329 (7). 77–85). Various models, concepts and tools of mathematical modeling are applied for development of mathematical models and modeling of oil field development processes and forecasting of processes occurring in productive reservoir systems. Mathematical modeling of oil deposits, reservoirs allows to perform a wide range of activities starting from research of flow hydrodynamics to solving of important problems of oil field development such as: delineation of oil reservoir; evaluation of oil reserves; geological and economic evaluation of oil fields; decision-making as to the choice of optimal oil field development (Kerimov et all, 2018: 52–56., Orazbayev et all 2021: 54(6), 1235–1241).

As it is known mathematical models of the unsteady oil flow in the reservoir environment are described by differential equations in partial derivatives. Mathematical models used for oil reservoir simulation include: reservoir system; differential equations in partial derivatives and auxiliary equations; numerical methods for solving the equation; solution algorithms implemented in the form of programs that enable computer aided simulation (Ospanov et all., 2016: 978-1-4673-8414-8. 103-109).

Many drawbacks of old methods of oil reservoir simulation have been eliminated in the improved versions of these methods. But there are also known, rather simple and effective old methods, which are currently practically, applied, for example, methods of oil reservoir simulation, which use the equations of material balance. Back in 70s of the last century the mass conservation equation for productive reservoir has been obtained, which equation is used in oil reservoir modeling (Kazhdan et all., 2018: 5-92335-257-3). This mass conservation equation describes the oil reservoir as a homogeneous one with constant rock and fluid properties and takes into account all the masses of fluid flowing in and out over a given period of time.

Oil reservoir models based on the mass conservation equation for a productive oil reservoir assume that parameters within the rock-fluid system are constant in all directions. Besides, saturations and pressures are assumed to be uniformly distributed throughout the oil reservoir, and any changes in pressures are transmitted instantaneously to all points within the reservoir. Taking into account the accepted assumptions the mathematical model of oil reservoirs, which is based on the mass conservation equation for productive oil reservoir, can be written in the following form:

$$N_p\left[B_t + B_g\left(R_p - R_{si}\right)\right] + W_p =$$
$$= N\left[\left(B_t - B_{ti}\right) + \frac{B_{ti}}{1 - S_{Wi}}\left(C_f + S_W C_W\right)\Delta p + \frac{mB_{ti}}{B_{gi}}\left(B_g - B_{gi}\right)\right] + W_e + W_i + G_i B_g \cdot \qquad (1)$$

In the given model (1) the following designations have been used, on the left side of the equation: N_p – quantity of produced oil; B_t and B_g – ratios of reservoir volume of oil together with dissolved gas and reservoir volume of gas, respectively; R_p and R_{si} – total gas factor and initial gas solubility, respectively; W_p – total water production. On the left side of the equation: N – the amount of oil initially confined in the reservoir; B_{ti} and B_{gi} – the reservoir volume factors for oil and gas at initial reservoir pressure respectively; S_{wi} and S_w – the initial and current water saturation of the porous medium respectively; C_f – rock compressibility; C_w – water compressibility; Δp – reservoir pressure depression; m - ratio of initial gas cap volume to initial reservoir oil volume; W_e and W_i – respectively - total edge water entering the productive reservoir and amount of water injected; G_i – total gas injected. The remaining figures of the right part of the equation are described in its left part.

Algebraic transformations of the above model, which are based on the mass conservation equation for the productive oil reservoir (1), allow to determine the following important parameters of an oil field: oil reserves; the amount of water flowing into the reservoir; the size of the gas cap and gas reserves as well as oil production. But this model is statistical by its nature and does not allow taking into account changes in fluid and rock properties in the reservoir, i.e., dynamic effects of fluid movement within the system are not considered. Other models such as the model based on the deployment of resistive-capacitive electrical grids (Orazbayev et all 2022: 15(4), 1573. 1-26) have been proposed to take into account the dynamics of oil mixture movement, i.e. to eliminate the drawbacks of the statistical model. In the context of this paper the authors will propose a model based on a system of integral-differential equations, which system includes basic equations based on the Darcy equation, mass conservation equation, energy conservation equation, mass limitation equation and oil saturation limitation equation.

The purpose of the scientific paper is conducting of a research of geological models of the supra-salt Kenkiyak field and developing a mathematical model on the basis thereof, which takes into account the dynamics of the oil mixture movement and simulation of the oil reservoir of the field under investigation.

To achieve the formulated goal the following research tasks are solved:

– study and description of geological models of Kenkiyak field with consideration of this field development, the geological characteristics and the operation rate;

– development of a mathematical model of Kenkiyak field horizons with high-viscosity oil, allowing to take into account the dynamics of the oil mixture movement;

– determination of the relative permeability at the end point of the studied field based on the models.

Research materials and methods. Materials for the research are geological and other data of Kenkiyak oil field, which is located in the southern part of Aktobe region, not far from Zhanazhol field. The field refers to the category of high-viscosity oil fields by supra-salt reservoirs. Development of Kenkiyak field since 1971 has been carried out with application of steam injection. On the basis of analysis of experimental-industrial development, long-term study of geological structure and research carried out in the field of steam-heat treatment technology the updated technological scheme of the field development with application of heat-transfer agents has been developed and is being implemented (Aidnalieva et all 2021:157., Gladkikh et all., 2017: 27(8). 90–93). Since April 1999 steam-heat treatment has been suspended and the main part of the field has been developed in the natural mode, except for the experimental section of block IV, where experimental works related to steam injection for development of supra-salt Middle Jurassic reservoirs of heavy oil in the Kenkiyak field have been started.

According to the data of laboratory research it was determined that viscosity of formation oil of the reservoirs under development is in the range of [55 - 1200 and more] MPa*s, and average values for oil zones vary from 137 to 203 MPa*s and for water-oil zones they vary from 277 to 532 MPa*s. Analysis of the actual data shows that the highest values of viscosity are characteristic for oils of water-oil zones. Total area of water-oil zones of reservoirs equals to 47% of their total area. The average value of operation ratio of operating well stock is 0.88, while the average value of injecting well stock is 0.91. The ratio of exploitation of the operating well stock has reached 0.68 (Aidnalieva et all., 2021: 157). The main volume of oil production is referred to the Middle Jurassic (Ju-II and Ju-III) horizons, from which the production share exceeds 90% of the total volume of oil produced.

It has been found out that Kenkiyak field is complicated by its structure: significant tectonic faults, a high degree of *permeable rock heterogeneity* by thickness and spreading, poor persistence of oil-saturated strata, wedging out thereof. This makes it difficult in certain regions to apply the technology of steam-heat process with continuous injection of coolant. In addition, the efficiency of steam-heat treatment of the reservoir is affected by sanding associated with lithological features of permeable rocks. The productive horizons of Middle Jurassic deposits are represented by poorly cemented clayey cement, sandy-aleuritic rocks, which are interlaced with clays. When considering coverage of each stratum by a grid of wells it was found out that only Ju-II (stratum "G") is the horizon most fully covered by a grid of wells, the other objects have significant oil-saturated areas which are not covered by a grid of wells.

This work develops a mathematical model of Kenkiyak oil field on the basis of systematized and processed geological information, taking into account the hydrodynamics of oil reservoirs as well as methods of building mathematical models.

System analysis methods (Orazbayev et all 2019: 13(4). 653-664), geological exploration methods, methods for determination of oil reserves (Galkin et all., 2021: 978-5-398-02611-5), forecasting and mathematical statistics methods (Minko et all.,2017: 978-5-4486-0035-7., Orazbayev et all 2020:10.15587/1729-4061.2020.219221), as well as methods of developing mathematical models of systems including systems of oil reservoirs (Gladkikh et all., 2018: 77–8., Orazbayev et all 2020: 54(6), 1235–1241., Orazbayev et all.,2022: 15(4), 1573. 1-26., Zheltov et all .,2019., Orazbayev et all., 2021: 8317. 1-22) are used to study geological models, to develop a mathematical model and to simulate the oil reservoir of Kenkiyak field.

Results.

1). *Study and description of geological models of Kenkiyak field, with consideration of the requirements of regulation of its development, geological characteristics and exploitation rate.* Based on the results of research and with consideration of the requirements of regulation of the development of Kenkiyak field, geological characteristics, exploitation rate 4 models of the typical geological elements were studied (Gladkikh et all., 2017: , 27(8). 90–93).

Model I: a model of a group of wells of Middle Jurassic section on the northern wing. А+Б+В horizons on the northern wing are exploited by natural energy using 25×25 grid system, 14 reservoirs are distinguished in the section, the average thickness of the oil reservoir is 15 m.

Model II: 4 models of a group of wells of Middle Jurassic section of the pilot-industrial section on the southern wing. А+Б+В horizons and Ju-I in the south wing were exploited by natural energy using 35×45 grid system, 11 reservoirs are distinguished in the section, the average thickness of oil reservoir for А+Б+В horizons is 27 m, for Ju-I horizon - 13 m.

Model III: the model of a group of wells of the western part of the pilot-industrial area on the southern wing. Horizon U-II(D) is exploited by steam using 53×19 grid system. Eight reservoirs are distinguished in the section, the average thickness for G oil reservoir is 17.1 m, for А+Б+В horizons - 5.65 m.

Model IV: horizontal well model for undeveloped Ju-I and Ju-II horizons with low degree of depletion and good connectivity, which are exploited using 23×11 grid system (see table 1). Three reservoirs are distinguished in the section, the average thickness of Ju-I horizon is 12 m, А+Б+В horizons - 15 m.

General position of modeling elements of all models is given in table 1.

Petrophysical properties of oil of supra-salt deposits of Kenkiyak field are shown in table 2.

On the basis of the given geological models, taking into account the petrophysical properties of oil of supra-salt deposits of Kenkiyak field it is possible to develop mathematical models of its horizons, which take into account the dynamics of oil mixture movement.

2) *Development of a mathematical model of Kenkiyak field horizons with high-viscosity oil, which allows taking into account the dynamics of oil mixture movement.* With consideration of the characteristics of the oil reservoir of the field a model of homogeneous porous medium should be applied. In the process of model development and simulation first the coordination by elements with development history, then - the forecast of reservoir development indicators is carried out. In addition, it is necessary to conduct analysis of sensitivity to various factors in order to obtain data for mechanical analysis of reservoir development, for selection of rational parameters, creation of typical models of a group of wells and profiles, and for optimization of parameters of the field development project (Orazbayev et all., 2019: 330(7).182-194).

A mathematical model of well shall be developed with the purpose of conducting computer aided modeling with consideration of the the reservoir tectonics, oil and water location, porosity, permeability and oil saturation of the oil reservoir, petrophysical properties of the permeable rock, characteristics of oil displacement curves and nature of vertical fluid flow along the well shaft. The regularity of fluid flow can be formulated by equations of motion, position and constancy of masses.

Table 1 – Main position of the simulated elements

Model	Number of wells		Number of grids, pcs.				Pace length, m		Simulated reservoir	Model	Appa-ratus
	Oil	Injected steam	X	Y	Z	Total	X	Y			
I	9	1	25	25	14	8750	10	10	Ju-1-Ju-III	Oil black model and heat-producing model	VIP, THERM
II	26	4	35	45	11	17325	8.8	9.13	Ju-I-Ju-III	Oil black model and heat-producing model	VIP, THERM

III	15	3	53	19	8	7208	10	10	Ju-II	heat-producing model	THERM
IV	3	2	23	11	3	759	10	10	Ju-I	heat-producing model	THERM

Table 2 – Petrophysical properties of oil of supra-salt deposits of Kenkiyak field

Parameters	Unit of measure	Value
Oil thermal stretch ratio	$1/^0C$	0,0008
Oil compressibility ratio	1/MPa	0,0000082
Oil density and oil weight by moles	kg/m^3, kg/mol	920, 260
Specific thermal capacity of oil	$kJ/kg.^0C$	2,1562
Combined oil compression ratio	1/MPa	0,0065
Rock heat transfer ratio	$kJ/d.m2.^0C$	110
Thermal capacity of rock volume	$kJ/m^3.^0C$	2572
Caprock heat transfer ratio	$kJ/d.m.^0C$	110
Caprock thermal capacity	$kJ/m^3.^0C$	2572
Oil viscosity in reservoir (Ju-II)	mPa·c	260
Depth and pressure	m, kPa	250, 2650
Oil reservoir temperature	^0C	19

After determining the location of wells and the mode of well operation it is possible to calculate the dynamics of the duration of development of injection and production wells and the reservoir using the computer aided implementation of reservoir models. Monitoring of well operation dynamics, optimization of development project and improvement of scientific solution on the basis of computer aided simulation of the reservoir is carried out on the basis of the studies performed by means of reservoir models.

In Kenkiyak field the oils of U-II(A+Б+B) and U-II(D) horizons is highly viscous. Due to the fact that since the U-II(A+Б+B) horizons have been put into production by natural energy in many areas the matching is carried out based on the "black oil" model, forecasting of operation by steam injection by applying a thermal model. For Ju-II(G) horizons in the heat-producing section of the southern wing the modeling is carried out on the basis of the heat-producing model.

The development processes of different high-viscosity oil reservoirs can be strictly described by the heat-producing model, which consists of basic equations based on the Darcy equation, mass conservation equation, energy conservation equation, mass limitation equation and oil saturation limitation equation:

– The mass conservation equation

$$\sum_{j=1}^{N_p}\iiint_V \frac{\partial}{\partial T}(\varphi\rho_j S_j\chi_{ij})dv+\sum_{j=1}^{3}\oint\!\!\oint_S(\rho_j S_j\chi_{ij}\upsilon_j)ds+q_i=0,\quad i=1,2,...,N_c, \tag{2}$$

where φ – is rock porosity; p_j – fluid density; S_j – fluid saturation; X_{ij} – number of moles of fluid composition; v_j – fluid flow rate; N_p – amount of fluid.

– Energy conservation law

$$\sum_{j=1}^{N_p}\iiint_V\left[\frac{\partial}{\partial T}(\varphi\rho_j S_j u_j)+(1-\varphi)\rho_{rock}C_p(T-T_i)\right]+\oint\!\!\oint_S(q_h+q_c)ds+Q_c+Q_h=0,\quad i=1,2,\cdots,N_c, \tag{3}$$

where u_j – internal energy of fluid *j*; p_{rock} – rock density; C_p – rock specific thermal capacity; *T* - rock temperature; T_i – temperature of *i* composition; q_h – enthalpy flow rate; q_c – heat flow rate; Q_c – heat source; Q_h – enthalpy source.

– Mole restriction equations

$$\sum_{i=1}^{N_c}\chi_{ij}=1.0 \tag{4}$$

– Oil saturation limitation equations.

$$\sum_{i=1}^{N_p}S_j=1.0 \tag{5}$$

The equations of the three-dimensional and three-phase black oil model to describe the oil reservoir are as follows:

$$\nabla\bullet\left[\frac{\lambda_o}{B_o}(\nabla p_o-\rho_o g\nabla D)\right]=\frac{\partial}{\partial t}\left(\frac{\varphi S_o}{B_o}\right), \tag{6}$$

$$\nabla\bullet\left[\frac{\lambda_w}{B_w}(\nabla p_w-\rho_w g\nabla D)\right]=\frac{\partial}{\partial t}\left(\frac{\varphi S_w}{B_w}\right), \tag{7}$$

$$\nabla\bullet\left[\frac{\lambda_g}{B_g}(\nabla p_g-\rho_g g\nabla D)+\frac{\lambda_o R_s}{B_o}(\nabla p_o-\rho_o g\nabla D)\right]=\frac{\partial}{\partial t}\left[\varphi\left(\frac{S_o R_s}{B_o}+\frac{S_g}{B_g}\right)\right]. \tag{8}$$

3) *Determination of relative permeability at the end point of the field under research based on the models.* As a result of the analysis of sealed core samples from well No.6009 of Kenkiyak field the oil-water relative permeability (K_{rw})

and oil-gas relative permeability (K_{rgw}) were determined by relative permeability at 20°C (normal) and 200°C (high) temperature using the following appropriate models (Gladkikh et all.,2017: 27(8). 90–93):

$$K_{rw} = K_{rwro(T)}\left(\frac{S_w - S_{wi(T)}}{1 - S_{wi} - S_{orw(T)}}\right) n_{wp}, \qquad (9)$$

$$K_{rgw} = K_{roce(T)}\left(\frac{1 - S_{orw(T)} - S_w}{1 - S_{orw(T)} - S_{wc(T)}}\right) n_{ow}, \qquad (10)$$

with indices in the models means water saturation of the porous medium for different situations and temperature values; $K_{rwro(T)}$ and $K_{roce(T)}$– are ratios of oil-water and oil-gas permeability; n_{wp} and n_{ow} are the amount of oil-water and oil-gas mixture.

On the basis of the data obtained using the above equations for the researched horizons of Kenkiyak field an oil-water relative permeability curve was drawn up, saturation of bound water, saturation of residual oil, values of the endpoints of water and oil phases were determined (Table 3).

Table 3 – Parameters of relative permeability of different reservoirs at temperatures of 20°C and 200°C

Horizons	Temperature, °C	$S_{wi(T)}$	$S_{orw(T)}$	$K_{rw}(S_{orw})$	$K_{rgw}(S_{wi})$
Ju-I	20	0,40	0,28	0,068	1,0
	200	0,571	0,169	0,43	1,0
А+Б+В	20	0,284	0,29	0,0762	1,0
	200	0,39	0,262	0,32	1,0
Г	20	0,32	0,23	0,1163	1,0
	200	0,42	0,2	0,33	1,0

Identification of mathematical models parameters. In order to clarify the reliability of the geological model and accuracy of the adopted parameters and to ensure the reliability of simulation results the identification of parameters of mathematical models is carried out as per development history data with the geological model using numerical simulation packages of the reservoir. As a result of simulation of the development history from 2010 to December 2020 it was found out based on the proposed mathematical model system that the adopted geological models and parameters thereof are sufficiently adequate, i.e. the parameters of the models are identified correctly.

Discussion. As a result of the analysis of the residual oil saturation field obtained on the basis of numerical simulation and actual pressure the following has been found out:

- А+Б+В horizons of the Middle Jurassic section on the experimental-industrial plot have been exploited for 30 years, in a considerable part of the plot, the area of which is 90%, the residual oil saturation is more than 60%, it decreased by 10% in comparison with the initial oil saturation. From this we can see the degree of the oil reservoir depletion is low. А+Б+В horizons are operated with application of steam injection, residual oil saturation of the area is 30%, which means that steam injection can effectively increase the degree of oil reservoir depletion;

- G horizon of the Middle Jurassic section in the western part of the southern wing has been operated for a long time by steam in series of wells; over the recent years the level of depletion reached about 35%, residual oil saturation is about 45%, it means that steam injection is an effective method to enhance oil recovery in this reservoir;
- study of the pressure field shows that during operation by means of natural energy the actual reservoir pressure is about 1.8 MPa, i.e. the reduction is 1 MPa of the initial pressure.

The performed identification of the parameters of the proposed system of mathematical model (2)-(10) has made it possible to evaluate the reliability of the proposed types of geological models and accuracy of the adopted parameters, which ensure adequacy of the models and the reliability of the simulation results.

Since when putting of horizons Ju-II(А+Б+В) of Kenkiyak field into operation mainly natural energy was applied, there was matching carried out with application of "black oil" model, forecasting of operation by means of steam injection with help of heat-producing model. Development processes of different high-viscosity oil reservoirs are described adequately enough by heat-producing model, which consists of basic equations based on Darcy equation, mass conservation equation, energy conservation equation, mass limitation equation and oil saturation limitation equation. The developed system of the mathematical model (2)-(10) on the basis of these equations adequately describes the studied sections of Kenkiyak field oil reservoir.

To the advantages of the proposed mathematical model used to simulate Kenkiyak field with high-viscosity oil on the basis of its geological models we can refer its ability to consider the dynamics of oil mixture movement and its sufficient adequacy.

To the disadvantages or limitations of the proposed mathematical model for modeling of oil fields we can refer the need for parametric identification, the cost of collecting and processing the necessary data and computer aided implementation, which are considered as separate tasks.

Conclusion. As a result of the research related to development of a mathematical model of Kenkiyak oil reservoir on the basis of its geological models the following basic results were obtained:

1). The geological models of Ju-I, Ju-II and Ju-III horizons of Kenkiyak field reservoir were studied and described with consideration of the requirements of regulation of its development, geological characteristics and exploitation rate.

2). A mathematical model was developed for the studied horizons of Kenkiyak field with high-viscosity oil, which allows taking into account the dynamics of the oil mixture movement. The developed mathematical model is based on the heat-producing model, which includes the basic equations based on the Darcy equation: mass conservation; energy conservation; mass limitation and limitation of oil saturation:

3). Using the proposed models the relative permeability at the end point of the studied horizons of Kenkiyak field was determined.

Information about the authors:

Isamar Isa – Doctoral student of the Department of System Analysis and Control of the Gumilyov Eurasian National University, Republic of Kazakhstan, Nur-Sultan city, st. Pushkin, 11, tel: +77761822656, e-mail: i*ssamar@mail.ru* , ORCID *https://orcid.org/0000-0003-0434-8314;*

Lyailya Taskalievna Kurmangaziyeva – Candidate of technical sciences, Professor of the Department of Software Engineering Kh.Dosmukhamedov Atyrau University, Republic of Kazakhstan, Atyrau city, Student Ave 212, tel. +77014501714, e-mail: kurmangazieval@mail.ru, ORCID: *https://orcid.org/0000-0003-0640-7306;*

Meiramgul Kadyrbaevna Urazgaliyeva – Senior Lecturer of the S.Utebayev Atyrau Oil and Gas University, Atyrau sity, st. Baimukhanov, 45a, Republic of Kazakhstan, tel: +77781720278, e-mail: *mira_090578@mail.ru* , ORCID: *https://orcid.org/0000-0002-3622-2356;*

Almagul Amangeldiyevna Kubasheva – Senior Lecturer of the S.Utebayev Atyrau Oil and Gas University, Atyrau sity, st. Baimukhanov, 45a, Republic of Kazakhstan, tel: +77014229433, e-mail: alma.kuba@mail.ru, ORCID: *https://orcid.org/0000-0002-8928-2109;*

Aktoty Gariflayevna Kassanova – Lecturer of the Department of Automation and Informatics of the Atyrau Institute of Engineering and Humanities, Atyrau sity, st. Hudin 5, tel: +77016560918, e-mail: *akkasanova@mail.ru*, ORCID: *https://orcid.org/0000-0002-6604-2575*.

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Директор отдела издания научных журналов НАН РК *А. Ботанқызы*
Заместитель директор отдела издания научных журналов НАН РК *Р. Жәлиқызы*
Редакторы: *М.С. Ахметова, Д.С. Аленов*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 14.10.2022.
Формат 70x90 $^{1}/_{16}$. Бумага офсетная. Печать – ризограф.
20,0 п.л. Тираж 300. Заказ 5.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19