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
Satbayev University

N E W S

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

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

5 (449)

SEPTEMBER – OCTOBER 2021

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**
ISSN 2224-5278
Volume 5, Number 449 (2021), 146-152 ***https://doi.org/10.32014/2021.2518-170X.108***

UDC 622.276.6

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INVESTIGATION OF DRAINAGE MECHANISM OF OIL FROM PORES OF OIL SATURATED ROCKS USING NITROGEN AT THE LABORATORY CONDITION

Abstract. The article comprises the selection of high-efficiency and cost-effective draining agents for the extraction of waste oil, which is becoming a global problem. The effectiveness of pushing residual oil with nitrogen in small cavities of the oil layer and in the capillary matrix was discussed.

The theory of the mechanism of pushing residual oil in the porous cavities using nitrogen and it is important to test in the laboratory.

The nitrogen is denser than oil; moreover it is gas which it can penetrate intensively at high pressures into cavities and capillary matrices, displacing residual oil from them along the cavities to the production wells.

In this laboratory experiment was used core samples from the North Karamandybas field after drying and then they are saturated with oil in the vacuum with weighting each ones. Then, a specially designed device was used to push oil using the nitrogen. It was concluded that the experience of pushing oil in oil-saturated cores samples with nitrogen has yielded positive results, using this method will be increased the oil recovery of the formation in the field. After analyzing the positive results of the laboratory work, the impact on the bottomhole formation zone in production wells allows to increase oil recovery of the formation, and also contributes to the recovery of residual oil from fine-porous cavities of the oil formation.

Key words: Nitrogen, oil, drainage agent, laboratory experiment, porosity, permeability, pore media of layers, cores, oil saturation.

Introduction. The paper has a strong focus on the use and study of modern methods to increase oil recovery, because there are many difficulties in the world regarding to this case. At present, the amount of technology used to increase oil recovery is only enough to extract half or less of the total geological reserves of oil in the field. When selecting injecting agents to increase oil recovery or reservoir pressure, emphasis is placed on the cost of the oil produced and the cost of using it.

It is obvious that in the process of extracting oil from production wells, the oil flow enters the bottom of the well through the cavities of terrigenous rocks. However, due to the capillary pressure and surface tension in these cavities, a certain amount of oil usually remains in these cavities.

With the help of a mathematical model it is possible to describe the process of displacement of oil by nitrogen from the cavities and capillary matrix in the rocks [1,4,5]. At the same time it is necessary to take into account the balance of forces acting on the residual oil in the small cavities and the capillary matrix. These can be: the pressure force of nitrogen, the gravitational force of the residual oil, the Archimedean force, the force of friction of the residual oil on the rock surface, and so on.

By injecting high-pressure nitrogen into the bedrock of the formation, it is possible to extract residual oil from the internal cavities of the rocks by pushing it to the bottom of production wells.

The efficiency of nitrogen injection into the oil reservoir during field development provides a real opportunity to extract residual oil from the porous cavities of the reservoir. Since this process is a lighter gas than oil in terms of nitrogen density, it penetrates quickly into small porous cavities and capillary tubes at high pressure and pushes oil through those cavities [2,3]. Therefore, the process of pumping oil with nitrogen at high pressure through small porous cavities and capillary tubes in the formation is considered to be due to the different densities of oil and gas.

Materials and methods. The task of laboratory research is to determine experimentally the main mechanism of nitrogen pushing of residual oil in the porous cavities of reservoir rocks and the rational mode and technological parameters of nitrogen injection into multilayer oil formations. The developed laboratory equipment is aimed at determining the mechanism of pushing oil in the porous cavities of the model by compressing the oil-saturated core with nitrogen on all sides.

The laboratory work process. The laboratory research work by Professor Abdeli D.J. was conducted in the laboratory of the Department of Petroleum Engineering, Satpaev University. In order to carry out the experiment of pumping oil with nitrogen in the laboratory, it is the first prepared in accordance with the core unit. After cutting the core, oil in accordance with the nitrogen by the pushing device, the porous cavities of the core are pre-cleaned in a special unit with high-pressure air by means of a compressor.

In the laboratory, the mechanism of pushing oil in the core with nitrogen is carried out as follows. After the porous cavities of the core are cleaned with high-pressure air, the core is first measured with an analytical laboratory scale. Then, the porous cavities of the core are soaked in oil in a special container for 10-12 hours to saturate it with oil.

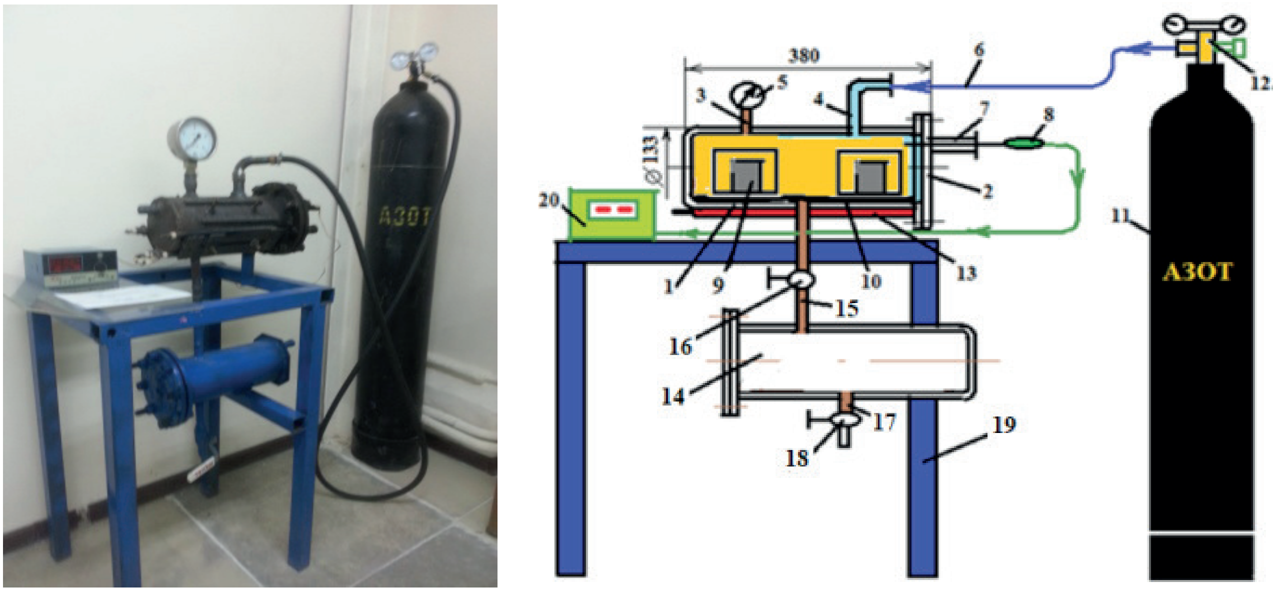

Figure 1. Schematic illustration (a) and general view (b) of the laboratory device.

By the order, to remove air bubbles in the porous cavities of the core and fill it with oil, it is placed in a special chamber and a vacuum is created with the help of a compressor. Thus, the core is completely saturated with oil [6,7,8].

The fig.1shows a schematic and general view of a laboratory device consisting of a horizontal cylindrical housing with a vertical lid (2). The cylindrical body has a diameter of 127 mm and a length of 400 mm. The cover of the case is fastened with bolts on both sides with a paronite float, which ensures the strength of the working chamber. Two tubes (3) and (4) are attached to the top of the cylindrical housing, which are equipped with a manometer (5) and a rubber hose (6). The cover shall be fitted with a cell (7) on the inside of the working chamber of the housing, through which the clogged side enters, and on the open side of the cell is placed a thermometer sensor (8). An oil-soaked core (9) is placed in a special beaker (10) inside the working chamber. At the bottom of the glass there is an empty space, which is covered with a mesh canopy. The working chamber is connected to the nitrogen cylinder (11) by means of a rubber hose through a manometer editor (12). The pressure of nitrogen inside the cylinder is 15 MPa. An electric heater (13) is mounted under the cylindrical housing, which is used to create a layer temperature inside the working chamber. Below the cylindrical housing is installed a storage chamber (14), which has a connecting tube (15) and a switch (16). The warehouse is equipped with a chamber output tube (17) and a switch (18). The cylindrical housing and storage chamber are mounted on a stand (19). The temperature sensor is connected to the thermometer (20).

During the laboratory work, the cavities are cleaned with air, the weight of the oil-soaked core is weighed on an analytical balance and placed in the working chamber of the device. The cover of the working chamber is tightly closed and fastened with bolts. The valve of the nitrogen cylinder is opened slowly until the required pressure inside the working chamber is reached. When the pressure required for nitrogen injection is reached, the nitrogen cylinder tap closes. The core is left in the working chamber for about 1 day. The oil pushed with nitrogen from the cavities of the core will collect in the empty space at the bottom of the glass. After setting the core for a day under the influence of nitrogen pressure, the tap of the working chamber is opened and nitrogen is released. The cover of the cylindrical housing is opened and removed from the working chamber with a core glass. The core is then weighed on an analytical laboratory scale and recorded in a special log. The weight of oil obtained by pushing nitrogen from the cavities of the core is determined by calculation.

Analysis of the results of laboratory work. Nitrogen injection of core oil was performed on five cores and repeated three times. The oil required for the experiment was imported from the North Karamandybas field, with an average density of 0.850 g / cm^3 and a viscosity of 5.08 mPa / s. Experimental work was carried out on the first unit, an experimental laboratory unit for the formation of the mechanism of pumping oil in the cavities of the model with nitrogen under the influence of the collector rock - the core. The second unit was designed to form a mechanism to push the oil-saturated core from one side to the other with nitrogen.

Firstly, after cleaning the cavities with air at high pressure, the core is weighed on an analytical laboratory scale. To saturate the core cavities with oil, soak them in a glass of oil for 10-12 hours. Then, in order to remove air bubbles in the cavities, the oil is completely saturated in a vacuum, which is placed in a special chamber and a vacuum is created in the working chamber with the help of a compressor.

Results. Then, in order to remove air bubbles in the cavities, the oil is completely saturated in a vacuum, for which it is placed in a special chamber and a vacuum is created in the working chamber with the help of a compressor. Finally, the first special unit for pushing the oil in the core with nitrogen will repeatedly push the oil with nitrogen. The obtained results are recorded in a special log and the necessary calculations are made.

First of all, five cores required for the experiment were developed, their weight before oil saturation was 85.05, 91.54, 83.80, 89.01, 88.60, respectively. After saturating them with oil in a special vacuum chamber at a pressure of 0.7 bar, the average weight on a special laboratory scale was 95.47, 102.08, 91.42, 102.16, 96.24. Thus, the average saturation weight of the cores was 10.42, 10.54, 7.62, 13.15, 7.51, respectively (Table 1).

Table 1 - Average of parameters for rock cores in the experiment

	Repetition	Number of rock cores				
		1	2	3	4	5
Wight (g) of oil before saturation	1	85,05	91,54	83,80	89,01	88,60
	2					
	3					
Pressure (bar) in a vacuum		0,7	0,7	0,7	0,7	0,7
Wight (g) of oil after saturation	1	95,65	104,50	93,84	105,38	99,39
	2	96,61	101,30	90,17	101,44	92,81
	3	94,16	100,45	90,27	99,67	96,53
	average	**95,47**	**102,08**	**91,42**	**102,16**	**96,24**
Saturation (g)	1	10,6	12,96	10,04	16,37	10,39
	2	11,56	9,76	6,37	12,43	4,21
	3	9,11	8,91	6,47	10,66	7,93
	average	**10,42**	**10,54**	**7,62**	**13,15**	**7,51**

From the obtained data, the oil saturation is the same in all samples and their oil saturation is 7.51 - 13.15 g. can be seen between (Fig. 2). It is observed that the oil saturation of the 1st, 2nd and 4th cores is higher than that of the 3rd and 5th cores (Figure 2).

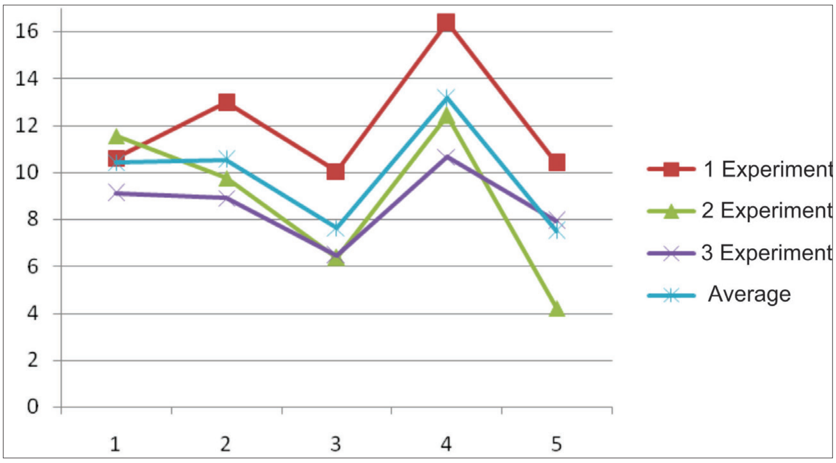

Figure 2. Diagram of oil saturated cores samples

Laboratory work was carried out to push the oil-saturated core, first in Unit 1 in Figure 17, and then in Unit 2 in Figure 15. Laboratory work was repeated 3 times in Unit 1 and 2 times in Unit 2. The chamber pressure was 5 MPa in both units. Including the results obtained at both units, the average values of oil saturation of the cores were 95.39, 101.82, 91.32, 101.48, 95.58, respectively (Table 2). The average weight of cores after nitrogen injection was 90.07, 96.68, 87.01, 96.53, 93.48, respectively. Thus, the weight of oil pushed as a result of nitrogen injection averaged 5.32, 5.14, 4.31, 5.55, 3.10 grams, respectively (Figure 3).

Table 2 - Results of the laboratory work on the injection of nitrogen into the porous cavities of the core in the reservoir rocks.

	№	Repetition	Number of rock cores				
			1	2	3	4	5
Weight of oil saturated cores before pushing with nitrogen (g)	1	1	95,65	104,50	93,84	105,38	99,39
		2	96,61	101,30	90,17	101,44	92,81
		3	94,16	100,45	90,27	99,67	96,53
	2	1	95,35	101,20	91,27	100,54	98,40
		2	95,18	101,65	91,08	100,39	90,77
	Average		**95,39**	**101,82**	**91,32**	**101,48**	**95,58**
Pressure in a vacuum (mPa)			5	5	5	5	5
Weight of oil saturated cores after pushing with nitrogen (g)	1	1	90,03	99,87	89,24	100,01	95,21
		2	90,28	95,96	86,79	95,13	90,80
		3	89,93	95,61	86,22	94,12	92,46
	2	1	90,05	95,24	87,35	98,77	99,74
		2	90,06	96,72	85,47	94,63	89,19
	Average		**90,07**	**96,68**	**87,01**	**96,53**	**93,48**
Wight of oil after the drainage (g)	1	1	5,62	4,63	4,60	5,37	4,18
		2	6,33	5,34	3,38	6,31	1,01
		3	4,23	4,84	4,05	5,55	4,07
	2	1	5,30	5,96	3,92	4,77	4,66
		2	5,12	4,93	5,61	5,76	1,58
	Average		**5,32**	**5,14**	**4,31**	**5,55**	**3,10**
Percentage of oil yield (%)	1	1	53	35	46	33	39
		2	55	55	53	51	48
		3	47	55	62	52	51
	2	1	51	62	53	42	48
		2	51	49	77	51	72
	Average		**51,4**	**51,2**	**58,2**	**45,8**	**51,6**

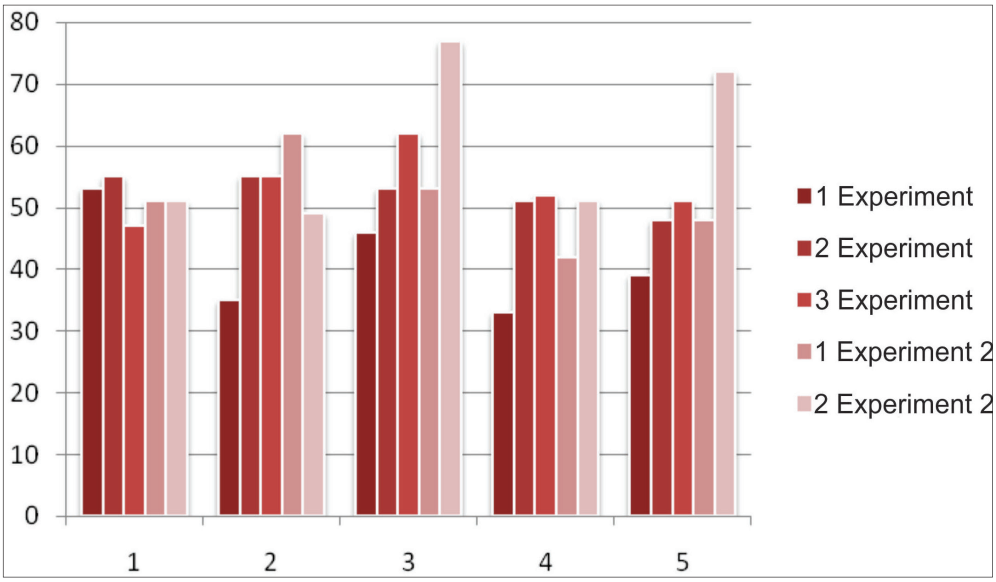

Figure 3. Percentage of oil in oil-saturated core pushed with nitrogen in Units 1 and 2

Discussion. As a result of experimental studies in the laboratory, the proportion of oil pushed with nitrogen from the porous cavities of the oil-saturated core was 45.8 - 58.2%, and it was found that the effectiveness of the push depends on the duration of action and pressure.

Because nitrogen has a much lower density than oil and is a gas, it enters the porous cavities and capillary tubes in the formation at high pressure and pushes the oil in that space downward under the same pressure. Therefore, the process of pushing oil in porous cavities and capillary tubes with nitrogen at high pressure can be considered as a difference in the density of oil and gas.

Conclusion. In this case, it can be concluded that the technology of nitrogen injection into the oil reservoir actually increases the oil recovery of the reservoir. This technology can be used to treat the edge of production wells with nitrogen, as well as nitrogen injection routes to maintain formation pressure from injection wells.

Due to this, nitrogen is denser than oil and is a gas, so it enters the cavities and capillary matrix at high pressure and displaces the residual oil from them along the cavities to the production wells. Therefore, the process of pushing residual oil with nitrogen in high-pressure cavities is due to the different densities of oil and gas.

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ЛАБОРАТОРИЯЛЫҚ ЖАҒДАЙДА ҚАБАТТЫҢ КЕУЕКТІ ҚУЫСТАРЫНДАҒЫ МҰНАЙДЫ АЗОТПЕН ИТЕРУДІҢ МЕХАНИЗМІН ЗЕРТТЕУ

Аннотация. Мақалада әлемдік проблемаға айналып отырған қабаттағы қалдық мұнайды алу кезінде қолданылатын өнімділігі жоғары әрі экономикалық тиімді болатын айдау агенттерін таңдау мәселелері қарастырылды. Мұнайлы қабаттың жіңішке қуыстарындағы және капиллярлы матрицадағы қалдық мұнайды азотпен итерудің тиімділігі талқылынды.

Қабаттың кеуекті қуыстарындағы қалдық мұнайды азотпен итеру барысындағы механизмін ашудың теориясы айтыла келе, оны зертханалық жағдайда жасап көрудің маңызды екендігі баяндалады.

Азот мұнайға қарағанда тығыздығы төмен және газ болғандықтан, жоғары қысымда қуыстар мен капиллиярлық матрицаға интенсивті түрде еніп, олардан қалдық мұнайды қуыстардың бойымен өндіру ұңғымаларына қарай ығыстырады деуге болады. Сол себепті, жоғары қысымда қуыстарда қалдық мұнайды азотпен итеру барысы мұнай мен газдың тығыздығының әртүрлі болуы себебінен жүзеге асады.

Лабораториялық жағдайда қабаттың кеуекті қуыстарындағы мұнайды азотпен итеру кезінде қолданылатын құрылғылардың жұмыс жасау механизмі таныстырылды. Солтүстік Қарамандыбас кенорнынан алынған керндердің алдымен құрғақтай және вакуумда мұнаймен қаныққаннан кейінгі салмақтары жеке-жеке өлшеніп алынды. Одан кейін арнайы дайындалған құрылғының көмегімен азотпен итеру жұмыстары жүргізілді. Мұнайға қаныққан керндердегі мұнайды азотпен итеру тәжірибесінен оң нәтижелер алынып, іс жүзінде кеорындарында қабаттың мұнайбергіштігін арттыруға мүмкіндік береді деп қорытынды жасалынды. Жүргізілген лабораториялық жұмыстан алынған оң нәтижелерді сараптай келе, өндіру ұңғыларының түп аймағына азотпен әсер ету арқылы мұнайлы қабаттың жіңішке кеуекті қуыстарындағы қалдық мұнайды шығарып алу тәсілі ретінде қолданып, қабаттың мұнайбергіштігін арттыруға мүмкіндік береді деп тұжырым жасауға болады.

Түйінді сөздер: азот, мұнай, айдау агенті, лабораториялық зерттеу, кеуектілік, өткізгіштік, қабаттың кеуекті қуысы, керн, мұнаймен қанығу.

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ИССЛЕДОВАНИЕ МЕХАНИЗМА ВЫТЕСНЕНИЯ НЕФТИ АЗОТОМ В ПОРИСТЫХ ПОЛОСТЯХ ПЛАСТА В ЛАБОРАТОРНЫХ УСЛОВИЯХ

Аннотация. В статье рассмотрены вопросы выбора высокопроизводительных и экономически эффективных перекачивающих агентов, применяемых при извлечении остаточной нефти пласта, ставшей мировой проблемой. Обсуждалась эффективность вытеснения остаточной нефти азотом в небольших полостях нефтеносного слоя и в капиллярной матрице.

Изложена теория вскрытия механизма вытеснения остаточной нефти азотом в пористых полостях пласта и изложена важность его разработки в лабораторных условиях.

Поскольку азот имеет меньшую плотность, чем нефть и является газом, можно сказать, что при высоком давлении он интенсивно проникает в полости и капиллярную матрицу, вытесняя из них остаточную нефть по полостям в сторону добывающих скважин. Поэтому при высоком давлении процесс вытеснения остаточной нефти азотом в полости осуществляется из-за различной плотности нефти и газа.

В лабораторных условиях был представлен механизм работы устройств, применяемых при вытеснении нефти азотом в пористых полостях пласта. Керн, извлеченный из скважин Северный Карамандыбас, исследовался сначала в сухом вакууме и после насыщения нефтью показатели измеряли отдельно. Затем с помощью специально подготовленного устройства были проведены работы по вытеснению нефти азотом. Получены положительные результаты из опыта вытеснения нефти азотом из нефтенасыщенных кернов, сделан вывод о том, что на практике это позволяет повысить нефтеотдачу пласта. Проанализировав положительные результаты проведенной лабораторной работы, воздействие на призабойную зону пласта в добывающих скважинах позволяет увеличть нефтеотдачу пласта, также способствует извлечению остаточной нефти из тонкопористых полостей нефтяного пласта.

Ключевые слова: азот, нефть, агент нагнетания, лабораторные исследования, проницаемость, пористость пласта, керн, нефтенасыщенность.

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

Редакторы: *М.С. Ахметова, А. Ботанқызы, Д.С. Аленов, Р.Ж. Мрзабаева*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 15.08.2021.
Формат 60x881/8. Бумага офсетная. Печать – ризограф.
4,6 п.л. Тираж 300. Заказ 4.

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