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ENHANCED OIL RECOVERY BY STEAM ACTION IN THE FIELDS OF KAZAKHSTAN


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The article discusses the use of steam exposure as an enhanced oil recovery (EOR) method, primarily focusing on its application in Kazakhstan's Karazhanbas and Kenkiyak fields. Steam injection, a process where steam is injected under high pressure into oil reservoirs, helps to reduce the viscosity of heavy oil, making it easier to extract. The method is particularly effective in reservoirs with low permeability and high viscosity, where traditional extraction methods are less efficient. The article highlights the significant role of steam injection in improving oil recovery rates, with increases of 10-20% in some fields.

KEYWORDS: *Hard-to-recover oil reserves, steam exposure, oil recovery of the reservoir.*

ПОВЫШЕНИЕ ИЗВЛЕЧЕНИЯ НЕФТИ С ПОМОЩЬЮ ВОЗДЕЙСТВИЯ ПАРА НА МЕСТОРОЖДЕНИЯХ КАЗАХСТАНА

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Данная статья рассматривает использование парового воздействия как метода увеличения нефтеотдачи (МУН), с основным акцентом на его применение в казахстанских месторождениях Каражанбас и Кенкияк. Инжекция пара – это процесс, при котором пар под высоким давлением вводится в нефтяные пласты, что помогает снизить вязкость тяжелой нефти, облегчая ее извлечение. Этот метод особенно эффективен *в месторождениях с низкой проницаемостью и высокой вязкостью, где традиционные методы извлечения нефти менее эффективны. В статье подчеркивается важная роль инжекции пара в повышении коэффициента извлечения нефти, с увеличением на 10-20% в некоторых месторождениях.*

КЛЮЧЕВЫЕ СЛОВА: *трудноизвлекаемые запасы нефти, воздействие пара, извлечение нефти из пласта.*

ҚАЗАҚСТАН КЕН ОРЫНДАРЫНДА БУДЫҢ ӘСЕРІМЕН МҰНАЙ АЛУДЫ АРТТЫРУ

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Жалпы мақалада бумен әсер ету арқылы мұнайды игеруді арттыру әдісі ретінде қолдану талқыланады, әсіресе оның Қазақстандағы Каражанбас және Кенкияк кен орындарында қолданылуы. Бу инжекциясы — бұл будың жоғары қысыммен мұнай қойнауларына енгізу процесі, ол ауыр мұнайдың тұтқырлығын азайтуға көмектеседі, осылайша оны алу оңайлайды. Бұл әдіс төмен өткізгіштігі мен жоғары тұтқырлығы бар кен орындарында әсіресе тиімді, мұнда дәстүрлі мұнай алу әдістері тиімді емес. Мақалада бу инжекциясының мұнай өндіру деңгейін арттырудағы маңыздылығы көрсетілген, кейбір кен орындарында өндіру деңгейі 10-20%-ға артқан.

ТҮЙІН СӨЗДЕР: *қиын алынатын мұнай қорлары, бу әсері, мұнай өндіру.*

Introduction. Oil is one of the most important natural resources. It is used as fuel, raw materials for the production of various products and materials. World oil reserves are limited, so it is important to use existing reserves effectively. There are many methods of increasing oil recovery. One of the most effective methods is steam exposure.

Steam exposure is a method of increasing oil recovery, which consists in injecting steam into the reservoir under high pressure. Steam heats the oil, making it more fluid and making it easier to extract it from the reservoir.

Steam exposure can be applied in fields with different types of formations. It is especially effective in fields with low permeability layers, from which it is difficult to extract oil using traditional methods. In Kazakhstan, the steam exposure method is used in the following fields: Karazhanbas, Kenkiyak. The most extensive work on steam exposure is carried out at the Karazhanbas field. Steam exposure has been used in this field since the 1980s. Currently, more than 200 steam wells are in operation at the field. Steam exposure is one of the most effective methods of increasing oil recovery. It allows you to increase oil recovery by 10-20%. And I took the data from these deposits as a basis, and it is during this analysis that we will draw a conclusion and showed that it is advantageous to choose steam injection in other deposits with high viscosity. In Kazakhstan, the steam exposure method is used in the following fields: Karazhanbas, Kenkiyak. The most extensive work on steam exposure is carried out at the Karazhanbas field. Steam exposure has been used in this field since the 1980s. Currently, more than 200 steam wells are in operation at the field. Steam exposure is one of the most effective methods of increasing oil recovery. It allows you to increase oil recovery by 10-20%.

And I took the data from these deposits as a basis, and it is during this analysis that we will draw a conclusion and showed that it is advantageous to choose steam injection in other deposits with high viscosity. This section will discuss mainly three thermal EOR processes applied in Kenkiyak, and Karazhanbas fields. The reservoir oil and rock properties of these fields are listed in *Table 2*. Kenkiyak and Karazhanbas fields are classified as heavy oils.

Table 1 – **The reservoir rock and fluid properties of Uzen, Kenkeyak, and Karazhanbas oil fields in Kazakhstan**

Parameter	Uzen	Kenkiyak	Karazhanbas
Crude Oil Components and Characteristics	10–25% Paraffins at 30 °C Pour Point	Heavy Oil	Heavy Oil
Viscosity, cP	3.5–4.2	150–700	375–550
Density, °API	35	21	19–22
P_{res}, MPa[a]	15-18 @ 54–69 °C	5.9 @ 19 –20 °C	3.6–4.0 @ 26 °C
P_b, MPa[a]	8.3–11.2 @ 60–70 °C	–	1.2–2.0 @ 26 °C
Lithology	Sandstone, IBS&M	Sandstone	Sandstone
Thickness, m	10-30 per zone	17	2-33 per zone
Depth, m	360-2,200	290–380	250–500
Porosity, fraction	21–25%	21–38%	28%
Permeability, mD	200-1,000	1,875	500
Oil in Place, MMBO	8,400	5	400
S_{oi}, %[a]	63–70%	65%	70%
S_{wi}, %	30–37%	35%	30%
Water Aquifer	–	Yes – Edge[a]	Yes – Edge
Productive horizons	23	–	7
High Permeability Channels	Yes	Yes	Yes

Karazhanbas oil field

The Karazhanbas field also contains heavy oil with viscosities ranging from 375 to 550 cP. It has been extensively developed due to a large resource target. Both steam flooding and in-situ combustion (ISC) techniques have been utilized at Karazhanbas over the last 30–40 years to recover oil from its estimated 400 million barrel of oil reservoir. *Figure 1* gives shows a map of Karazhanbas with thermal EOR application locations.

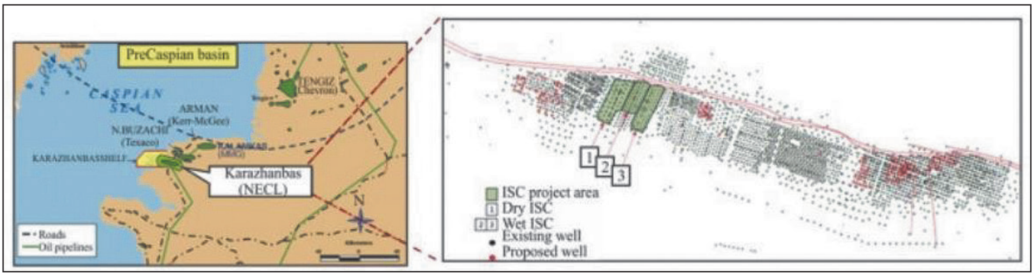

Figure 1 – **Map of the Karazhanbas Oil Field with thermal EOR well locations. ISC stands for In- Situ Combustion [1].**

Steam flooding follows the same principles described in the Kenkiyak oil field; however, continuous steam injection is used instead of cyclic steam injection in Karazhanbas field. Because with continuous steam injection the heat delivery to the reservoir is more stable, steam flooding has yielded incremental recoveries as high as 40% over a 20-year period. The location of these steam projects are the areas outside the in-situ combustion (ISC) polygons shown in *Figure 2*. These areas do not appear to have a consistent spacing or pattern orientation across the field; however, with a detailed review of recoveries by area and by zone and a well-planned redevelopment, recompletion, or down-spacing campaign, additional reserves may be accessible. Two types of in-situ combustion (dry and wet) processes were applied in Karazhanbas Field. In Zone 1 shown in *Figure 2*, dry combustion and in Zone 2 and Zone 3 shown in *Figure 2*, wet combustion were implemented. With the implementation of wet combustion, 32%–40% incremental recovery was achieved over a 13-year period with a 40%–60% water cut, whereas dry ISC was less effective, achieving a 20% incremental recovery over a similar timeframe with a water cut between 24% and 46%.

Kenkiyak oil field

The Kenkiyak field was produced through depletion beginning in 1967, reaching water cuts up to 80%. However, the field contains heavy oil at shallow depths, making it an ideal candidate for thermal recovery via steam injection. Wet (saturated) cyclic steam injection began in 1975 with great success, and a superheated cyclic steam injection pilot began in 2006. The estimated primary recovery was 21.6% and oil rate increased by 61.9% after the application of superheated cyclic steam injection. When vapor steam is injected into a cold, heavy oil reservoir, its high heat capacity is efficiently transferred, which lowers oil viscosity and results in reduced interfacial tension and increased volumetric flow velocity. The Kenkiyak field contains 5 million barrels of this cold, heavy oil, and superheated cyclic steam injection has been both modeled and pilot tested as an EOR technique. Superheated steam has a temperature that is well beyond the boiling point temperature of water and is also referred to as dry steam (100% vapor). If designed correctly, superheated steam can

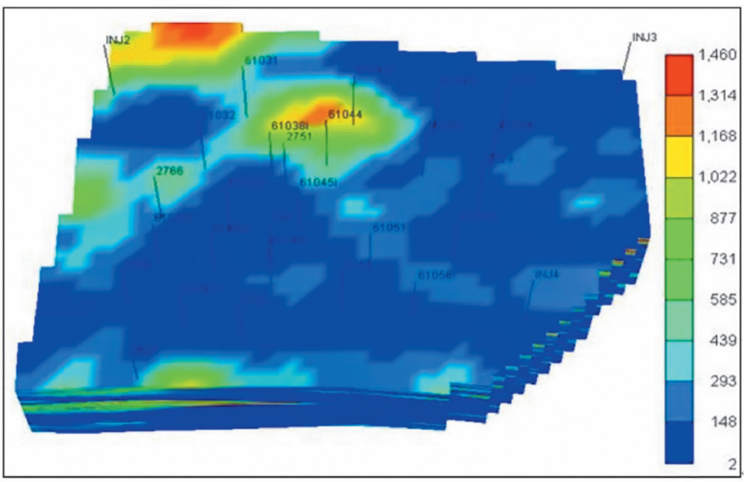

Figure 2 – **Typical well groups used for history match and parameters optimization for superheat steam injection. [3]**

lose heat while traveling through surface infrastructure and down the wellbore without (1) condensing. While this is the most efficient way to reduce the oil viscosity and improve sweep efficiency, it comes at a financial cost. It takes more fuel gas, and therefore, higher operating costs, to generate superheated steam as compared to saturated steam. [2]

As I previously showed that the oil in these fields is highly viscous and as has already been proven by theory, heavy oil becomes less viscous at high temperatures. In *Figure 3*, you can see how much temperature affects the viscosity of the oil. Using the example, we will also consider the Kenkiyak and Karazhanbas deposits in *Figure 3*.

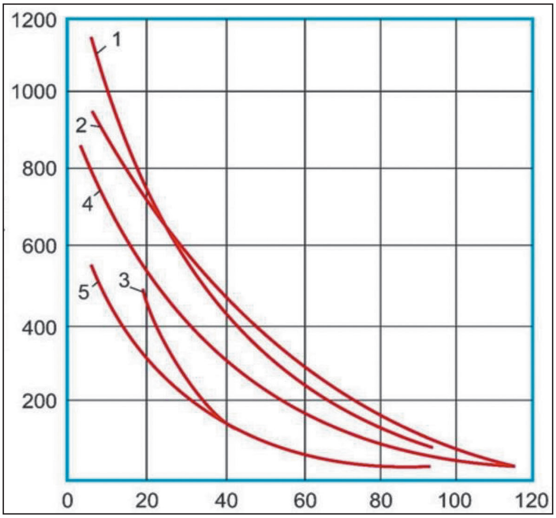

Figure 3 – **Dependence of oil viscosity on temperature [4] 4 – Karazhanbas; 5 – Kenkiyak**

From this graph, we can see the viscosity of the oil as well as the temperature and at what temperature the viscosity of the oil fell. In this graph indicators 4 and 5 are the indicators of the deposit Karazhanbas и Kenkiyak. The oil recovery coefficient is the ratio of the amount of oil, extracted from the deposit or part of it since the beginning of development during time (t), to the balance reserves deposits. The significant difference in density between steam and liquid during wet steam injection results in steam override that steam gathers on the top of the reservoir.

Material and methods. This study utilizes a range of field data, laboratory experiments, and modeling techniques to evaluate the effectiveness of steam exposure as an enhanced oil recovery (EOR) method in Kazakhstan's Karazhanbas and Kenkiyak fields. The primary materials used in this research include geological and reservoir data, such as rock permeability, porosity, and oil viscosity, as well as historical production and steam injection data from both fields. Information on steam injection rates, recovery factors, and water cuts was sourced from field operators to analyze the performance of different steam injection methods over time.

Laboratory experiments focused on the relationship between temperature and oil viscosity were conducted to understand how steam affects fluid properties. This data, combined with injection well performance data, such as pressure and temperature profiles, was used to assess the effectiveness of various steam injection strategies, including cyclic and continuous steam flooding, as well as superheated steam injection. Geographical data, including maps showing the layout of steam injection wells, were also used to evaluate the spatial distribution of steam projects within the fields.

The methods employed in this study included theoretical modeling to simulate thermal recovery processes and comparative analysis of different steam injection techniques. By reviewing field data on well performance and analyzing the impact of steam injection on oil viscosity, the study aimed to identify optimal operational conditions and assess the incremental recovery rates achieved through steam exposure. The findings provide insights into the efficiency of steam injection as a method for increasing oil recovery in heavy oil reservoirs and offer valuable data for further optimizing thermal EOR techniques..

Results and discussion. Work process

1. The injection stage. At this stage, steam under high pressure and temperature (usually 300- 340 °C) is pumped into the reservoir through an injection well. Steam heats oil and reservoir water, reducing their viscosity.

2. The warm-up stage. After a sufficient amount of steam has been pumped into the formation, it remains in the formation for several days or weeks to give it time to warm up.

3. The production stage. After the formation is warmed up, the well is switched to production mode. The oil, liquefied by steam, rises to the surface through the production well.

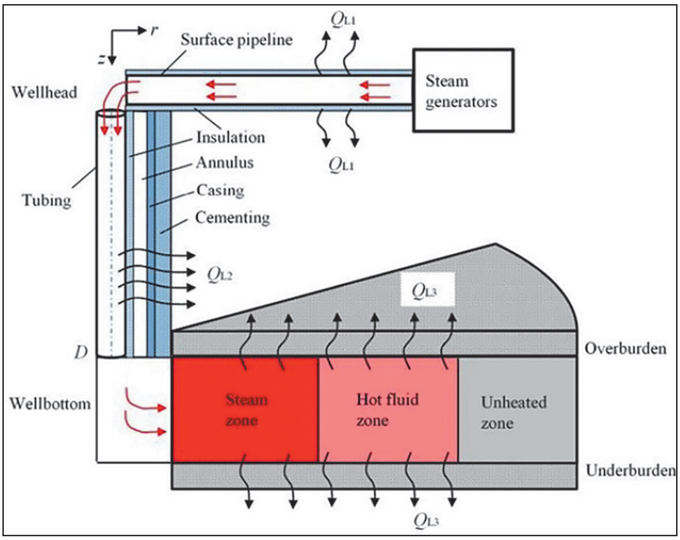

Figure 4 – **The process of steam injection into the well [5]**

Steam injection can significantly increase oil recovery. In some cases, it can increase oil recovery by 50% or more. This means that more oil can be extracted from the same field.Steam injection can also extend the life of the deposit. In some cases, it can extend the life of a field by 20 years or more.

Conclusion. The research presented emphasizes the benefits of both cyclic and continuous steam injection methods, with the latter offering more stable and efficient heat delivery, which leads to higher incremental recovery rates. In the Karazhanbas field, continuous steam injection has achieved up to 40% incremental recovery over a 20-year period, whereas wet in-situ combustion (ISC) methods have also shown notable success with recovery rates of 32-40%.

The Kenkiyak field, with its heavy oil at shallow depths, has greatly benefited from thermal recovery techniques, including saturated cyclic steam injection and superheated steam injection. The success of superheated steam injection, though more costly due to increased fuel gas requirements, highlights its efficiency in lowering oil viscosity and improving recovery rates, contributing to a 61.9% increase in oil production. The reduction in oil viscosity at higher temperatures, as demonstrated in the provided graphs, further supports the significant role that steam injection plays in enhancing oil recovery. Both fields, Karazhanbas and Kenkiyak, represent the potential for other high-viscosity oil fields to benefit from steam injection as an EOR method. The ability to achieve 10-20% incremental recovery, extend the life of oil fields, and unlock additional reserves makes steam injection a highly valuable technique for optimizing oil recovery. Furthermore, the findings suggest that with further research, optimization of injection patterns, and careful planning, additional reserves can be accessed in these fields, ensuring sustainable oil production for years to come.

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