ABSTRACT
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Introduction

To maintain the rate of hydrocarbon production worldwide, new fields have been developed, as well as so-called off-balance reserves, which previously could not be developed. A significant proportion of such fields are reservoirs with high-viscosity oils. The largest reserves of high-viscosity oils are located in Western Kazakhstan at the Karazhanbas , Severnoye Buzachi, Kalamkas, Kenkiyak, Moldabek Vostochny, and S. Balgimbayev fields . These fields are characterized by high oil viscosity (up to 45,000 mPa s), low thermal conductivity of rocks, and a high degree of pore space clogging, which significantly limits the effectiveness of traditional enhanced oil recovery methods [1]. For such fields, the use of thermal enhanced oil recovery (EOR) methods is relevant in order to improve development efficiency and increase the overall oil recovery factor (ORF).

Developing high-viscosity fields requires not only the use of modern methods for enhancing oil recovery, but also consideration of engineering and technical limitations associated with the design, profile, and condition of wells, which play a key role in the effectiveness of any thermal or chemical method.

Features of drilling engineering for the Karazhanbas field and other similar facilities include:

- high level of borehole curvature and complications, which limits the ability to deliver reagents to the wellbore zone;
- poor quality of cementing and inter-column flows, which reduce the efficiency of thermal and gas-generating technologies;
- limitations on the temperature resistance of tubing and casing strings, which requires the development of safe heat generation modes;
- difficulties in ensuring controlled delivery of the alloy due to the presence of sand plugs, caverns and colmatation zones;
- the need to optimize hydraulic modes during lowering and injection operations to prevent complications.

Therefore, the technology for using multicomponent alloys must be adapted not only to the reservoir characteristics but also to engineering constraints, equipment operating conditions, and well design properties. This makes the integration of drilling engineering a key part of the development and implementation of thermal gas-chemical treatments.

The introduction of combined technologies is especially effective in Fields with hard-to-recover and highly viscous oils, where traditional chemical or thermal methods fail to provide the desired results, are suitable for thermal-gas-chemical treatments, involving reactions of aluminum with water, generating hydrogen, heat, and gas, creating a thermobaric expansion effect and improving the permeability of the wellbore zone [12–15].

Increasing temperature reduces oil viscosity and removes asphaltene -resin-paraffin deposits, while the resulting gas expands pore space and improves formation permeability. Thus, the method combines elements of thermal, gas, and chemical treatments, ensuring comprehensive restoration of well productivity [16].

Thermal gas-chemical stimulation (TGCS) is widely used in oil recovery enhancement, particularly at fields with high-viscosity oil and low-permeability reservoirs. The method is based on the reaction of multicomponent aluminum alloys with acidified formation water, resulting in the release of heat and a gas phase that creates a short-term thermobaric pulse. This facilitates the destruction of clogging deposits, increases permeability, reduces oil viscosity, and creates an alkaline environment that improves oil displacement from the porous medium.

Relevance of the work

Large oil and gas reserves have been discovered in Kazakhstan, making the country one of the largest oil exporters currently and in the near future. According to some estimates, hydrocarbon reserves account for 1.8% of global oil reserves.

In recent years, the strategic objective of the development of Kazakhstan's oil and gas complex has been the stabilization and gradual increase of oil production, both through the development of new deposits and fields, and through improving the efficiency of operating old oil facilities.

With traditional hydrocarbon reserves depleting, increasing attention is being paid to hard-to-recover fields (HRR). HRR includes heavy, highly viscous oils, the volume of which in our country is estimated at over 900 million tons .

The use of traditional, widely used technologies for producing high-viscosity oils results in low oil recovery factors (ORFs), resulting in lost profits for subsoil users, and also causes environmental damage. It is important to note that engineering and technical limitations associated with the design, profile, and condition of wells, which play a key role in the effectiveness of any thermal or chemical method, must be taken into account.

Thermal gas-chemical treatment is widely used in enhanced oil production, particularly at fields with high-viscosity oil and low-permeability reservoirs. The method is based on the reaction of multicomponent aluminum alloys with formation water, resulting in the release of heat and a gas phase that creates a short-term thermobaric pulse. This helps break down clogging deposits, increases permeability, reduces oil viscosity, and creates an alkaline environment that improves oil displacement from the porous medium.

Justification for the need to conduct this research work presented in the form of a dissertation

According to international reviews [21–24], physical and chemical methods remain the most widely used (70–75% of the global IDN market). Thermal technologies account for approximately 20%, while combined technologies account for no more than 5–7%, but their share is growing due to the development of heavy oil projects.

In the structure of the IDN in the world:

- Physical methods — ≈ 40%;
- Chemicals — ≈ 30%;
- Thermal — ≈ 20%;
- Combined and hybrid - ≈ 10%.

The most common technologies—steam-thermal (CSS, SAGD), in-situ combustion, polymer and chemical flooding—have high energy consumption and a small heating radius, which limits their use in the development of heterogeneous formations with high oil viscosity.

thermogas-chemical methods based on localized heat and hydrogen generation directly within the reservoir are becoming increasingly relevant . One promising approach is the use of multicomponent alloys capable of releasing significant amounts of heat and hydrogen gas when interacting with water, increasing reservoir permeability and reducing oil viscosity, making drilling engineering a necessary component of successful technology implementation.

Information on the scientific and technical level of development presented in the dissertation work

The proposed technical solution is innovative, confirmed by a protected patent of the Republic of Kazakhstan and a number of scientific publications both in Kazakhstan and abroad.

The proposed technical solutions will significantly impact the level of scientific research and ensure qualitative growth of scientific and technical potential.

The dissertation is of high significance on a national and international scale and will enhance the status and prestige of Kazakhstan's oil and gas industry on the global stage.

This scientific work is related to the research and development work on the PCF IRN “BR24992868 - Development of innovative technology and software products for the use of multicomponent alloys to increase the productivity of high-viscosity oil wells.”

Scientific novelty :

- for the first time, a complex method of thermogas-chemical impact on a productive formation was proposed, based on the controlled interaction of multicomponent aluminum alloys with acidified formation water;
- optimal parameters for alloy feed and conditions ensuring effective thermal-gas-chemical action without destruction of the bottomhole formation zone were determined;
- a design of a well module for the dosed supply of alloy to the well bottom and regulation of the reaction rate is proposed, taking into account the compatibility of alloys and reaction products with tubing and casing.

The aim of this dissertation is to develop and scientifically substantiate a technology for the production of high-viscosity oil using multicomponent aluminum alloys to increase well flow rates by means of thermobarochemical stimulation of the productive formation.

The object of the study is thermobarochemical drainage to increase the production of high-viscosity oil at fields in Kazakhstan.

The subject of the study is a system of using multicomponent alloys to increase the productivity of high-viscosity oil wells.

Research objectives:

1. Analysis of global and domestic experience in the application of thermal, chemical and combined methods of intensifying oil production.
2. Analysis of the influence of drilling engineering factors, including the state of the cement ring and the presence of inter-column flows, on the effectiveness of thermal gas-chemical treatment of the formation.
3. hydrogen generation and numerical modeling of thermogas-chemical processes using the ECLIPSE Thermal software package and determination of the radius and intensity of formation heating.
4. Experimental studies on a physical model of the wellbore bottomhole zone of the temperature increase process during injection of a multicomponent alloy into the bottomhole zone, testing the operating modes of the "water - alloy" system over time.
5. To develop an engineering concept for a borehole module system for continuous, dosed supply of alloy to the well bottom.
6. To evaluate the technical and economic efficiency of the technology application using the example of the conditions of the Karazhanbas field .

The main provisions submitted for defense:

1. An integrated approach to the study of the area of expansion of the mechanism of complex thermogas-chemical impact on the formation, based on the reactions of multicomponent alloys with acidified formation water, accompanied by the release of heat and hydrogen.

2. Development of a technical solution for the creation of an engineering concept for a borehole module system for continuous metered supply of alloy to the well bottom.

3. Basic patterns of changes in the temperature regime in the near-wellbore zone of a well during the interaction of a multicomponent alloy and acidified formation water.

Theoretical and practical significance of the work

The theoretical significance of the work lies in the innovative technology of thermal impact on the bottomhole zone of the well

The practical significance of this work lies in the development of a scientifically proven technology for enhancing oil recovery in formations with high-viscosity oil. The use of multicomponent aluminum alloys allows for a reduction in oil viscosity, a larger heating radius, increased well flow rates, and a reduction in thermal maintenance costs. This technology can be integrated into existing steam-thermal stimulation systems at the Karazhanbas, Kenkiyak, and Severny Buzachi fields, ensuring increased well flow rates and stable production.

Testing the results of the dissertation work

The results of the dissertation work were published in international peer-reviewed scientific journals included in the Scopus / Web of Science database: 2025. Socar Journal proceedings Q 2, 56%.

Connection of work with scientific research projects and programs

The candidate's dissertation work was completed within the framework of the implementation of grant funding "Zhas Galym" AP25793601 " Increasing the efficiency of oil field waterflooding by taking into account the interaction of wells and selecting the optimal scheme for their location" (implementation period 2025 - 2027) and TFP BR24992868 "Development of innovative technology and software products for the use of multicomponent alloys to increase the productivity of high-viscosity oil wells" (implementation period 2024 - 2026) carried out with the support and funding of the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

Publications

The main results of the study are reflected in eight scientific publications. Four of these articles were published in journals included in the Web of Science and Scopus databases. Four articles were also included in publications approved by the Committee for Quality Assurance in Education and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

Structure and scope of the dissertation

The dissertation consists of an introduction, four sections, a conclusion, and a list of 140 references. The work is 112 pages long and includes 33 figures and 20 tables.