ANNOTATION

dissertation work of Zhetekova Lyazzat Bishebaevna on the topic: «An increase of the efficiency of West Kazakhstan deposits exploitation with hard-to-recover oil reserves» submitted for degree of Doctor of Philosophy (PhD) degrees in the educational program 8D07210 (6D070800) – Oil and Gas Business

The relevance of the research:

The majority of oil fields in the Republic of Kazakhstan are currently in the exploitation stage, characterized by declining oil production. It is important to note that highly viscous, heavy oils now account for more than half of the world's proven reserves and, according to various classifications, are considered difficult to recover. In the near future, one of the most pressing challenges will be to enhance the efficiency of developing fields with these hard-to-recover oil reserves.

A significant focus should be placed on the creation and improvement of classification methods for hard-to-recover reserves, as well as on technologies based on thermal effects, monitoring, and regulation of oil extraction processes. Additionally, controlling water inflows into wells is crucial. The successful application of thermal technologies is linked to the development of innovative solutions that offer not only technical and technological advantages but also economic efficiency, while expanding the range of geological conditions where they can be applied.

In any geological setting involving deep-lying oil deposits, a key issue is the advancement of methods for monitoring and regulating production processes. This is essential to maintain high oil recovery rates under favorable filtration conditions and to limit the increase in water content in the extracted products.

Research shows that the lack of clear scientific justification when selecting methods for influencing formations with hard-to-recover reserves complicates the choice and implementation of technological solutions aimed at improving the efficiency of oil recovery from such reservoirs.

Rationale for the need for this research work: Technological decision-making in oil extraction often occurs under conditions of uncertainty, necessitating the use of information analysis methods that account for these uncertainties. Alongside this, a detailed study of development conditions and methods is crucial. As technological experience in extracting high-viscosity, heavy oils shows, the potential use of thermal extraction methods must be explored. Among the known thermal methods, the most widely used technologies involve the injection of coolants into the formation. However, alternative combined technologies also need to be considered.

It is important to note that the development of oil fields in Kazakhstan, such as Karazhanbas, Kenkiyak, and Kalamkas, is particularly challenging due to the limitations of traditional extraction methods. To fully grasp the meaning of "hard-to-recover oil," it is essential to understand the characteristics and conditions that classify these reserves as such. Moreover, Kazakhstan possesses significant oil

reserves with diverse properties and occurrence conditions, which influence the degree of difficulty in their extraction.

Therefore, it is essential to develop new methods for classifying oils and assessing the difficulty of their extraction. This includes the application of advanced technologies for developing fields where traditional methods would not allow for significant oil recovery. This research is particularly relevant to the oil fields in Kazakhstan.

The purpose aim of the dissertation: To improve the methods of analysis and decision-making to enhance the efficiency of wells operating in fields with hard-to-recover oil reserves at a late stage of development.

Research objectives:

Analyze the characteristics and classification methods of hard-to-recover oil reserves based on a set of attributes.

Develop a classification method for hard-to-recover oil reserves based on their properties, composition, and occurrence conditions.

Conduct a statistical analysis of oil production dynamics and provide a predictive assessment of production indicators for future periods.

Evaluate the technological efficiency of production wells and the geological and technical measures implemented at the field.

Perform a statistical analysis of the outcomes of hydrochloric acid treatments and assess the technological efficiency of their application in the field under study.

Object of the study:

The system of analysis and decision-making aimed at increasing the efficiency of hard-to-recover oil production.

Subject of the study:

Methods for classifying hard-to-recover reserves and decision-making processes for selecting techniques to displace high-viscosity oil within this system.

Research methods:

Data processing and analysis were carried out using methods of mathematical statistics to address the identified problems. Fuzzy cluster analysis was applied to classify hard-to-recover reserves. Decision-making on the optimal method for influencing the reservoir was based on the principles of fuzzy set theory.

Basic provisions for defense:

A comprehensive classification of oils based on their properties (viscosity, density), composition, and occurrence conditions, utilizing fuzzy cluster analysis.

Predictive assessment of future oil production values through statistical analysis of production dynamics.

Identified patterns between total solubility and the concentrations of hydrochloric and hydrofluoric acids.

Scientific novelty of the work:

The scientific basis for the creation and practical application of a methodology for classifying different field types (oil, oil and gas, and gas) is substantiated. This methodology assesses the complexity of reserve development

based on a set of characteristics (composition, properties, and occurrence conditions).

A method for classifying hard-to-recover oil reserves in Kazakhstan is proposed. This method, based on fuzzy cluster analysis, improves upon previous methods by considering impurities present in the oil.

A new parameter is introduced to characterize the complexity of reserve extraction, accounting for both occurrence conditions and the properties and composition of hard-to-recover oils.

As a result of statistical analysis, a method and corresponding expressions for the predictive assessment of oil production indicators and the technological efficiency of applied measures are proposed.

Patterns between total solubility and the concentrations of hydrochloric and hydrofluoric acids are studied, with corresponding expressions derived.

Practical significance of the work: This research offers significant practical contributions to the field of oil extraction, particularly concerning hard-to-recover oil reserves. The author conducted a comprehensive analysis of existing classification methods, identifying key characteristics and features that affect the complexity of extraction—such as viscosity, density, composition, and occurrence conditions. This analysis highlighted the shortcomings and limitations of current classification methods, laying the groundwork for developing a more accurate and comprehensive approach.

Building on this analysis, the author developed a new method for classifying hard-to-recover oil reserves that incorporates their physicochemical properties, composition, and geological occurrence conditions. Utilizing fuzzy cluster analysis, this method more accurately considers the complex interrelationships among various features and provides sound recommendations for field development.

The study also included a detailed statistical analysis of the oil production dynamics at the target field. Using the data obtained, forecast models were developed that enable highly accurate estimations of future production values. This facilitates more efficient field operation planning and informed decision-making in production process management.

Additionally, the author analyzed the efficiency of utilizing production wells and assessed the effectiveness of geological and technical measures implemented at the field. Key factors influencing well productivity were identified, leading to recommendations for optimizing operations and enhancing the overall efficiency of oil production.

Finally, a statistical analysis was performed on data from the application of hydrochloric acid treatments at the field. Patterns influencing the efficiency of this method were identified, and its technological effectiveness was assessed. The results confirmed the feasibility of using hydrochloric acid treatments under the specific conditions of the field, enabling practical recommendations for improving its application.

Compliance with scientific development directions or state programs: The dissertation complies with the priority direction of scientific development

approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan in the direction 1. Ecology, environment and rational use of natural resources: incl. 21) Development and operation of oil and gas fields.

The personal contribution of the author is: The author has made a significant personal contribution to the research, development, and justification of new methodological approaches for classifying hard-to-recover oil reserves and enhancing the efficiency of their extraction. The author independently conducted all key stages of the study, including problem formulation, methodology development, data analysis, and the creation of practical recommendations.

Reliability of the results: The reliability of the scientific findings and conclusions is ensured through the use of modern mathematical methods for data processing, information analysis, and decision-making. The consistency of the results from both theoretical and experimental studies has been validated using appropriate criteria.

Description of the main research results: The author conducted a comprehensive analysis of existing methods for classifying hard-to-recover oil reserves, identifying key characteristics that affect extraction complexity, such as viscosity, density, composition, and occurrence conditions. This analysis revealed the limitations of current classification methods, laying the groundwork for developing a more accurate and comprehensive approach.

Building on this, the author developed a new classification method for hard-to-recover oil reserves, incorporating physicochemical properties, composition, and geological conditions. The method employs fuzzy cluster analysis, which provides a more accurate understanding of complex relationships between various factors, offering sound recommendations for field development.

A detailed statistical analysis of the oil production dynamics at the studied field was also conducted. Based on the data, forecast models were developed that provide highly accurate estimates of future production values. These models enable more efficient field operation planning and support informed decision-making in managing the production process.

The author further analyzed the efficiency of production wells and assessed the effectiveness of geological and technical measures implemented in the field. Key factors influencing well productivity were identified, and recommendations were made to optimize their operation, enhancing the overall efficiency of oil production.

Lastly, a statistical analysis was conducted on the use of hydrochloric acid treatments at the field. The study identified patterns affecting the efficiency of this method and evaluated its technological effectiveness. The results confirmed the suitability of hydrochloric acid treatment for the field's conditions, leading to practical recommendations for improving its application.

Approbation of the work results: The results of the dissertation work and its main provisions were reported and discussed at: International Scientific and Technical Conference "13th International Conference on Application of Fuzzy Systems and Soft Computing (ICAFS)", Warsaw, Poland, August 27–28, 2018;

International Scientific and Practical Conference "Geological and Technological Aspects of Development of Hard-to-Recover Hydrocarbon Deposits" (Aktau, April 18, 2019); International School-Seminar of Young Scientists and Students, Oil & Geoecology, (Baku, December 3-8, 2018); International Scientific and Practical Conference "Development of Science and Technology in the Development of the Subsoil of Kazakhstan", dedicated to the 90th anniversary of Academician Sh. Yessenov; International Scientific and Practical Conference "Methods of Enhanced Oil Recovery and Intensification of Oil Production". Aktau, Kazakhstan. April 27, 2018. International Scientific and Practical Conference "Modern Methods of Developing Fields with Hard-to-Recover Reserves and Unconventional Reservoirs". Atyrau, Kazakhstan. September 5-6, 2019; International Scientific and Technical Conference "10th International Conference1o2n Theory and Application of Soft Computing, Computing with Words and Perceptions - ICSCCW 2019". Prague, Czech Republic. August 27-28, 2019; International Scientific and Technical Conference "11th World Conference "Intelligent System for Industrial Automation" (WCIS-2020) (Tashkent, Uzbekistan, November 26-28, 2021).

Publications: Based on the dissertation, 13 works have been published, including: 2 articles in journals indexed in the Scopus database, 3 articles in scientific journals recognized by the Committee on Quality Assurance in Science and Higher Education. The remaining articles have been published in international scientific journals and presented at practical conferences.

Volume and structure of the dissertation: The dissertation includes an introduction, 4 chapters, main conclusions and recommendations, a list of references with 131 titles, and 4 appendices. The work comprises 117 pages of text, 9 tables, and 22 figures.