E3S Web of Conferences **549**, 07009 (2024) https://doi.org/10.1051/e3sconf/202454907009
TransSiberia 2024

Prospects for the implementation of SWAG-technology to enhance oil recovery at the Rechitskoe field using flue and flare gases

Alexander Drozdov[1*] and *Evgeniya* Gorelkina[1,2]

[1]Peoples' Friendship University of Russia named after Patrice Lumumba, 117198 Moscow, Russian Federation, 117485 Moscow, Russia
[2]Sergo Ordzhonikidze Russian State University of Geological Prospecting, Department of the Development and Operation of Oil and Gas Fields, 117485 Moscow, Russia

Abstract. This article proposes the introduction of SWAG-technology at the Rechitskoe oil field of RUE Belorusneft. An analysis of previously conducted research on the implementation of technology at the selected facility revealed a number of technological factors that reduced the effectiveness of the method. It is proposed to use pump-ejector systems – devices that will allow obtaining and pumping a water-gas mixture with the required pressure. To ensure rational gas content, it is advisable to add flare and flue gases to the water, which will reduce the carbon footprint. The addition of foaming surfactants helps to improve the characteristics developed by the booster pump, suppress the coalescence of gas bubbles and increase the efficiency of injection of the water-gas mixture.

1 Introduction

Over more than half a century of oil production history in the Republic of Belarus, the main fields of the Pripyat trough have entered the final stage of development. They are characterized by a high degree of reserve depletion (70-90%) and water cut of extracted products (up to 80-90%). Currently, in the RUE Production Association Belorusneft, about 70% of the remaining recoverable oil reserves are classified as "hard to recover". The imbalance in the rate of selection of active and hard-to-recover reserves is accompanied by the fact that the share of the latter is rapidly increasing. The reserves of newly discovered deposits are insignificant, they mainly fall into the category of hard-to-recover, requiring innovative technological solutions for their cost-effective development and production [1, 2].

Under these conditions, to maintain oil production at planned levels, the main task is to increase oil recovery factors (ORF) compared to design ones in deposits with active reserves and to increase the rate of recovery and recovery factor in deposits with hard-to-recover reserves [3, 4].

One of the solutions to these problems could be the widespread use of gas methods. Until recently, the waterflooding method to maintain reservoir pressure was considered the most progressive. However, during waterflooding, more than half of the recoverable oil reserves

* Corresponding author: drozdov_an@mail.ru

remain in the reservoir [5-11], and therefore there is currently growing interest in the use of SWAG-technology technology on oil reservoirs in order to increase oil recovery. The trend of deterioration in reservoir properties of objects involved in development shows that innovative technologies with gas injection will effectively replace waterflooding [12-14].

The first assessment of the possibility of using SWAG-technology in the oil fields of the Pripyat Trough was undertaken in works [15-17]. In addition to a theoretical review of the possibility of using SWAG-technology in the fields of the Republic of Belarus, laboratory and numerical studies were carried out to assess the effectiveness of WGW in the fields of the Pripyat trough, on the basis of which this technology was recommended for pilot industrial use [18].

Subsequently, BelNIPIneft specialists assessed the possibility of using SWAG-technology to increase oil recovery using three agents: stripped gas, carbon dioxide and nitrogen. For the primary implementation of SWAG-technology, nitrogen was chosen as a gas agent, which was caused by a simpler method of obtaining it and relatively minimal costs for the implementation of the project. Then, at the deposits of three fields of the Pripyat trough, field tests were carried out on the injection of a fine water-nitrogen mixture, which was created at the mouth using a special ejection-dispersing device (EDD) with technological support from the company – the developer of this technology, INCO LLC. However, the injection of the mixture was carried out for a short time, which resulted in the absence of a visible technological effect in the form of additional production [18]. After this, work on SWAG-technology at RUE Belorusneft was stopped.

This article discusses the possibilities of resuming the introduction of SWAG-technology at the Rechitskoe oil field of RUE Belorusneft, but at a different, higher technological level, using pump-ejector systems, as well as flue and flare gases of the Belarusian gas processing plant.

2 Statement of the problem

Injection of a water-nitrogen mixture consisting of water used in the reservoir pressure maintenance system (RPM) and nitrogen obtained from air was carried out during field tests [18, 19] in the fields of Belarus using mobile high-pressure nitrogen compressor units (Fig. 1 and 2).

For this purpose, an EDD was installed at the mouth of the injection well, consisting of two blocks: an ejector and a dispersing unit (Fig. 3). The ejector sucked nitrogen supplied from a mobile nitrogen unit with a stream of water, mixed the phase and carried out preliminary grinding of the gas. On the next device, the gas phase was further dispersed.

The main disadvantage of this technology was the use of mobile high-pressure nitrogen compressor units PKSA 9/200, TGA-10/250, TGA-20/250 and A-100.

They require high diesel fuel consumption. Thus, the PKSA 9/200 compressor is mounted on the basis of a KAMAZ 43118 vehicle driven by a diesel internal combustion engine with a power of 270 kW, and the TGA-10/250 is mounted on the basis of a KAMAZ 63501-40 vehicle with a diesel power of 320 kW. To ensure round-the-clock operation of compressor units, it was necessary to ensure an uninterrupted supply of diesel fuel, the specific consumption of which for each compressor was 60-75 l/hour (1.44-1.8 m^3/day). Ultimately, this led to significant operating costs that were not recouped, and the cessation of fishing experiments after a short time, during which it was impossible to obtain a technological effect from the impact.

In addition, there were periodic shutdowns of nitrogen compressor stations due to overheating; it was also noted that it was impossible to regulate the volumetric gas flow rate in the required range of values, and that the developed maximum pressure during long-term operation turned out to be less than the rated values by about 3 MPa [1].

The unresolved problem of technology and equipment for the effective implementation of water-gas impact remains extremely relevant for the Republican Unitary Enterprise "Production Association "Belorusneft". Thus, according to [1], for the conditions of development of the carbonate reservoir of the Zadonsk intersalt deposit of the Rechitskoe field, the optimal method of organizing SWAG-technology is the option of pumping a water-gas mixture in a ratio of 25% nitrogen and 75% water in reservoir conditions into injection wells 1852, 120, 124, 126, 133, 140, 314. The expected additional oil production by the end of development (2090) is 716 thousand tons.

Fig. 1. Injection of a water-gas mixture into an injection well using the technology of INKO LLC [19].

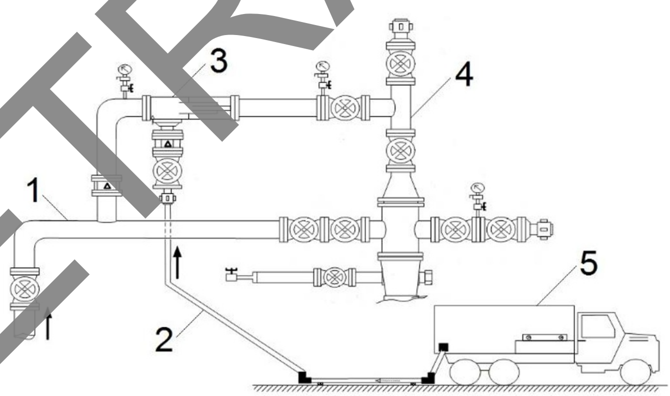

Fig. 2. Scheme of pumping a water-gas mixture into an injection well using the technology of INKO LLC [19]: 1 – water pipeline, 2 – nitrogen supply line, 3 – ejection-dispersing device, 4 – well, 5 – mobile compressor nitrogen unit.

 https://doi.org/10.1051/e3sconf/202454907009

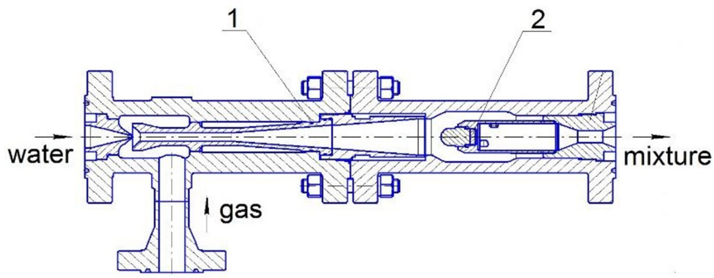

Fig. 3. Diagram of the ejection-dispersing device of INKO LLC [19]: 1 – ejector, 2 – dispersing unit.

3 Methodology

To solve this problem, the most acceptable option is to use pump-ejector systems.

Pump-ejector systems include vane pumps, ejectors and pipeline fittings, and in some cases also low-pressure compressors [20, 21]. One of the diagrams of pump-ejector systems is shown in Fig. 4.

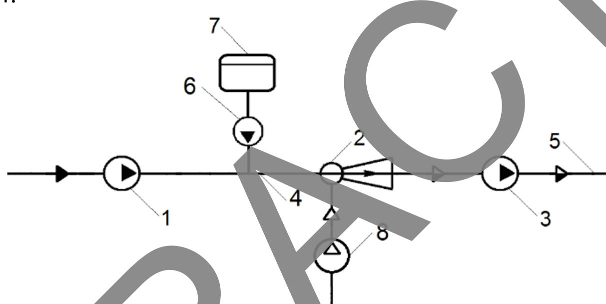

Fig. 4. Schematic diagram of one of the pump-ejector systems: 1 – power pump, 2 – ejector, 3 – booster pump, 4 – water pipeline, 5 – water-gas mixture injection line, 6 – dosing pump, 7 – container with foaming surfactants, 8 – compressor.

SWAG-technology of the formation using this system is carried out as follows.

The water-gas mixture created by ejector 2 is pumped into injection wells and foam-forming surfactants (surfactants) are added to the water-gas mixture. To do this, an electrically driven power pump 1 supplies water under pressure through a water conduit 4 into the working nozzle of the ejector 2. When water flows through the working nozzle at high speed, a vacuum is created in the receiving chamber of the ejector 2, into which gas is sucked in through the gas supply line from the low or medium electric compressor 8 pressure. At the same time, foam-forming surfactants from container 7 can be supplied into the flow by dosing pump 6 to suppress the coalescence of gas bubbles and increase the stability of the mixture. In the flow part of the ejector 2, the flows are mixed and a water-gas mixture is formed.

At the exit from ejector 2, the water-gas mixture has some increased pressure, which, however, is not enough to pump the water-gas mixture into injection wells. Therefore, after the ejector 2, the water-gas mixture is pressurized with an electric multi-stage centrifugal pump 3 and pumped under high pressure through line 5 into the injection wells.

To avoid a decrease in the operating characteristics of the booster pump 3 due to the harmful effects of gas, the free gas content in the mixture at the inlet of pump 3 is maintained no higher than the critical gas content for non-cavitation operation on a water-gas mixture.

When implementing this SWAG-technology, it is possible to use the existing infrastructure of the waterflooding system, which significantly reduces costs compared to other methods.

The pumps and compressor of the system are electrically driven and can operate for a long time – for years, without the need to constantly supply diesel fuel.

Such a pump-ejector system was previously successfully implemented at the Samodurovskoye field [21]. Formation water entered the ejector nozzle from the pump of the cluster pumping station TsNS-240-1422. A horizontal multistage centrifugal pump ESP8-1600-1450 was used as a booster pump. During operation, the ejector, into the nozzle of which water was pumped by the TsNS-240-1422 pump, pumped out the low-pressure associated gas entering its receiving chamber from the first and second separation stages of the Samodurovskaya water preliminary discharge installation, where it was sent along with the produced liquid from Samodurovsky, Efremo-Zykovskoye and Spassky fields. In addition, gas was also supplied to the system's ejector intake using a low-pressure compressor through a gas pipeline from the oil treatment plant at the Ponomarevskoye field. From the ejector outlet, the water-gas mixture under some increased pressure was supplied to the input of the ESP8-1600-1450 pump, which pressed the mixture to the pressure required for injection into injection wells. During operation, the pump-ejector system operated stably, completely pumped out the required flow of associated petroleum gas, and there were no interruptions in the supply of the ejector or booster pump.

Since RUE Belorusneft utilizes almost all associated petroleum gas, with most of it supplied to the Belarusian Gas Processing Plant (BGPZ), to resume work on water-gas treatment, it is most advisable to use flue gas (consisting of 87-89% nitrogen and gas) as a working agent. 10-11% from carbon dioxide) and flare gases from the BGPZ.

It should be noted that this plant is very well located almost on the border of the Rechitskoe oil field, the main producing asset of RUE Belorusneft, in close proximity to the oil field and wells (Fig. 5). This will make it possible to organize SWAG-technology at the Rechitskoe field with minimal costs. At the BGPZ it is necessary to install a compressor that develops a pressure of up to 1-2 MPa for pumping flue and flare gases, and also to lay a gas pipeline from the compressor to the oil field, where the block cluster pumping station (BCPS) of the RPM system is located. A pump-ejector system should be placed at the field according to the diagram shown in Fig. 4, connecting the ejector nozzle to the discharge line of the BKNS pump, the ejector receiving chamber to the gas pipeline from the compressor, and the outlet to the water pipelines to the injection wells.

Initially, pilot-industrial injection of a water-gas mixture by a pump-ejector system using flue and flare gases can be carried out into the same injection well 128 of the Zadonsk deposit of the Rechitskoe field, into which the water-nitrogen mixture was previously pumped [1] for some short time.

Previous studies [22] have studied the characteristics of liquid-gas ejectors quite well, but some features of the operation of a multi-stage booster centrifugal pump using a water-gas mixture created by the ejector have remained unexplored. In particular, when selecting the necessary equipment for future implementation at the Rechitskoe field, it is important to know to what value of the input gas content the system's booster pump will operate stably, without reducing its parameters.

In this regard, experimental bench studies were carried out on the operation of a multistage centrifugal pump on a water-gas mixture created by an ejector with various concentrations of a foaming surfactant – Neftenol VVD.

As a model of the booster pump of the pump-ejector system, we used a section of the ESP5A-100 pump containing 80 stages. The operating parameters of a pump with a pre-connected ejector for water-gas mixtures were measured at an excess pressure at the pump inlet of 2 MPa. Fresh water was used as the liquid. The ejector contained a diaphragm nozzle with a diameter of 3.2 mm, a cylindrical mixing chamber with a diameter of 7.1 mm and a length of 340 mm, and a diffuser with an opening angle of 5.5°. When conducting experiments, the bench research methodology presented in [23] was taken as a basis, which allows one to obtain the characteristics of a pump using a water-gas mixture prepared by an ejector. This method involves the supply of water from the tank to the intake of a power pump, which forces it into the ejector nozzle, into the receiving chamber of which compressed gas (air) is supplied from the compressor. From the outlet of the ejector, the water-gas mixture goes to the intake of the booster pump under study. Various operating modes are established by regulating the flow and pressure of water and gas using valves and a reducer.

Fig. 5. Satellite view of the Rechitskoe field: 1 – Belarusian gas processing plant, 2 – oil field, 3 – wells (according to [24]).

A distinctive feature of the experiments from experiments [23] is the study of pump operating parameters on “water-gas” and “water-surfactant-gas” mixtures when changing the volumetric concentrations of the foaming surfactant. At the same time, a shelf gravity separator was additionally installed in the stand, designed to separate the foaming water-gas mixture coming from the pump and subsequently direct it to the degassed water tank.

The experiments were carried out with a liquid supply of 60-62 m^3/day, using “water-gas” and “water-surfactant-gas” mixtures and various input gas contents β_{in}.

The gas content at the pump inlet βin was calculated using formula (1)

$$\beta_{in} = \frac{Q_{g.in}}{Q_w + Q_{g.in}}, \tag{1}$$

where Q_g.in is the gas flow rate under thermodynamic conditions at the pump inlet,
Q_w – water supply.

Using formula (2), the pressure P_P developed by the pump was determined

$$P_P = P_{out} - P_{in}, \tag{2}$$

where P_{out} is the pressure at the outlet of the pump,
P_{in} – pressure at the pump inlet.

In addition, the average integral parameters of the pump were calculated using the method presented in [25]. The average integral pump flow $Q_{av.i}$ when pumping out a gas-liquid mixture was calculated using the formula

$$Q_{av.i} = \frac{1}{P_{out} - P_{in}} \int_{P_{in}}^{P_{out}} Q(P)dp, \tag{3}$$

where *Q(P)* is the dependence of the volumetric flow rate of gas liquids *Q* on the pressure *P* along the path of movement from the inlet to the pump to the outlet (from P_{in} to P_{out}).

The average value of the mixture density ρav in the pump was found as

$$\rho_{av} = \frac{M_m}{Q_{av}}, \tag{4}$$

where M_m is the mass flow rate of water-gas mixture passing through the pump.

Next, we calculated the value of the average integral pressure H_{av}

$$H_{av} = \frac{P_P}{\rho_{av} \cdot g} = \frac{(P_{aut} - P_{in})Q_{av}}{M_{av} \cdot g}, \tag{5}$$

Based on the measurement data, the dependences of Q_{av} and H_{av} on the input gas content β_{in} at various surfactant concentrations were plotted.

4 Discussion of results

Fig. 6 and 7 shows the dependences of the average integral flow and average integral pressure of the ESP5A-100 pump on the input gas content, obtained at various concentrations of the foaming surfactant (Neftenol VVD).

With an increase in the input gas content and a constant liquid supply, the values of the average integral supply increase, and the average integral pressure decreases. The addition of a foaming surfactant helps suppress the coalescence of gas bubbles and improve the operation of the pump on a gas-liquid mixture, while the greatest effect of the surfactant is observed when its concentration in water increases to 0.025%. A further increase in the concentration of Neftenol VVD to 0.03% leads to a slight improvement in the pump operating parameters.

To determine to what inlet gas content the pump does not experience the harmful effects of free gas, the dependence of the average integral pressure on the average integral flow was plotted at a maximum surfactant concentration of 0.03% and various gas contents at the inlet (Fig. 8). The same graph shows the pressure characteristic of the pump on water.

Head-feed curves plotted in mean integral coordinates must be interpreted as follows. When pumping homogeneous and gas-liquid mixtures, the resulting curves are not a function of the density of the pumped medium. In this case, they coincide as in the case of non-cavitation operation, while the viscosities of the media are equal or so small that they do not have a noticeable effect on the characteristics of the pump. If the curve is located below the characteristics for a homogeneous liquid, then this indicates artificial cavitation in part of the pump stages.

The invariability of the H_{av} – Q_{av} curves relative to the density of the mixture allows one to compare the characteristics of pumps with different input gas contents of the gas-liquid mixture.

From a comparison of the characteristics on water and the gas-liquid mixture, it follows that the pressure characteristics of the pump on water and the water-gas mixture are practically the same up to an input gas content of 0.505, and only at higher gas flow rates does the pressure on the mixture begin to decrease compared to the water characteristic.

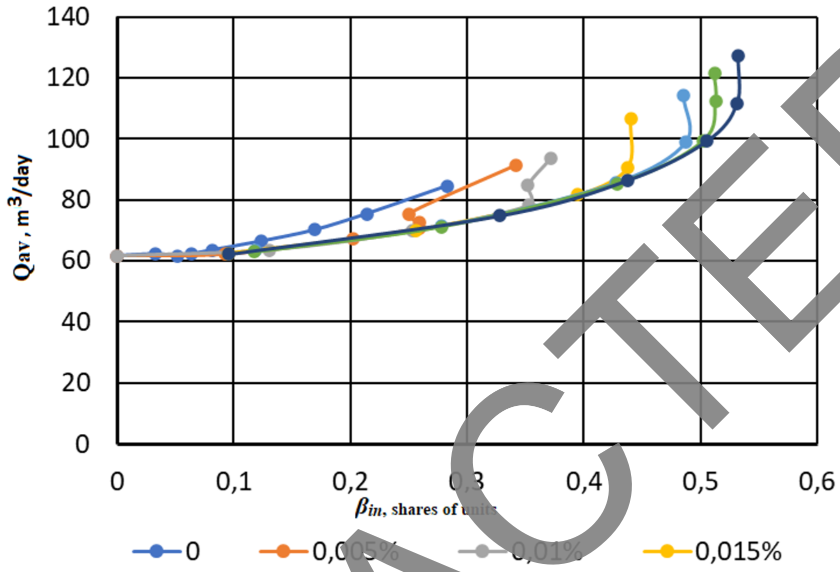

Fig. 6. Dependences of the average integral flow rate of the ESP5A-100 pump on the input gas content, obtained at various concentrations (from 0 to 0.03%) of VVD Neftenol.

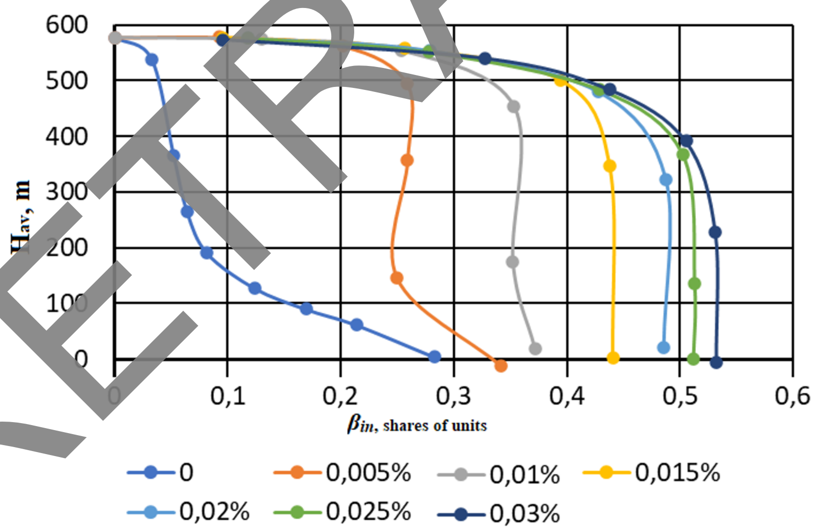

Fig. 7. Dependences of the average integral pressure of the ESP5A-100 pump on the input gas content, obtained at various concentrations (from 0 to 0.03%) of VVD Neftenol.

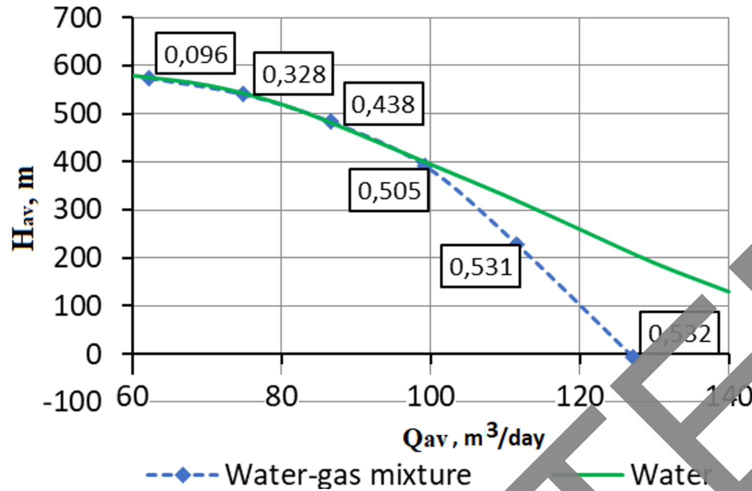

Fig. 8. Comparison of the dependence of the average integral pressure of the ESP5A-100 pump on the average integral supply on a water-gas mixture obtained at a concentration of 0.03% Neftenol VVD (numbers near the experimental points show the values of the input gas content) with the pressure characteristic of the pump on water.

Consequently, dispersing the mixture with an ejector and adding the foaming surfactant Neftenol VVD allows the booster pump to operate successfully up to 50% gas content at the inlet, which allows the successful use of a pump-ejector system for injection of water-gas mixtures at the Rechitskoe field in a wide range of gas contents.

In addition, it is known [26, 27] that the use of surfactant compositions, in addition to increasing the foaminess and stability of gas-liquid mixtures, is very effective for increasing oil recovery from carbonate reservoirs. Previously, the addition of an alkaline agent to aqueous solutions of surfactants (Neonol AF9-10 and AF9-12) was used in 1988 during waterflooding on the same intersalt deposit of the Zadonsk horizon of the Rechitskoe field during a field experiment. Then both a decrease in water cut and an increase in oil production rates were obtained. This makes it possible to use, when introducing SWAG-technology at the Rechitskoe field, the synergistic effect of increasing oil recovery from the use of injection of water-gas mixtures with surfactants, flue and flare gases from the BGPZ, while simultaneously reducing the carbon footprint and the environmental situation by reducing emissions of industrial gases into the atmosphere.

5 Conclusion

To solve the extremely pressing problem of technology and equipment for the RUE "Production Association "Belorusneft" for the effective implementation of water-gas impact, the most acceptable option is the use of pump-ejector systems.

Since RUE Belorusneft utilizes almost all associated petroleum gas, with most of it supplied to the BGPZ, to resume work on SWAG-technology, it is advisable to use flue and flare gases from the BGPZ, which is conveniently located almost on the border of the Rechitskoe oil field, as a working agent.

This will make it possible to organize SWAG-technology at the Rechitskoe field with minimal costs. At the BGPZ it is necessary to install a medium-pressure compressor for pumping flue and flare gases, and also to lay a gas pipeline from the compressor to the oil field, where the BKNS of the pressure maintenance system is located. A pump-ejector system should be placed in the field by connecting the ejector nozzle to the flow line of the BKNS pump, the ejector receiving chamber to the gas pipeline from the compressor, and the outlet to the water conduits to the injection wells.

The use of foaming surfactants makes it possible to significantly increase the stability of water-gas mixtures, expand the operating area of the booster pump without reducing characteristics, and also use the synergistic effect of increasing oil recovery while introducing SWAG-technology at the Rechitskoe field while reducing the carbon footprint and the environmental situation by reducing emissions of industrial gases into the atmosphere.

Acknowledgments

The research was carried out at the expense of the grant of the Russian Science Foundation (RSF) № 24-29-00882 "Scientific substantiation of technology for increasing the stability of water-gas mixtures to increase oil recovery while reducing the carbon footprint" (https://rscf.ru/en/project/24-29-00882/).

References

1. P.P. Povzhik, N.A. Demyanenko, *System-addressed approach to the development, planning and implementation of technologies for enhancing the production of hard-to-recover and unconventional oil reserves in the fields of the Pripyat trough* (Minsk, Four quarters, 2023)
2. S.V. Arefiev, A.Yu. Bruslov, A.V. Denisov, Bulletin of Russian academy of natural sciences, **24**(1), 47-56 (2024)
3. P.N. Strakhov, A.A. Belova, A.A. Markelova, E.P. Strakhova, Oil Industry, **2**, 46–49 (2021) DOI: 10.24887/0028-2448-2021-2-46-49
4. A.Yu. Belov, A.A. Belova, P.N. Strakhov, Oil Industry, **3**, 50–53 (2021) DOI: 10.24887/0028-2448-2021-3-50-53
5. Y. Shestopalov, A. Shakhverdiev, Symmetry, **13**(**10**), 1884 (2021) DOI:10.3390/sym13101884
6. A.K. Shakhverdiev, Y.V. Shestopalov, I.E. Mandrik, S.V. Arefiev, Oil Industry, **12**, 118–123 (2019) DOI:10.24887/0028-2448-2019-12-118-123
7. A.K., Shakhverdiev, Y.V. Shestopalov, Lobachevskii Journal of Mathematics, **40**(**10**), 1695–1710 (2019) DOI:10.1134/S1995080219100226
8. A.Kh. Shakhverdiev, G.M. Panakhov, E.M. Abbasov, I.E. Mandrik, S.I. Bakhtiyarov, Oil Industry, **11**, 76–78 (2006)
9. A.Kh. Shakhverdiev, G.M. Panakhov, E.M. Abbasov, Oil Industry, **11**, 61–65 (2002)
10. A.Kh. Shakhverdiev, L.P. Rybitskaya, Oil Industry, **4**, 65–68 (2003)
11. A.N. Drozdov, N.A. Drozdov, E.A. Malyavko, Y.L. Alekseev, I.K. Shayhutdinov, A.G. Zakharyan, *Society of Petroleum Engineers - SPE Russian Oil and Gas Exploration and Production Technical Conference and Exhibition 2012*, **2**, 852–866 (2012) DOI:10.2118/160687-ms
12. P.P. Povzhik, A.A. Kudryashov, K.Yu. Medvedev, *Prospects for the use of gas methods to increase the oil recovery factor at the fields of RUE PA Belorusneft. In: Effective technologies for the development of hydrocarbon deposits*, in Proceedings of the international scientific and practical conference, October 1-4, 2013, Gomel, Rechitsa, 58-64 (2013)

13. M.M. Irani, V.P. Telkov, SOCAR Proceedings, **S2**, 248-256 (2021) DOI: 10.5510/OGP2021SI200606
14. Yu.A. Poddubny, A.Yu. Poddubny, Drilling and oil, **12**, 43-49 (2020)
15. S.I. Grimus, SOCAR Proceedings, **3**, 24-28 (2010)
16. K.Yu. Medvedev, P.P. Povzhik, A.A. Kudryashov, Engineering practice, **8**, 92-97 (2013)
17. V.A. Banny, I.V. Lymar, E.N. Khodkov, A.A. Tishkov, Engineering practice, **8**, 104-105 (2013)
18. A.A. Kudryashov, *Results of the experimental implementation of water-gas stimulation in the fields of the Republic of Belarus*, In: Effective technologies for the development of hydrocarbon deposits. Abstracts of reports of the international scientific and practical conference, October 1-4, 2013, Gomel, Rechitsa, 58-64 (2013)
19. Results of the experimental implementation of water-and-gas method in the fields of the Republic of Belarus (https://www.belorusneft.by/sitebeloil/.content/docs/conf_011013_stuff/section1/kudryashov---rezultaty-opytnogo-vnedreniya-vodogazovogo-vozdejstviya-na-mestorozhdeniyah-respubliki-belarus.pptx?ysclid=ltn1mf9trc493673446)
20. V.S. Verbitsky, K.A. Goridko, A.E. Fedorov, A.N. Drozdov, Oil industry **9**, 106-109 (2016)
21. A.N. Drozdov, E.I. Gorelkina, SOCAR Proceedings, **S2**, 009-018 (2022) DOI: 10.5510/OGP2022SI200734
22. A.N. Drozdov, E.I. Gorelkina, Journal of Mining Institute, **254**, 191-201 (2022) DOI: 10.31897/PMI.2022.34
23. V.S. Verbizky, K.A. Goridko, A.E. Fedorov, A.V. Dengaev, V.N. Martynov, Oil Industry, **11**, 132-135 (2015)
24. https://www.google.ru/maps/@52.2958445,30.2338663,2090m/data=!3m1!1e3?entry=ttu
25. A.N. Drozdov, V.S. Verbitsky, D.N. Lambin, A.V. Dengaev, *Society of Petroleum Engineers - SPE Production and Operations Symposium 2011*, *SPEOKC 2011*, SPE 141291, Oklahoma City, OK, 311-317 (2011)
26. N.A. Veremko, Oil and Gas Industry, **2**, 11-12 (1989)
27. L.E. Lenchenkova, *Enhanced oil recovery using physical and chemical methods* (Moscow, Nedra, 1998)