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Increasing the efficiency of operating time and reducing maintenance time of transport systems

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Abstract
The Gremikhinsky oil field contains heavy-grade, high-sulfur, high-resinous, paraffin-base crude oil, and the produced reservoir fluid is highly corrosive. All this results in the formation of asphaltene-resin-paraffin deposits (ARPD) and stable oil-water emulsions, which in turn leads to premature failure of downhole pumping equipment. In this work, the scope of measures to prevent malfunctions of pumping units is considered. The use of the SONKOR-9701 inhibitor through a special design of the ESP power cable with a capillary conveying line for supplying the chemical reagent to the reception delivers the chemical reagent directly to the required entry point with the most effective dosage and ensures a prompt change of the dosage and type of the reagent. With this technology, the reagent is not consumed for the repletion of the oil column in the annular space; its adsorption is on the surface of the casing and tubing. Thus, the reagent targeted with just specific technological causes and the greatest effect is ensured. Due to the introduction of a special cable with a capillary conveying line, it is planned to increase the average operating time for failure and, consequently, reduce the maintenance job at the Gremikhinsky oil field. It is also predicted the additional volume of extraction because of a special submersible cable device (SSCD), as well as by increasing the delivery (capacity) rate of the pump.

Keywords
Oil, electric centrifugal pump, time between failures, reagent.

Introduction

Most of the fields currently in operation are at the third stage of development. The depletion is accompanied by large volumes of associated water with a water cut of 95.8% (Energybase, 2022).

The stock of operating wells of the Bashkir facility of Gremikhinsky field (Dyachuk, 2015) operates 185 electric pumping units with a theoretical efficiency from 45 m^3/day to 400 m^3/day. The depth of the pump descent is in the range of 843-1275 m at dynamic levels of 171-1088 m; the charge coefficients are 0.1-1.8.

The flow rate of wells for liquid at the Bashkir facility is 2-525 m^3/day with a water cut of 45-99%; production indices vary in the range of 0.4-139.2 m^3/day/MPa (Abd Ali et al., 2021). Reservoir pressures in the recovery zone are 6.0-13.8 MPa, bottom–hole pressures are 1.3-10.2 MPa, which is 25-200% of the oil bubble-point pressure.

Since the facility is at the third stage of development, the wells have been in operation for a large amount of time. Therefore, there is a decrease in the time between failures (Ageev 2011).

Figure 1 shows the dependence of ESP failures on operating time.

Some wells have reached a water cut of 99%, which is due to its breakthrough through the washed layers, as well as possible leakiness of well fasteners (Handrik et al., 2017). There is no significant growth in oil production in wells. It is worth mentioning the factors complicating the operation of the ESP, including the high viscosity of the fluid and the corrosive activity of the produced fluid.

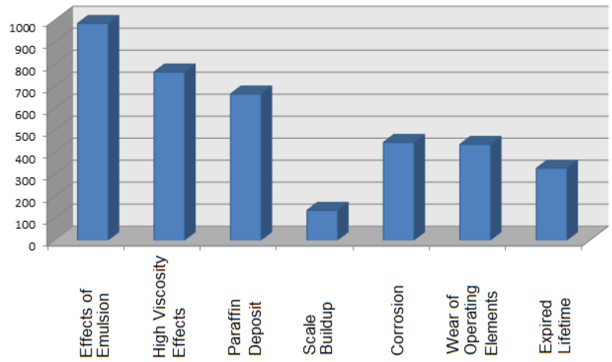

Fig. 1. Dependence of ESP failures on operating time

The hazard of accidents in wells equipped with submersible centrifugal pumps for oil production will be the main concern for many years to come, requiring great efforts from developers and manufacturers to solve it (Bulatov, 2014). The chief causes for the failure of the ESP at the Gremikhinsky oil field are shown in Figure 2.

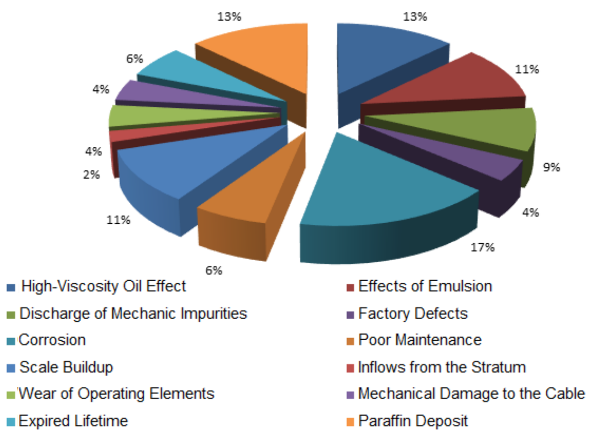

Fig. 2. The main causes for the failure of the ESP at the Gremikhinsky oil field

Under complicated geological and physical conditions for the main development facilities of the Gremikhinsky oil field (Saga, Blatnicka et al., 2020), the operation of the electric centrifugal pumps of the ESP occurs with various difficulties. The main types of complications are:

– deposition of asphaltenes, resins and paraffin in the bottom-hole zone of the formation and on the surfaces of the borehole and ground equipment;
– scale buildup in the bottom-hole zone of the formation and on the surfaces of the borehole and ground equipment;
– formation of stable oil-water emulsions in the well and oil pipelines;

– premature failure of deep-pumping equipment in directional wells;
– corrosion of borehole and ground equipment.

The simultaneous effect of all these factors, the natural wear of the ESP equipment, strongly affects the technological indicators of oil production and causes the need for additional geological and technical measures to restore the productivity of wells and increase the average operating time for failure of downhole pumping equipment (DPE) (Sapietova, Saga et al., 2011).

Material and Methods

In recent years, there has been a tendency to increase the number of refusals due to a decrease in the injection. Consequently, it is necessary to competently select equipment at wells and establish its technological mode of operation to ensure optimal operation of the reservoir – pump system.

The causes for the increase in scale buildup failures are (Causes, 2022): the lack of a forecast; the lack of intake capacity of the well for injecting scale inhibitors during well servicing; the location of ECP units for a long time in a salt-saturated environment. Basically, iron sulfide deposits occur at these wells, for which there is no effective inhibitor (Klarák et al., 2022). Sometimes violations of treatment technologies occur; the volumes of the injected inhibitor are not equal to the issue of protection against scale buildup for a given period of time (from 6 months to one year). The lack of intake capacity of the well leads, in some cases, to the failure of workable units of an electric centrifugal pump (ECP) during the post-guarantee maintenance.

Cleaning of the faces and flushing of the borehole with subsequent post-guarantee maintenance during wellbore intervention should be a prerequisite in the fight against scale buildup. Failures of installations due to wear of the pump's working units have decreased compared to 2014, but this does not mean that the problem has been solved unambiguously positively in all cases (Kuric, Klačková et al., 2022). There is much work to be done for oil fields to optimize the operating modes of wells equipped with ESP units in order to prevent the wear of operating parts. Failures due to corrosion of downhole motors (DHM) and the wear sleeves have not decreased. The addition of a corrosion inhibitor during post-guarantee maintenance has not given any significant changes due to the lack of intake capacity of the well; paraffin deposits also remain the main issue that reduces the efficiency of DPE. At wells with scale buildup, it is necessary to raise failed ESP units in a timely manner in order to prevent hardness deposition and corrosion (Wiecek, Burduk et al., 2019).

Problems associated with the formation of heavy oil deposits and asphaltene sediments during the operation of wells are accompanied by a number of other complications that aggravate the situation in the production of high-viscosity oil.

Currently, the vast majority of production wells are drilled by the cluster method, which causes the drilling of slanted and horizontal wells. To a certain extent, the curved sections of wells negatively impact the mean time before failure (Midor et al., 2022; Ivanova et al., 2022).

During the operation of wells with submersible electric centrifugal pumps, round-trip operations are complicated and slowed down, the cable is often damaged, and there are cases of deformation of units.

Despite the fact that the pump decent interval (Kopas, Saga et al., 2017), as a rule, is located at the site of stabilization or reduction of the angle of inclination, the overall curvature along the wellbore and, especially the rate of curvature changes in the pump setting interval directly affects the operating time of pumping equipment for failure and can lead to accidents. In practice, there are often cases when the ESP is lifted without an electric motor and the lower section of the pump, and the break occurs during the operation of the pump or when lifting. As a rule, the studs in the connecting elements of the pump break off or turn away (Saga, Jakubovicova, 2014). That occurs because of the following factors:

– poor-quality manufacture of studs, as well as their installation without spring washers;
– bending of the units during round-trip operations, as a result of which there is a residual deformation of the studs;
– vibration of the units under relatively small bending forces.

To eliminate the latter factor, the choice of the pump release interval is important. The operating manual of the ESP limits the curvature of the well in the area of operation of the installations. The rate of curvature set should not exceed three minutes at 10 m depth.

Thus, the recommendations for reducing the accident rate of ESP can be summarized as follows (Nasyrov, 2020):

1. To increase the effectiveness of treatments against scale buildup, monitor the removal of the inhibitor in all treated wells. Post-guarantee maintenance and round-trip operations should be carried out only after bottoms up and injection logging during well servicing.

2. Increasing the submergence of the ESP under the dynamic level with the provision of free gas by no more than 5-15%.

3. Treatment against heavy oil deposits, asphaltene sediments and emulsion in wells equipped with ESP should be carried out in a complex way: by chemical method – by a periodic supply of an inhibitor (solvent) and emulsifier into the well annulus.

4. In case of leaks in the tubing through the body, conduct a metallographic analysis for the quality of the metal.

5. When setting a coated ESP complete with centralizers for fear that it could undergo any mechanical damage.

6. On well servicing, the flushing of the bottom holes of wells equipped with ESN installations should be carried out qualitatively, and fresh water and oil should be used in absorbing wells to prevent formation clogging and loss of productivity (Saga, Vasko, 2009).

These measures make it possible to reduce the number of accidents with the ESP by an average of 30-50% (subject to the technology of installation and descent operations).

To address the harmful effect of gas on the operation of the ECP, the submersion of the pump under the dynamic level is carried out, as a result of which the pressure at the intake increases and the volume flow of free gas decreases due to compression, i.e., the solubility of the gas in oil increases (Saga, Blatnicky et al., 2020). At a depth where the pressure at the pump intake is greater than or equal to the saturation pressure of oil, all gas is dissolved in oil, and its harmful effect ceases. However, this additionally requires tubing, cable, and a pump that develops a greater head.

Currently, scientific and technological progress is heading towards using ESPs designed to work with increased input gas content (Muravev et al., 2019; Moroz et al., 2020). For this purpose, the first 10-15 working stages (impellers and guide devices) installed on an increased supply of gas-liquid mixture are used. In field conditions, it is easy to do this using working stages from a pump of the same dimensions but with a larger feed (Kopas et al., 2017).

From the analysis of the work of the ESP, it can be seen that the main reasons for the failure of the ESP in recent years remain unchanged since the working conditions of the ESP are difficult and sometimes unacceptable. This is influenced by the high water cut, hardness, corrosion aggressiveness of the extracted water due to the ageing of deposits, deposits of paraffin, large removal of mechanical impurities and sand as a result of large depressions in the formation and a large content of suspended solids (CSS) in the waters used, especially in the initial stage of injection into the formation.

Methods of Dealing with Complications During the Operation of ESP at the Gremikhinsky Oil Field

Measures to optimize the operation of downhole pumping equipment (DPE) can be attributed to one of the most significant geological and technical measures (GTM) in the field. This type of GTM is the simplest and most effective means of increasing and maintaining the level of production in the field. Additional oil production in this type of GTM is associated with forced fluid extraction, as a rule, with an increase in the water cut of the extracted fluid. An increase in the pump size and pumping parameters leads to an increase in the depression on the formation, which contributes to the flow of fluid from previously unreached sublayers. At the same time, the impact on the sublayers is not carried out selectively, as a result of which water inflows through the most permeable sublayers or overflows due to leakage of cement behind the column are possible. These measures can be dangerous as far as sharp water breakthroughs. Therefore, it is necessary to constantly monitor the water content of the products of optimized wells in order to take appropriate measures in the event of a water breakthrough. The success of the optimization is also high due to the duration of the effect (Vasko, Saga et al., 2020). The duration of the effect in the form of increased oil extraction through wells varies from several months to several years.

Measures to optimize the DPE in the field were carried out annually; the maximum number falls in 2008 and 2009. The most effective measures are such as increasing the diameter of the ESN and sucker rod pumps (SRP) and transferring wells from SRP to ESN. Due to 135 GTM (12.2% of the total number of GTM) carried out during the analyzed period at 117 wells, 143.3 thousand tons of oil were additionally produced (excluding the transition effect), which is 23.3% of the total amount of additional production. However, due to these measures, 9 times more water was additionally extracted. High costs are required for further preparation of highly watered products and disposal of reservoir waters; therefore, it does not always become economically profitable to use such GTM.

Measures to Prevent and Combat Heavy Oil Deposits, Asphaltene Sediments

The main factors that determine the possibility of passing the processes of heavy oil deposits, asphaltene sediments on the oilfield and downhole equipment during the development of the field are:

– low reservoir temperatures (28° C), their decrease in the bottom-hole zone of the formation, when the liquid rises along the tubing column and moves through the oil collection system;

– high content of sulfur (up to 6.36%), asphaltene sediments (up to 34.4%), paraffin (up to 5.77%), and other high molecular weight hydrocarbon compounds in the extracted oil.

To prevent heavy oil deposits, asphaltene sediments (Mitroshin 2020) during the development of the Gremikhinsky oil field, it is recommended to apply the following measures:

1. In problem areas, the use of asphaltene-resin-paraffin deposits inhibitors (SNPH-1004, SNPH-7843, Progalit, etc.) by feeding dosing pumps into the annulus of wells. The dosage of the inhibitor is determined experimentally and depends on the properties of the oil and its water content.
2. The use of tubing with glass enamel coatings. Tested on the fields of JSC Orenburgneft. The strength and adhesion of the enamel are high; chips are not observed during the descent operations and transportation. The use of this type of coating reduces the number of asphaltene-resin-paraffin deposits on the inner surface of the tubing and protects against corrosion and abrasive wear.

It is proposed to use the following measures to remove asphaltene-resin-paraffin deposits:

1. With a slight curvature of the borehole (the zenith deviation of the trunk is no more than 5-10°) and the absence of formation of persistent emulsions, the use of plate scrapers on rods with a rod rotator or centralizer scrapers is recommended. This technology, in most cases, allows one to completely abandon the washing of elevators of these wells with hot oil. A petal scraper can be used to clean unlined tubing at wells equipped with ESP. To do this, the wellhead fittings must be equipped with a lubricator device. The descent and ascent of the scraper are carried out by means of a manual or automatic winch.
2. Washing of tubing columns with solvents such as ML-72, ML-80, hydrophobic emulsion solutions, hexane fraction, salt-benzine mixture, and RT-1 reagent. All these reagents are used in the fields of Udmurtia. Flushing by the recirculation method "lift-tube" enables asphaltene-resin-paraffin deposits to be removed from the surfaces of downhole equipment in the interval from the wellhead to the depth of the pump descent. To carry out these operations, the acid pumping unit UNK-16/5.118 and the acid treatment unit of wells ANC-32/50 can be used.
3. The use of steam-mobile units (SMU-1600/100) to remove asphaltene-resin-paraffin deposits from the surfaces of downhole equipment is effective during the wellbore intervention. Steaming of the equipment on a specially equipped rack, which excludes environmental pollution with petroleum products, ensures almost complete removal of asphaltene-resin-paraffin deposits from the equipment. Steam-mobile installations are successfully used to remove asphaltene-resin-paraffin deposits from the internal surfaces of short switch lines and pipelines mounted from steel pipes without lining, group measuring unit (GMU), other units and devices that do not have parts made of not thermally resistant materials.
4. Start of scrapers and balls in the systems of in-field oil transportation to remove asphaltene-resin-paraffin deposits from the inner walls of pipes. The pipeline section must be mounted from steel pipes without internal lining, one inner diameter without constrictions and extensions and must be equipped with chambers for starting the device, receiving the device, and a container for collecting solid paraffin.

Measures to Prevent and Combat Scale Build-Up

During the operation of the Gremikhinsky oil field, scale buildup on borehole equipment is possible due to changes in thermodynamic conditions and the physical and chemical equilibrium state of the salt-associated water during its movement from the reservoir into the wells, from the perforation zone to the mouth along the tubing column and further along the oil collection system (Figiel, Klačková 2018). In addition, during major repairs of wells, repairs of borehole equipment and technological operations, it is possible to mix reservoir water with water of a different salt composition, which also causes a violation of the physical and chemical equilibrium of fluids.

In practice, there are no effective methods for removing hardness from the walls of equipment. Therefore, the main role in the fight against scale buildup is played by their prevention.

The choice of methods for preventing scale buildup at the Gremikhinsky oil field should be based on the results of studies of the probability of precipitation of certain salts in oilfield equipment. Diagnostics of the probability of precipitation of salts dissolved in reservoir water into sediment is recommended to be carried out by constant monitoring of the chemical composition of the waters extracted from wells along the way. With a high degree of probability (95%), wells are planned to be treated with appropriate inhibitors.

Scale buildup prevention can be implemented using reagent and non-reagent methods:

1. Reagent methods that are based on lowering the rate of scale buildup under the action of special reagents called scale inhibitors. The following inhibitors of Russian production are recommended for well treatment: PAF-13A, SNPH-5311, SNPH-5312 (for carbonate precipitation); Incredol, NTF, ICD-1, PAF-41, SNPH-5301 M, SNPH-5312, SNPH-5314 (for carbonate and gypsum precipitation). The main advantages of these products are their high efficiency at relatively low costs, about 1-20 mg/l, high thermal stability (90-150°C), and good compatibility with polymers, glycols, corrosion inhibitors and emulsifiers.
2. The use of equipment and pipes with protective coatings that reduce the roughness of the walls and adhesion strength.
3. Reduction of the water content of the extracted products (water isolation measures).

Measures to Prevent and Combat Scale Build-Up

Oil extracted from wells together with reservoir water forms stable oil-water emulsions under certain conditions. The stability of emulsions depends on many factors, the main of which are:
– the degree of dispersion of the emulsion;
– a type of emulsifier that forms armour shells on the surface of water droplets, the mechanical strength of which increases over time;
– pH of emulsified reservoir water;
– the presence of a double electric charge on the droplets of the dispersed phase;
– temperature of mixing liquids (water and oil);
– viscosity of oil, etc.

Over time, emulsions go old, become more resistant and are difficult to destroy, so it is necessary to prevent the formation of persistent emulsions at the very beginning of the technological process of oil production, that is, in the well (Buryukin 2020). To this end, the following measures should be carried out in the field:

1. The choice of the operating mode of the well and pumping equipment should be made from the conditions of the least stuttering and mixing of the flow.
2. The use of emulsifiers, which are fed by dosing pumps to the bottom or to the wellhead, to separate sections of the oil collection. The most effective emulsifiers for the destruction of oil-water emulsions of the Gremikhinsky oil field are Reapon-4B, SNPH-4315D, DIN-1D, STX-6, and OFC-D. The range of emulsifiers is constantly updated by domestic and foreign manufacturers. The selection of the most effective reagents is carried out experimentally, first in the laboratory and then in field conditions.

Corrosion Prevention and Control Measures

During the operation of the field, downhole and oilfield equipment may be corroded.

Corrosion can be caused by the high corrosion activity of the associated water and the use of highly aggressive agents in the treatment of the bottom-hole zone to increase the well's productivity.

At the stage of construction of new wells, in order to prevent external corrosion destruction of production columns of producing wells from the impact of reservoir waters, special attention should be paid to the quality of well fastening, high-quality cementing of casing columns with cement bringing to the wellhead. To increase the tightness of threaded connections of casing pipes, it is necessary to use sealing materials.

During operation, geological and technical measures with the use of highly aggressive surroundings for processing the bottom hole zone should be regulated to protect the columns of producing wells. When injecting reagents, measures should be provided to reduce their corrosive activity.

The cause of corrosion of oilfield equipment may be the presence of hydrogen sulfide in the extracted products, the formation of which in reservoir products is caused by the vital activity of sulfate-reducing bacteria (SRB). Contamination of reservoir systems by microorganisms usually occurs during the injection of surface waters containing sulfates and microflora, for example, during technological and repair operations. SRB can be located in oilfield apparatuses, pipes and tanks, for example, under the sediments of paraffin, mechanical impurities, corrosion products and thickened oil.

In order to prevent corrosion of technological equipment, it is necessary to monitor the intensity of corrosion using test samples constantly. If an increase in the rate of corrosion is detected, it is recommended to implement a set of measures aimed at both increasing the corrosion resistance of equipment and reducing the corrosion activity of the extracted products.

In order to increase the corrosion resistance of the equipment, it is recommended to replace the most critical components and parts with those made of stainless alloy steels, polymer materials or polymer coatings. With the high water content of the extracted products and the absence of ARPD deposits in the oil collection system, it is preferable to use pipes with internal lining, for example, polyethene.

Reduction of the corrosion activity of the extracted products is achieved by methods of treatment of wells and equipment with bactericides (Alpan, SPNX-1004, Soncid-8101, Soncid-8102, SNPH-1050, etc.) and dosing of corrosion inhibitors into wells and the oil collection system (SNPH-1004, Corexit SXT-1003, Sonkor-9701, etc.) (Morozov 2009).

Results

The Main Directions for Increasing the Average MTBF of Wells Equipped with ESP

The reservoir fluid produced by the pumps has a high corrosion activity. For this reason, mainly it concerns the submersible motor and hydraulic protection, thousands of submersible electric motors are written off annually in our country. Currently, there are quite a large number of ways to meet these issues.

Chemical, physical and technological methods of corrosion protection are distinguished.

Chemical methods. Depending on the mechanism of action, barrier-type corrosion inhibitors, neutralizing, removing, and others are distinguished. The effect of barrier-type reagents is based on the formation of a film on the surface of the equipment, neutralizing - by increasing the pH of the medium, removing - by removing aggressive components from the medium. The category of other inhibitors includes reagents that suppress the vital activity of bacteria, primarily SRB. Corrosion inhibitors can be fed both into the well and into the reservoir. The supply to the well can be carried out by means of wellhead dispensers into the annular space or to a given point along the capillary by periodic injection into the annular space using aggregates or submersible borehole containers. In the case of using an encapsulated reagent, it is "loaded" into the sump. The reagent is fed into the reservoir by injection into injection wells through the maintaining reservoir pressure system or by introducing an inhibitor with a silencing fluid.

Among the new feeding technologies, it is possible to note the injection of an inhibitor in a vaporous state (VapourrhaseCorrosionInhibitor, VpCI) by Cortec. Using this steam, all microcracks on the surface of the equipment can be delivered, thereby forming a very thin and dense protective coating. However, this method is quite complicated from the point of view of implementation technology.

Capillary tubes are also manufactured by various companies. The line of these products can be considered on the example of the company Inkomp-Neft (Ufa). One of the manufacturers of capillary systems is the Perm company Synergy-Leader". It supplies a set of equipment consisting of a dispenser, a capillary tube and additional components necessary to implement the technology. The installation includes a submersible metering valve with a disconnecting element for mixing the chemical reagent with the extracted products and a tubing coupling that provides the reagent into the tubing column to any depth. Among the advantages of this technology, it should be noted the high accuracy of reagent dosing, reduced consumption relative to injection into the annular space and the ability to quickly determine the required concentration of the reagent and the effectiveness of its action. At the same time, such a unit is difficult to mount, and its use increases time and costs.

Physical methods. Today, various grades of steel and alloys are used to manufacture oil-producing equipment, which has different degrees of resistance to corrosion. It is recommended to use a corrosion inhibitor when operating equipment made of low-alloy steel, whereas equipment made of high-alloy steel and nickel alloys do not require inhibition. Today, almost every manufacturing company has its own "recipe" for the manufacture of corrosion-resistant materials. Thus, REDA offers niresist-4 (30% Ni, 5% Cr, 5.5% Si, 1% Mn, 2.6% C) and steel-5530 (30.5% Ni, 5.3% Cr, 5.1% Si, 2.7% C, as well as Mo, V, Mn). Both materials are characterized by resistance to aggressive environments and significant wear resistance. At the same time, they are distinguished by their high cost. The working bodies of the ECN can also be made of polymer materials. Such parts have a number of advantages over products made of traditional steel and alloys. Thus, the polymers produced by Izhnefteplast are characterized by corrosion resistance and low weight, which in turn reduces the mass of the rotor and starting currents. The high purity of the flow channels and low adhesion of the material contributes to an increase in the efficiency of the ECP by 3-5%. When using polymers, galvanic pairs are not formed between the materials, and it is possible to change the material of the guide bushing. An important characteristic of polymers is their relatively low cost. At the same time, the effectiveness of their use in the composition of the ECP is limited by the unprocessed technology of re-application of working bodies after operation in Western Siberia and low resistance to mechanical impurities.

Application of protective coatings. The physical meaning of the use of protective coatings, representing the second group of physical methods of corrosion protection, is to isolate the material's surface from aggressive media, bacteria and mechanical wear (Babusiak et al., 2021). Depending on the chemical composition, there are epoxy, phenolic, epoxy-phenolic, novolac, nylon, urethane and polyethene coatings. There are special technologies for applying protective coatings. These technologies make it possible to apply stainless iron-based alloys, nickel-based alloys, hard alloys, stainless steels, zinc and aluminium, as well as their alloys, as coatings. The technologies provide high adhesion strength of the coating to the protected surface, while they are distinguished by the complexity of the application and high cost.

Technological methods. Technological methods of corrosion control include, in particular, the selection and preparation of an agent (water) in the maintaining reservoir pressure system. The injected agent for this event is selected, taking into account the corrosive aggressiveness of the medium. Fresh water sources are checked for the level of contamination of SRB. This method is very effective, but its implementation involves the presence of several sources of water for injection, as well as significant costs for the preparation of the agent. Another technological method is to limit the water flow into the well. It is used in the case of water intake due to leakage of the EC and cement stone; its implementation requires cattle. In the case of a water breakthrough in a productive reservoir, water-insulating compositions are used within the framework of the method. The disadvantages of the method include the complexity of implementation and significant costs.

Discussion

Selection and justification of the use of technology to increase the MTBF

To address the concerns of reducing scale back-up, heavy oil deposits, asphaltene sediments, and corrosion, according to RF patent No. 24040 dated 29.01.2012, a special cable device (SSCD) is manufactured with a capillary in a common armoured sling for supplying various reagents to receive submersible pumps.

To prevent the impact of corrosion on the deep-pumping equipment, the Sonkor-9701 inhibitor is dosed through SSCD at the rate of 30 g/m^3 of liquid.

The primary task is to reduce the specific consumption of chemical reagents and increase the efficiency of their use in conditions of a complex composition of the extracted emulsion.

In this regard, the Bashneft company has developed and implemented technology for dosing chemical reagents for receiving deep pumps (Klačková et al. 2020). The technology consists of the following: a special design of the ESP power cable with a capillary channel for supplying a chemical reagent to reception has been developed. Figure 3 shows the construction of a special cable with a polyethene tube.

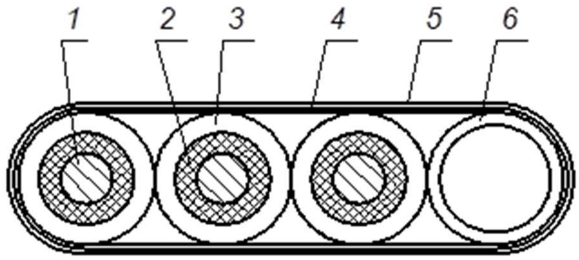

Fig. 3. Construction of a special cable with a polyethene tube:
1-copper core; 2, 3-insulation layer; 4-rubberized fabric layer; 5-armour made of galvanized steel tape; 6-capillary polyethene tube

The flow diagram of the inhibitor is shown in Figure 4.

During the underground service of a complicated well, the power cable of the ESP electric motor is changed to a special cable with a capillary tube (Kuric, Gorobchenko et al., 2019). Depending on the task, the dosing of the chemical reagent is carried out either at the interval of perforation of the well or at the reception of the borehole pump.

A container with a chemical reagent and a metering pump is installed at the wellhead. The dispenser tank is filled with a chemical reagent, and the selected reagent is dispensed into the well using the dispenser pump.

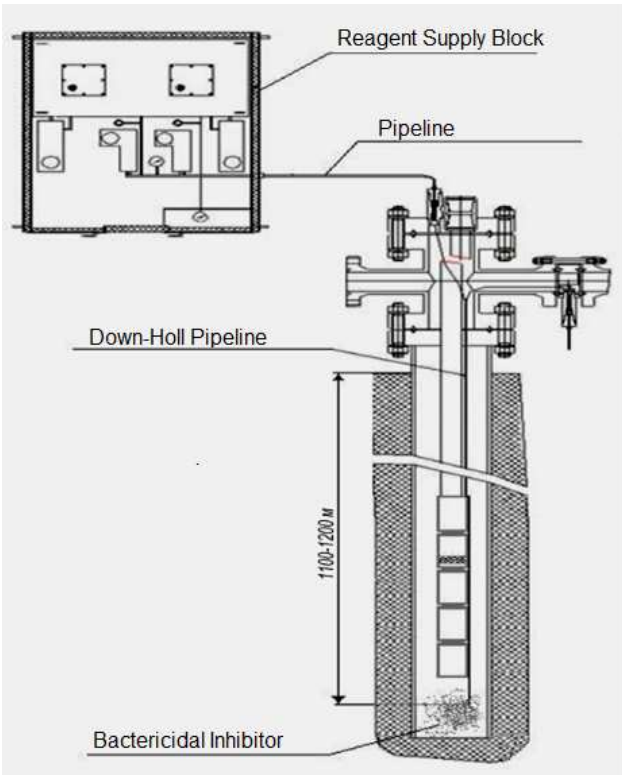

Fig. 4. Flow diagram of the inhibitor

During the underground service of a complicated well, the power cable of the ESP electric motor is changed to a special cable with a capillary tube (Kuric et al., 2021). Depending on the task, the dosing of the chemical reagent is carried out either at the interval of perforation of the well or at the reception of the borehole pump.

A container with a chemical reagent and a metering pump is installed at the wellhead (Klačková et al., 2019). The dispenser tank is filled with a chemical reagent, and the selected reagent is dispensed into the well using the dispenser pump.

This technology ensures the delivery of the chemical reagent directly to the required entry point with the most effective dosage and allows to change of the dosage and type of the reagent quickly. With this technology, the reagent is not consumed for saturation of the oil column in the inter-tube space, its adsorption on the surface of the casing and tubing (Kuric, Klarák et al., 2022). This achieves the most economical consumption of it exclusively for specific technological purposes and ensures the greatest effect from the use of a chemical reagent.

Equipment for the metered supply of chemical reagents is used in the operation of oil and gas wells in complicated conditions (Blatnicky, Dizo et al., 2020). It is intended for metered injection of liquid emulsifiers and inhibitors into pipelines and installations of the field oil transportation and treatment system, into the deep pump reception area, into the perforation zone, and into the annulus space in order to carry out oil demulsification inside the pipeline and protect pipelines and equipment from corrosion, salt gypsum deposits. The equipment is manufactured in an explosion-proof design (Baniari, Blatnicka et al., 2017). It is used in temperate and cold climates. The ground equipment serves to supply the reagent from the dosing point to the downhole equipment. The downhole equipment is designed to supply the reagent to a given depth. The reagent supply equipment (RSE) consists of a wellhead unit for the reagent supply (WURS) and ground equipment.

Equipment is installed in the wellhead reagent supply unit: a metering pump that performs continuous volumetric dosing of reagents, a technological tank, and an instrumentation and automation section.

The process tank has a level indicator for visual monitoring of the liquid level, as well as for monitoring the reagent flow. It is manufactured in two versions: carbon steel with anti-corrosion coating and stainless steel 10X18H10T.

The control system supports: local control of the pump-dispenser drive – start / stop from the manual control panel, two programmable modes of operation of the dispenser: continuous, cyclic (periodic stop and start of the drive), automatic stop of the dispenser to control the pressure in the discharge line.

The wellhead unit WURS /04.00K-0.7/250-0.4 was selected for this project,

where WURS is the wellhead unit for reagent supply;

04.00 – execution;

K – corrosion-resistant design of the container;

0.7 – feed, l/hour;

250 – nominal pressure of the pump, kg /cm^2;

0.4-volume of the tank, cubic.

The ground equipment consists of a ground pipeline and an input device. The ground pipeline supplies the reagent to the wellhead valve input device. It is a thin-walled stainless steel tube protected from mechanical damage by two layers of steel wire braid.

The UBPR executions are presented in Table 1.

Table 1. Execution of UBPR

Parameters	**WURS-04.00**	**WURS-04.01**
Insulated container with a heated container	+	1
Temperature control of the reagent in the tank, automatic control of the tank heater according to the relay control law – turning on the heating when the set minimum temperature is reached and turning off when the set maximum is reached	+	2
Monitoring of the reagent level in the tank by two discrete threshold signals on request on request	on request	on request
Control of the operation of the metering pump drive	on request	on request

The pipeline is manufactured by a conditional passage DN 4 and DN 6. To prevent corrosion wear of the pipeline, several protection options are provided, depending on the operating conditions.

Technical specifications are presented in Table 2.

These technical conditions apply to the film-forming corrosion inhibitor SONKOR-9701, designed to protect the equipment and pipelines of the waterlogged oil collection system and reservoir pressure maintenance systems from corrosion caused by the aggressiveness of the pumped medium, with a constant dosage.

The corrosion inhibitor SONKOR-9701 is a mixture of the reaction product of amines and fatty acids of tallow oil with solvents.

To protect the working bodies of the ESP and tubing columns from the deposition of paraffin and corrosion, the capillary tube descends below the compensator. To avoid damage to the tube in the range of the electric motor, centralizers are installed on the tread and compensator. In wells with buffer pressures, the ends of capillary tubes are equipped with check valves. Diagnostic methods of electrical equipment in failure mode can also be considered (Abramov, 2015, Nikitin 2020, Peterka 2020; Kovanič 2013; Kovanič 2019; Kovanič 2020; Kovanič 2021).

Due to the introduction of a special cable with a capillary tube, it is planned to increase the average operating time for failure and, accordingly, reduce the number of ongoing repairs at the Gremikhinsky oil field. To obtain additional production due to the introduction of the SPKU method at the projected wells, as well as by increasing the pump feed rate.

Table 2. Technical specifications

Parameters	**Conditional size of the pipeline**	
	DN-4	**DN-6**
Outer diameter of the pipeline, mm	9.1	10.8
Nominal pressure, MPa	40	60
Maximum pressure, MPa	50	70
Radial load on the pipeline, MPa, not less than	25	30
Breaking force, kN, not less than 50	50	60
The radius of permissible bending of the tube, mm, not less	200	
Friction pressure loss, MPa	3	1.4
Pipeline capacity, l/h, no more than	55	75

Technological Efficiency Determination of the Proposed Technology

To determine the technological efficiency, we choose wells with high fluid viscosity and corrosive activity of the producing fluid. The initial data for determining the technological efficiency are presented in Table 3.

According to the calculation method, the average time to failure of downhole pumping equipment (DPE) is the ratio of $DPE = T / N$,

where T is the total time worked from the moment of the push-button start of the downhole equipment to the moment of its failure (Mingaleva et al. 2019). If the worked time (*T*) for the well where the failure occurred is outside the design period (moving year), then the calculation takes into account all the worked time from the moment of the last push-button start of the well to failure, regardless of the billing period, day;

N is the number of failures of downhole equipment for the reporting period (rolling year), pcs.

We calculate the *DPE* according to the appropriate formula. Analyzing the data obtained as a result of the implementation of the Gremikhinsky oil field event, it can be noted that the DPE for wells equipped with ESP increased and, due to the reduction in idle time, led to an increase in oil production.

It can be predicted that the introduction of a capillary tube against asphaltene-resin-paraffin deposits and corrosion will lead to a decrease in the frequency of repairs.

Table 4 shows the results of the calculation of the Gremikhinsky oil deposit. It can be seen from the calculations that with the unchanged ESP fund, due to the introduction of the method, the number of repairs decreases every year, and this has a positive effect on the additional production for 3 years will amount to 4149.7 tons of oil.

Table 3. Initial data

No of a well	Well-rate before		Dynamic level, m	Static level, m	Bottom-hole pressure, MPA
	Oil, t/day	Fluid,m^3/day			
598	8.1	219	340	wellhead	77.4

439	1.8	99	293	wellhead	89.0
357	5.9	129	519	354	55.6
288	1.2	64	724	wellhead	38.8
312	5.2	187	340	wellhead	146.5
24	4.0	87	593	wellhead	109.6
238	19.1	415	528	wellhead	116.6
446	5.0	90	980	wellhead	74.1
638	5.1	184	471	168	108.0
383	2.1	45	1004	340	108.6

Table 4. Dynamic of changes in indicators

Year	WO number	Repair rate	Waste time,day	Time in operation, day	DPE,	Year	WO number	Repair rate
Without technology								
2010	41	0.63	57.6	307.4	455	78.5	24130.9	
2011	45	0.58	52.8	312.2	503	77.8	24289.1	
2012	41	0.63	57.6	307.4	442	79	24284.6	
2013	42	0.60	56	309	466	79	24411	
2014	38	0.60	56	309	466	79	24411	
2015	39	0.60	56	309	466	79	24411	
With technology								
2013	39	0.58	52.80	312.2	594	81.37	25403.7	992.7
2014	35	0.53	48.00	317.0	665	81.37	25794.2	1383.2
2015	32	0.47	43.20	321.8	740	81.37	26184.8	1773.8

Conclusions

Centrifugal pumps are used in various industries, they are usually part of a larger system, and therefore their reliability can affect the productivity of the system (Qazizada et al., 2018).

In terms of the capacity of geological and recoverable oil reserves drilled and operated by wells, the Bashkir layers are the main object of development of the Gremikhinsky oil field. The object is in the third stage of development. The development of reserves is accompanied by large volumes of associated water.

All oil-producing wells in the field are mechanized and equipped, mainly with ESN and SRP. At the same time, the share of ESN is 32%, and the share of SRP is 60% of all operating wells. Most of the accumulated oil production was obtained at the expense of SRP (87%) and 12.8% at the expense of ESN.

A comparison of the design and actual indicators showed that, in general, the field is observing the implementation of the design indicators of development. The project fund has been fully implemented.

The oil of the Gremikhinsky field is heavy in density, high-sulfur, high-resinous, and paraffin, and the produced reservoir fluid has high corrosion activity. All this leads to the formation of asphaltene-resin-paraffin deposits and persistent oil-water emulsions, which in turn leads to premature failure of deep-pumping equipment. Having considered all measures to prevent these problems, it can be concluded that the most optimal is the use of the Sonkor-9701 inhibitor through a special design of the ESP power cable with a capillary channel to supply the chemical reagent to reception.

This technology ensures the delivery of the chemical reagent directly to the required entry point with the most effective dosage and allows to change of the dosage and brand of the reagent quickly. With this technology, the reagent is not consumed for saturation of the oil column in the inter-tube space; its adsorption is on the surface of the casing and tubing. This achieves the most economical consumption of it exclusively for specific technological purposes and ensures the greatest effect from the use of a chemical reagent.

Based on the calculations of technological efficiency, it can be predicted that the introduction of a capillary tube against asphaltene-resin-paraffin deposits deposition and corrosion with an unchanged ESP fund will lead to a decrease in the number of repairs, which in turn has a positive effect on the average operating time for failure. Forecast with the application of the proposed technology, additional production for 3 years will amount to 4149.7 tons of oil.

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