ATLANTIS PRESS

Advances in Engineering Research, volume 177

International Symposium on Engineering and Earth Sciences (ISEES 2018)

Mining Technology Using Oil Installations of Electric Centrifugal Pumps in the Harsh Conditions (in case of Vankor Field)

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Abstract— **The paper shows the results of studies conducted in order to determine the causes and mechanisms of the occurrence of such complicating factors as asphaltene-resin-paraffin deposits, mechanical impurities, salts, equipment corrosion. The analysis showed that factors complicating the operation of pumps include significant removal of highly abrasive quartz sand layers, deposits in the pump and in the tubing string of precipitated asphaltene-resin-paraffin deposits and inorganic salts, as well as the aggressiveness of the formation waters that contribute to equipment corrosion. The authors of the article have developed new and upgraded previously known technologies to combat these factors and proposed appropriate recommendations.**

Keywords— asphaltene-resin-paraffin deposits; associated water, reagent testing; inhibition; calcite deposits; aggressive components, produced water

I. Relevance of the Topic

The development and exploitation of oil fields in a number of Russian regions are complicated by the significant amount of suspended solids (SS) in the composition of produced products, asphaltene-resin-paraffin deposits (ARPD) and aggressive components of formation waters. The appearance of such complications leads to wearing, jamming and failure of downhole equipment due to the deposition of various sediment types on the inner surface of ESP pumps and tubing. Oil companies suffer from significant losses in oil production, as well as from the cost of combating complications; they replace equipment and carry out repair work. The presence of mechanical impurities in the pumped fluid itself raises problems for the protection of expensive equipment from abrasive wear and jamming of the working parties with solid particles, increasing the turnaround time of the wells. Other complicating factors in varying degrees increase the negative impact on oil production, the presence of SS.

The deposition of paraffin, asphaltene substances on the inner surface of the tubing due to increasing hydraulic resistance reduces production and, ultimately, leads to an emergency situation. Corrosion of downhole and surface equipment, due to the aggressiveness of formation water, increases the abrasive wear of the surface of the equipment.

The high content of bicarbonate in the produced water and CO2 is the cause of salt deposition in oil wells.

Among the most significant developments in the field of oil exploration and production in Eastern Siberia of the Russian Federation is the commissioning in 2009 of the Vankor Field, which is unique in hydrocarbon reserves and in commercial development. The operation of the field has already shown highly characteristic features of the complications described above [1].

Filters of various designs and modifications, installed at the bottom of the wells or receiving pumping installations, have found wide application in areas of sand formation in wells. The purpose of their application is to keep SS in filters located below the ESP system.

With a high content of mechanical impurities, the use of standard gas-sand anchors becomes ineffective due to low values of centrifugal forces. A common drawback of the filters installed at the bottom or intake of pumps is the fairly rapid clogging of non-flowing cells and the need for their frequent flushing with lifting equipment [2, 3].

However, the use of filters only does not solve the problem of combating other complications, it also requires an integrated approach to the development of effective technologies. It is quite obvious that it is required to combine filtration of the produced products with the impact on the liquid of various chemical reagents, preventing the formation of sediment in the wells and corrosion of equipment.

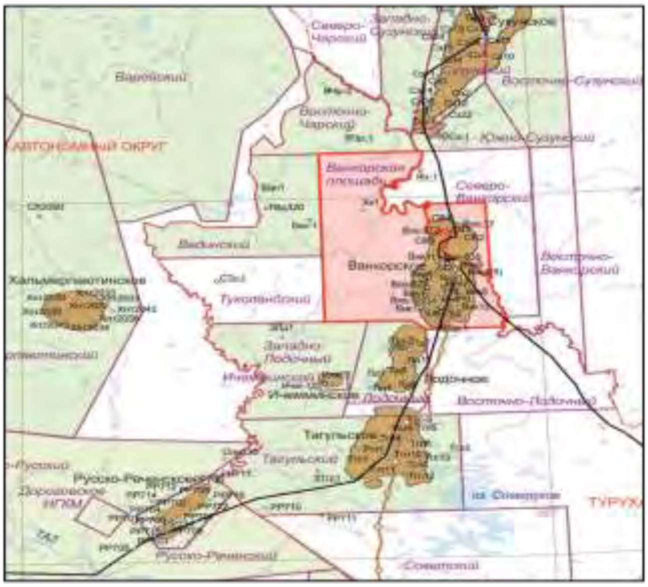

Fig. 1. Geographical disposition of the Vankor Field

In oil and gas production, a certain amount of experience has been accumulated that allows exploitation of complicated wells with ESP. New methods are being developed and introduced to prevent and remove sediments from the surface of downhole equipment, cleaning downhole fluids from high-frequency fluids and slowing down metal corrosion. However, the reserves in the development of methods to combat complications in the operation of wells are far from exhausted. In this regard, on the one hand, at the present stage, deep research is needed on the qualitative and quantitative influence of a number of complicating factors on the ESP operation, on the other hand, on the development of complex methods that allow in the process of dealing with the main complicating factor, including the presence of SS, solve and associated problems of improving the efficiency of operation of wells with ESP.

A. The study objective

The study objective is the development of technological methods to combat complications in wells equipped with ESP systems based on the study of the influence of various factors on the operation of submersible units and the hydrodynamics of suspended flows in the wellbore.

B. Studies

Studies are devoted to a brief analysis of the development and main types of complications in the operation of oil and water wells of the Vankor Field. The research results and their interpretation can be applied at many oil fields in Russia and other countries.

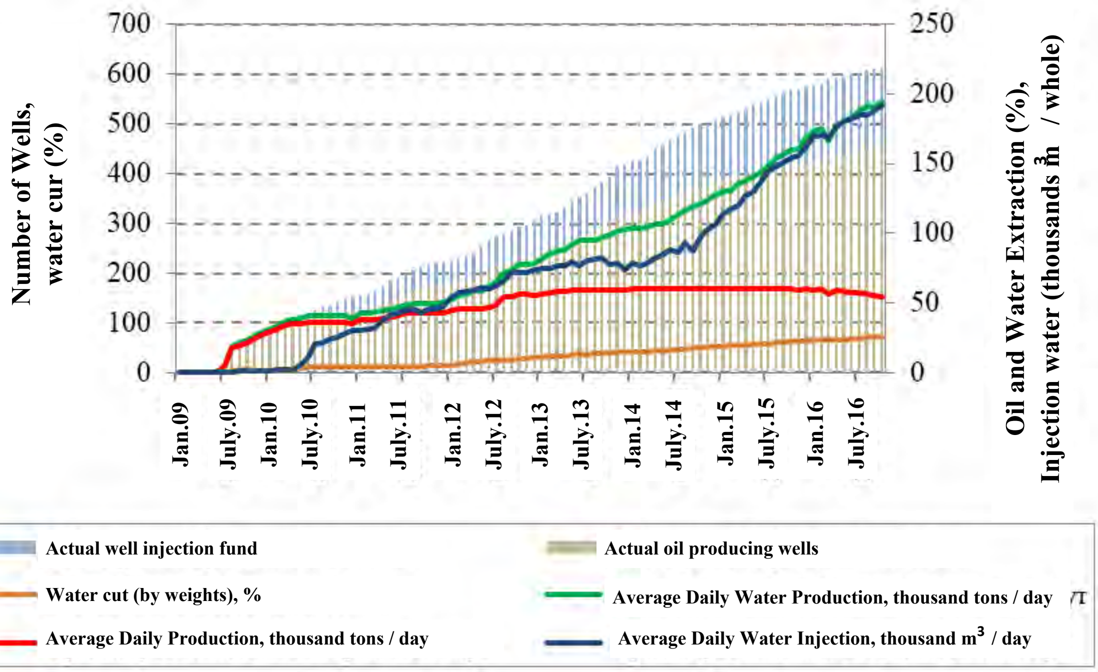

Fig. 2. Mining development and field stock indicators

II. Development of the Oil Field Analysis

Studies of the composition of the oils of the Cd-IX, Hx-I and Hx-III-IV formations showed significant paraffin content (2.26, 4.42 and 3.89%) and solid suspended particles (HDP) up to 500 mg / l. The deposits of calcite and iron carbonate salts are incorporated in the surface of the well's submersible equipment.

Results of the laboratory analysis:

- presence of calcite deposits on the power cable and the ESP motor, i.e., on those parts of the submersible equipment that are subjected to intense heating during the operation of the pump;
- presence of quartz sand of various particle size distribution in the ESP impellers.
- Based on the analysis of produced water separated from the produced oil SLE. 118, 128, and water samples from the RVS-2000 1a, 1b for the reception of the BKNS installed:
- produced water from wells refers to calcium chloride type, sulfate-free; the presence of alkaline-earth metal cations was noted: calcium - 408–546; magnesium, 85–126; strontium - 63–81 and barium - 4–7 mg / l. and the presence of iron ions - 4-15 mg / l .; the presence of cations of calcium, iron and barium causes the possibility of scaling of calcite, iron carbonate, barite under certain physico-chemical conditions;

The deposition of inorganic salts in the process of oil production was simulated using the PVTsim13 software package. The initial data for the calculation were the thermobaric parameters of the operation of the submersible equipment and the compositions of the reservoir oil and produced water.

TABLE I. WELL STOCK DATA

Performance indicators	2016 (project design document)	2016 (in fact)
Well stock (producing wells/key wells), pc.	440/166	461/157
Stock ratio (prod./key.), u.f.	2.65	2.94
Share of mechanized stock, %	100	94.14
Stock share with hydraulic fracturing,%	0	0
Average year oil production rate for ANS 2016, tons / day	122.8	147.04
Operating methods	ESP	ESP, flowing method
Well completion types	Slot filter, ResFlow and Equalizer	
Well type	Horizontal directional, horisontal	

As a result of the simulation it was found that in wells 118 and 128 there is a risk of precipitation of calcite and iron carbonate salts at bottom hole conditions. Sediment analysis 340 and 356 actually confirmed the presence of calcite crust on submersible borehole equipment. The composition and physico-chemical properties of deposits ARPD from wells 833, 122 bis, 132, 110, 728, 120 are determined.

As a result of research, it was established that with oil density of 814 - 904 kg / m3, the content of asphaltene in oil is more than 3%, and the content of resins, which are natural stabilizers of aggregative stability of asphaltene, is 1.26–2.79%, which is a rather low figure. Thus, we can conclude that the aggregate stability of oil is low and the change in the temperature-pressure conditions of the oil recovery leads to a violation of the stability of asphaltenes and the formation of ASV precipitation. The problem of formation of a solid phase in oil is further complicated by the fact that the average content of paraffin in oil samples is 3.72%, which corresponds to the saturation temperature of oil with paraffin tnnp and the beginning of the formation of paraffin 14–15 ºC. An indirect assessment of the formation of the solid phase was obtained from rheological studies [4].

The dependence of the kinematic viscosity of oil on the density is shown in Figure 3.

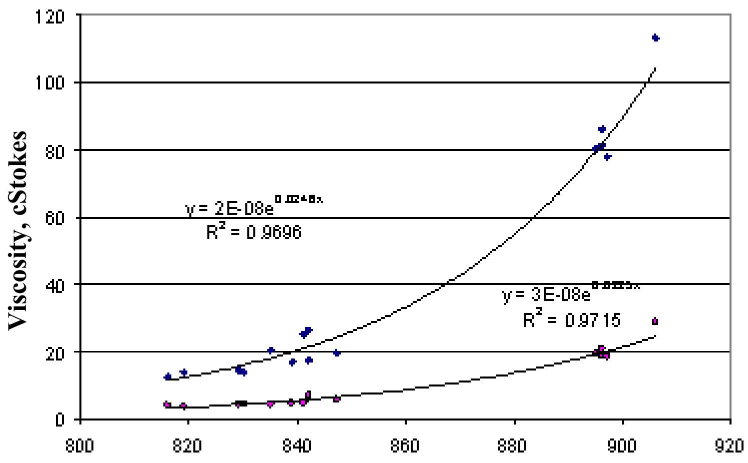

Fig. 3. The dependence of the viscosity of Vankor Field oil samples from density at temperatures of 20 and 50 ºC

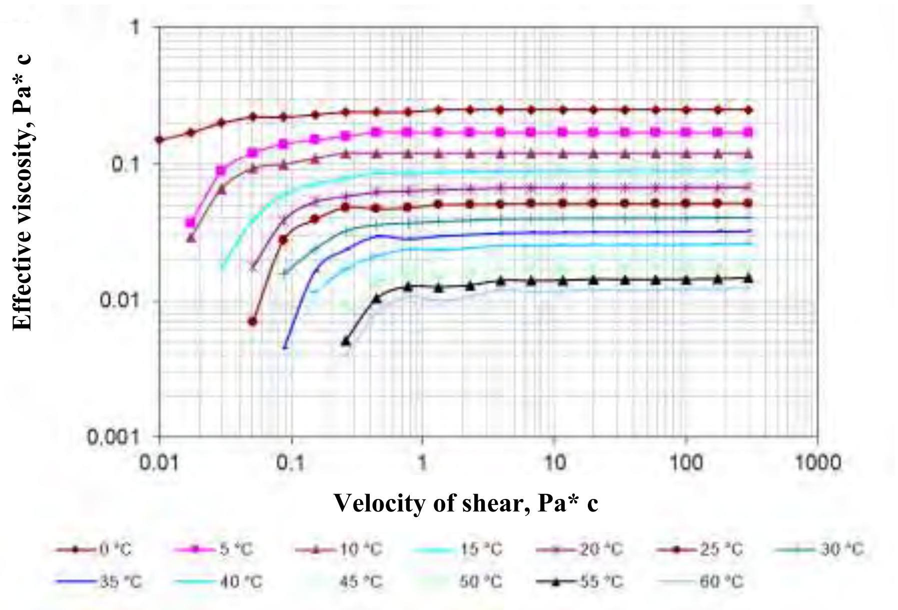

Fig. 4. The dependence of the effective viscosity of oil well 128 on shear rate in temperature range 0–60 ºC

TABLE II. ARPD CONTENT FROM THE COMPLICATED WELLS

Well	ARPD hitch, g	Asphaltene		Resin		Paraffin		Oil components	
		weight, g	*% of the hitch*	*weight, g*	*% of the hitch*	*weight, g*	*% of the hitch*	*weight, g*	*% of the hitch*
122 bis	0.4372	0.0163	3.7	0.1045	23.9	0.2172	49.7	0.0992	22.7
833	0.5738	0.1729	30.1	0.0955	16.6	0.2147	37.4	0.0907	15.8
120	0.5265	0.3174	60.3	0.0409	7.8	0.0422	8.0	0.126	23.9
132	0.7474	0.168	22.5	0.0852	11.4	0.1347	18.0	0.3595	48.1
110	0.5522	0.1325	24.0	0.0684	12.4	0.0862	15.6	0.2651	48.0
728	0.5524	0.0342	6.2	0.0696	12.6	0.363	65.7	0.0856	15.5

Samples of sediments from wells belong to the paraffin (well 122 122 bis, 728) and asphaltene (well 833, 120, 132, 110) types.

The melting point of paraffinic hydrocarbons is in the range of 40–49 ºC, which is typical of oil fields in Western and Eastern Siberia [5]. From the numerical dependence of the number of carbon atoms in the paraffin molecule and its melting point, the following relationship was obtained:

$$C = 11.63 \cdot e\ 0.0148T, \quad (1)$$

where C is the number of carbon atoms in the paraffin molecule; T is the melting point of paraffin, in degrees. Paraffin hydrocarbons deposited in the wells of the Vankor Field (Nizhnehetskaya svita) have the chemical formula C21.3N44.6 - C27.4N56.8

Based on the information provided by the ORMF CJSC Vankorneft, measuring temperature and pressure in a number of wells showed that in the well conditions of the Vankor field, due to the crystallization temperature, paraffin precipitation is impossible, and therefore the deposition of asphaltenes and their associates is in sediments due to their co-crystallization with asphaltenes. Moreover, in the composition of degassed oil from the wells of the field, the content of asphaltenes in the samples varied in the range of 2.91–4.93%, silica gel resins - 1.26–2.93%, paraffins - 2.78–5.79%.

The mineralogical composition of HDTV in the extracted products of the field has been studied. According to the RN "UfaNIPIneft", obtained in SLE. 373 bis, 591, 545, 702, it is shown that:

- calcite, quartz and corrosion products are represented in the sediments of the downhole equipment. In this regard, the index of the aggressiveness of deposits varies in the range of 0–89.7 units. Samples with a high content of quartz have the highest index of aggressiveness; sediments containing calcite and corrosion products are less aggressive;
- calcite deposits are represented by granular formations, cortical secretions and rhombohedral crystals;
- corrosion products are represented by highly porous, cavernous magnetic particles from dark brown to black
- quartz is represented by transparent angular-rounded grains. From a horizontal high-yield well 373 bis (flow rate of 1 295 m3 / day) quartz granulometry is represented by grains of the prevailing sizes: 0.5–0.25 mm - 45% (spheres 0.6; rounded 0.5); 0.25–0.16 mm - 45% (spheres. 0.6; rounded. 0.5). From the vertical well 545 (flow rate of 68 m3 / day) quartz grain size distribution is represented by grains smaller size - 0.16–0.1 mm - 80% (spheres. 0.5; rounded. 0.5).

Studies have been carried out on HDTV of ASF deposits and on the influence of technological factors on their formation.

TABLE III. CALCULATION OF THE CRITICAL CONCENTRATION OF ASPHALTENES IN THE RESERVOIR OIL

Characteristics of the crude oil and oil-bearing formations	**Option 1**		**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**	
Composition of reservoir oil, mole%	***Yak 3-7***	***HX 3-4***	***Yak 3-7***	***HX 3-4***	***Yak 3-7***	***Yak 3-7***	***HX 3-4***	***HX 3-4***
Nitrogen + rare	0.3	0.11	0.3	1.9	0.18	0.1	0.13	0.09
Carbon dioxide	0.2	0.04	0.2	1.9	0.05	0.06	0	0.04
H2S	0	0	0	0	0	0	0	0
Methane	36.58	53.34	36.44	49	25.35	34.89	45.21	49.06
Ethane	0.53	2.73	0.53	4.24	0.27	0.12	2.97	2.73
Propane	0.32	3.04	0.32	4.6	0.29	0.21	3.16	3.04
Isobutane	0.17	1.49	0.17	2.36	0.21	0.06	1.62	1.49
n-butane	0.1	2.18	0.1	1	0.04	0.04	2.24	2.18
Isopentane	0.03	1.32	0.03	0.42	0.03	0.05	1.33	1.32
n-pentane	0.02	1.19	0.02	0.4	0.02	0.04	1.2	1.19
C6 + higher	61.75	34.56	61.89	34.18	73.56	64.4	42.12	38.88
Molar mass of degassers. of oil	267	191	267	191	285	277	206	206
The density of degassers. oil, kg / m3	900	846	906	850	904	899	839	839
Reservoir pressure, atm	159	271	158	271	162	161.5	273	273
Reservoir temperature, ° C	34	65	31.6	65	35	30.3	59	59
Critical concentration of asphaltenes in oil,%	**6**	**0.5**	**6.5**	**0.5**	**7.5**	**6**	**0.7**	**0.6**

[a] Note. Option 1 - data from the project document “Section 1-2.doc”. Option 2 - data from the file "Restore_stvoshestv_Vankor.rtf". Options 3–6 are data from Schlumberger sample research reports.

The calculation of the critical concentration of asphaltenes in the oil of the Vankor field using the PVTsim13 Program, taking into account the various data available on the composition of the reservoir oil, shows that the critical concentration above which a loss of asphaltenes from their oil of the Vankor field is observed is 6–7 , 5%, and for oil of the NX III-IV reservoir - 0.5–0.7% (Table 3)..

Taking into account the content of asphaltenes in the oil, the precipitation of asphaltenes is predicted when oil is extracted from the layers of the "Nizhnekhetskaya svita". Figure 5 shows that the oil of this "svita" in reservoir conditions is unstable with respect to the asphaltenes they contain, and as the oil rises along the elevator, they will fall out.

Under the conditions of high turbulence in the flow of produced well products in the ESP and tubing, the precipitated asphaltene agglomerates are dispersed and receive the possibility of further association with paraffinic hydrocarbons. Thus, an increase in the deposition rate of ARPD in the wells may be observed with an increase in their production rate and intensive deposition of asphaltene. To confirm these assumptions, we analyzed the impact of the operational parameters of the wells on their inter-treatment period (ITP) of work.

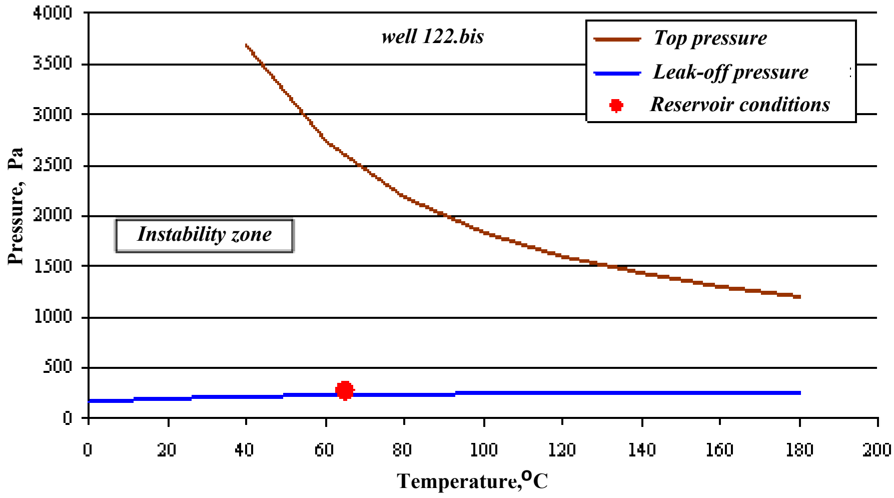

Fig. 5. The zone of oil instability in well 122 bis in relation to the deposition of asphaltene

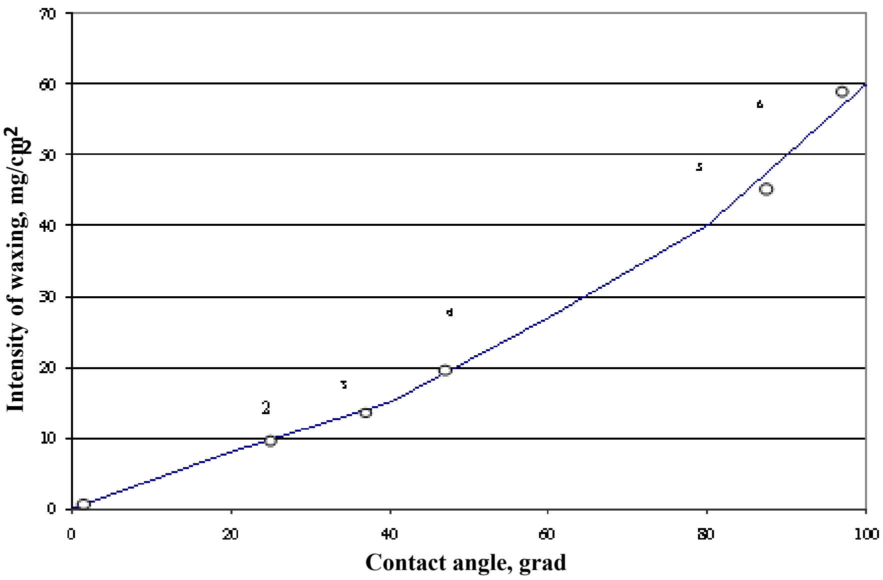

Fig. 6. The dependence of the intensity of waxing on the degree of hydrophilicity: 1 - glass; 2 - steel; 3 - polyvinyl chloride; 4 - polyamide AK-7; 5 - fluoroplast-4; 6 - polyethylene

In particular, for wells of the Nx 3-4 formation of the horizontal type, the dependence of the ITP (24 hours) on the flow rate for an elevator with a diameter of 89 mm is

ITP = 162.58 · D – 0.7439, (1)

For wells of the Yak 1-2 horizontal type, a similar dependence is

ITP = 0.0033D + 9.8433, (2)

For wells of the Yak 3-7 vertical type, the dependence is

ITP = 46,924 · D – 0.2851, (3)

where D is the well flow rate, m3 / day.

Calculations by formulas (1), (2) and (3) show a decrease in the well ITP operation, i.e. the increase in the intensity of deposition of ASPV with an increase in its flow rate.

Defined ways of dealing with deposits ASV in wells with ESP.

To prevent asphaltene deposits in tubing, the following methods were tested:

- tubing with protective coatings,
- ubing with protective coatings,
- asphaltene scale inhibitors.

Moreover, the use of tubing with protective coatings is recommended for well MOP operation from several hours to several days in a wide range of flow rates of 50–1 200 m3 / day [5,6]. The issue of using as a coating of ultrahigh molecular weight polyethylene (UHMWPE), which has more favorable characteristics than effectively used fluoroplastic [7, 8, 9], is under study. As studies conducted at the base of the Institute of Chemistry and Chemical Technology (ICCT) of the Siberian Branch of the Russian Academy of Sciences in Krasnoyarsk have shown, the friction coefficient of UHMWPE is 5 times less than that of the fluoroplastic and has a relatively high impact strength..

As a protection against ASV deposits, silicate-enamel coatings were tested and recommended. The advantage of this type of coating is its hydrophilicity and, as a result, a decrease in adhesiveness (Figure 6) on it of compounds with C – C bonds (paraffin hydrocarbons). It can be seen that silicate-enamel coatings have the lowest intensity of waxing.

Magnetic activators are recommended for use at MOS from several hours to several days in the range of flow rates not more than 200 m3 / day. Inhibitors of deposition of asphaltenes are recommended for use at MOP from several hours to several days in the range of flow rates not more than 50–100 m3 / day.

An effective method of removing asphaltene deposits, which allows the tubing to be completely cleaned, is to wash the wells with aromatic solvents [10, 11]. Using heated solvents, they accelerate the solvation of asphaltene molecules. If there are mixed deposits on the walls of the equipment, then the use of composite organic solvents to dissolve paraffin and asphaltene compounds is effective.

As solvents were tested:

- Nefras ASPO, TU-0251-019-77711740–2007 (industrial solvent);
- petroleum ether 40–70 degrees, TU-6-02-1244–83 (analogue of gas gasoline);
- toluene, GOST 5789–78 (aromatic hydrocarbon);
- solvent SNPCH-7014A,
- solvent P-020 LLC FLEK, TU 2458-016-24084384–2006,
- solvent P-017 LLC FLEK, TU 2458-016-24084384–2006,
- solvent Fores SA-30.

For dissolving were used paraffin SLE. 728 (paraffin type deposits) and ARPD SLE. 110 well 833 (asphaltene type of sediment).

III. Analysis of the Research Results

Analysis of the research results showed:

1. Solvents mostly affect asphaltene-type asphalt paraffin. To remove them at low temperatures in the tubing, it is preferable to use light paraffin hydrocarbons, dissolving solid paraffins and destroying ARPD structure, for example, the solvent Fores SA-30.
2. Paraffin-type paraffin wax are well removed with light paraffin hydrocarbons and aromatics. The preferred duration of dissolution in static conditions is not less than 6 hours. To remove an asphaltene-type ARPD, research and selection of effective additives that increase the dissolving ability of organic solvents is necessary.

For testing, a “blank” oil sample that did not contain an inhibitor was used, and samples containing the inhibitor content of 100, 200, 300, and 500 mg / l in the original oil.

TABLE IV. The Effectiveness Of Paraffin Inhibition Of Well 110

Inhibitor	The effectiveness of inhibition at the dosage,%		
	100 mg/l	***200 mg/l***	***500 mg/l***
DP VAS-410	4	60 (at 300 mg/l)	53
Asphaltene inhibitor «NALCO»	12	36	66
Inhibitor ASPO ES 3019 «NALCO»	15	80	21
SNPH-7941	19	32	71
SNPH-2005	34	38	40
HPP-007	5	36	35

Six ASPO inhibitors were tested - depressant additive VES-410, asphaltene inhibitor "NALCO", inhibitor of AFS EU 3019 "NALCO", SNPCH-7941, SNPCH-2005, HPP-007.

The results of the experiments are presented in table 4 on well 110.

The results of the testing allow us to recommend two samples for use:

- inhibitor ARSP EU 3019 "NALCO", which allows you to inhibit sediments at a dosage of 200 mg / l by 80%,
- depressant additive VES-410, inhibiting deposits by 60% at a dosage of 300 mg / l.

The methods of sand control in wells are considered.

The analysis of the chemical and granulometric composition of HDTV, selected from production and water wells of the Vankor field, was carried out.

Below are presented for the study of 4 sediment samples: VDK No. 1, VZ No. 9, VDK No. 1, VZ No. 5, VDK No. 1, VZ No. 12 from the ESP drive wheels and sample sediment from VDK No. 1, OZ No. 12, taken from a sand filter.

It is established that the deposits on the filters of pumps are represented by quartz sand SiO2. ITP hardness of quartz sand is 7. Sand grains in all samples with ESP (No. 1–3) showed statistically comparable sizes that fit into the following particle size classes: 1) 0.5–0.25 mm - 3–6%; 2) 0.25–0.16 mm - 35–40%; 3) 0.16–0.1 mm - 32–38%; 4) less than 0.1 mm - 16–30%. As can be seen from these data, grains are mainly represented by three granulometric classes belonging to fine-grained sandstones (0.1–0.25 mm) and siltstones (less than 0,1 mm). The proportion of medium-grained sand grains (0.5–0.25 mm) is greatly reduced.

The shape of grains of large granulometric classes (0.2–0.5 mm) is close to isometric (approximately 90% of grains) with an isometric ratio of 0.7 and higher. About 10% of the grains of this granulometric class are represented by elongated forms with an isometry factor of 0.5–0.6. Grains close to lamellar with angular restrictions, which are products of mechanical destruction of primary debris grains, are also found here.

Grains of smaller granulometric classes (less than 0.2) are almost completely represented by isometric forms with an isometric coefficient of 0.7–0.9.

Sediment sand filter VZ № 12 / VDK № 1 on the content of sand fractions differ significantly from samples with ESP and are characterized by the following size classes: 1) more than 0.5 mm - 2%; 2) 0.5–0.25 mm - 38%; 3) 0.25–0.16 mm - 35%; 4) 0.16–0.1 mm - 20%; 5) less than 0.1 mm - 5%. The presence of a fraction of a fineness greater than 0.5 mm — 2% and a significant content of a fraction of 0.5–0.25 mm — 38% were noted. At the same time, the fraction of size less than 0.1 mm is present in a relatively small amount - 5%.

To combat the negative impact of HDTV on the work of the ESP system, various methods are used, summarized in Table 5.

TABLE V. MATRIX OF CRITERIA FOR THE APPLICABILITY OF SAND PROTECTION METHODS

Protection methods	The essence of technology	Protection area	Application area
Mechanical:	Installation of filters and other equipment below and above ESP to prevent from mechanical impurities	Pump intake, pump	Weak and moderate sand removal without pouring it
use of filter systems, sludge traps	Operation of high-performance ESP at a reduced frequency - 35–40 Hz	Pump intake, pump	Weak and moderate sand removal without pouring it
Chemical: pumping resins and their compositions in the PPP	Creating a porous screen in the PPP to prevent the destruction of the collector	Perforation interval, pump intake, pump	Intensive removal of sand with pouring
dosing of scale inhibitor	Prevention of calcite precipitation as a cementing agent for quartz particles	Pump intake, pump	Weak and moderate sand removal without pouring over the face. Deposits of complex composition
Physico-chemical: proppant application	Creation of proppant packing behind the production string and in the formation	Perforation interval, pump intake, pump	Intensive sand removal with pouring and the formation of cavities

As an effective method of reducing sand formation, it is based on the injection of a curable resin into the bottom hole formation zone, which partially fills the pore space after curing. The structure of the resin after curing and the order of injection of components is presented in Figure 7. The analysis for the period from 2009 to 2010 of resin injection in 7 wells of the Barsukovsky direction showed an increase in pump operating time from 40 to 73 days and a decrease in the content of HDTV products from 196.4 to 101 mg / l. (Figure 8). With a general decrease in the average nominal capacity of pumps from 143.8 to 99.5 m3 / day, the flow rate of the liquid and oil changed slightly.

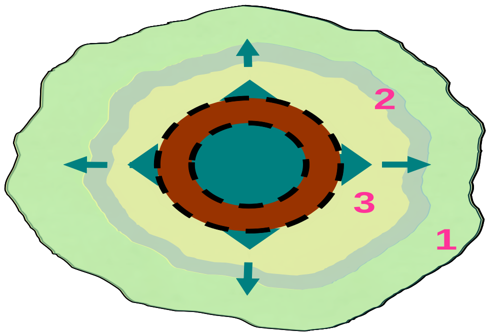

Fig. 7. The type of porous structure and the setting scheme in the PPP of the LINK resin: 1 - injection of the buffer rim with hardener Link-O; 2 - Link-C resin injection with Link-G blowing agent; 3 - pumping hydrophobic liquid

A new design of a combined separator has been developed, researched and implemented in the Vankor Field, which allows cleaning the fluid in the mesh material and in the field of centrifugal forces. It is determined that the efficiency of the separator is particularly evident when the size of HDTV more than 150 microns. (Patent of the author No. 2441150). The introduction of the separator allowed us to increase the operating time for ESP failure from 90 to 368 days.

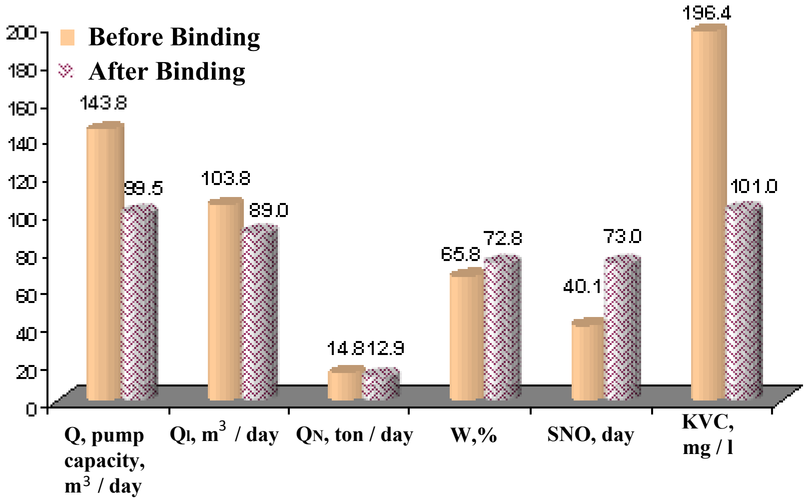

Fig. 8. Comparison of operating parameters before and after applying resin link

Conducted research to determine the factors of corrosion damage to metals.

It can be seen that corrosion in the submersible borehole equipment proceeds through the carbon-dioxide mechanism. At the same time, the presence of oxygen in samples from water wells and in samples for BKNS-2 and BKNS-4 in an amount of 0.2–1.0 mg / l indicates that water is pumped into the layers with a sufficiently high oxygen content, which in the presence of hydrodynamic coupling; it can reach reactive production wells. The analysis of water for the content of cations and anions was carried out on a Spectroscan X-ray fluorescence spectrophotometer, as well as in a titrimetric method.

High mineralization of produced water (3 ... 42 g / l) is the main cause of the corrosivity of the environment. The results of the evaluation of the corrosivity of the samples and solutions of the killing prepared from salts are presented in Tables 6 and 7, respectively.

TABLE VI. CORROSION AGGRESSIVENESS OF WATER SAMPLES FROM THE VANKOR FIELD

No. of test	Place of sample selection	Corrosion speed, $g/m^2 \cdot h$
2	Yakovlevskaya svita 3–7, well 332, 14	0.07
49	Nizhnehetskaya svita 1, well 701, 102	0.06
61	DL1 – NS, well 2 VDK-1	0.06
77	After RVS BKNS-4	0.07

Experimentally it was found that the presence of SIS accelerates corrosion processes under precipitation by 2–3 times, while the corrosion rate of metal above sediment increases only by 1.2–1.5 times. Recent studies show that oil-field equipment is influenced by a complex of corrosive factors. , the biological component of which cannot be reduced only to the action of biogenic hydrogen sulfide and iron sulfide [12, 13].

In 25% of cases, corrosion failures occurred with a water cut of less than 50%. The analysis shows that in such cases the erosion-abrasive factor plays a dominant role due to the high speed of the SHC.

The calculation of the average temperatures on the face of the seam was made using the source file "Map of work of the April.xls fund" with the data of temperature sensors installed on the SEM case. The temperature of the product after the ESP was conventionally assumed equal to the temperature of the submersible electric motor, since with the passage of formation fluid along the SEM body and through the pump, it is heated. The results of the calculation of the average temperature at the bottom of the seam are presented in Table. 8.

According to the de Waard-Lotz-Dagstad method (de Waard, Lotz, Dagstad, 1995), taking into account the effect of water-cut downhole production, SHC speed, removal of mechanical impurities, corrosive aggressiveness of downhole products, the corrosion rate of the downhole equipment was calculated by the well depth.

TABLE VII. AVERAGE TEMPERATURES OF SEM AND PRODUCTS AT THE BOTTOM OF FORMATION

Reagent for the preparation of killing fluids	Density	Corrosion speed, g/m^2·h, (mm/year)	
		T = 20 °C	T = 80 °C
Potassium chloride KCl	1.04	0.10 (0.11)	0.11 (0.12)
	1.08	0.07 (0.08)	0.10 (0.11)
	1.12	0.07 (0.08)	0.09 (0.10)
	1.16	0.05 (0.06)	0.08 (0.09)
Calcium chloride $CaCl_2$	1.16	0.06 (0.07)	0.04 (0.04)
	1.21	0.05 (0.06)	0.04 (0.04)
	1.26	0.03 (0.03)	0.03 (0.03)
	1.32	0.03 (0.03)	0.02 (0.02)

TABLE VIII. AVERAGE TEMPERATURES OF SEM AND PRODUCTS AT THE BOTTOM OF FORMATION

Layer	Number of wells with readings T, pcs.	Average Tdv, ° C	Reservoir temperature under the project, °C
Hx 3-4	19	71.6	60
Hx 1	34	74.1	65
Yak 3-7	109	55.3	35

It is shown that the maximum corrosion rate for carbon and low-alloy steels is observed in the temperature range from 50 to 100 ºC.

In actual operation conditions of the wells, the current between the pad and the casing can reach amperes, and the flow rate of the fluid can increase to several tens of meters per second. This significantly increases the intensity of the electro-etching of the metal and reduces the operating time of the SEM and the pumping unit as a whole.

The main factor determining the corrosivity of the transported products and causing VSO corrosive failures is the high water content of the products [14]. At the corrosion fund, the average production water cut has passed through the phase inversion point and transports products like "oil in water" with an external corrosive aqueous phase, while in the rest of the fund the average water content corresponds to a low aggressive water-in-oil emulsion.

IV. CONCLUSIONS

1 Statistical analysis of the main types and degree of complications in the operation of wells with ESP in the Vankor Field showed that factors complicating the operation of the pumps include significant removal of highly abrasive quartz sand from the layers, deposits in the pump and in the tubing column of ASFO deposits and inorganic salts, as well as aggressiveness of formation water, contributing to corrosion of equipment.

2 It was established that the deposits on the pump filters are represented by quartz SiO_2 sand with Mohs hardness– 7. Sand grains in all samples with ESP (No. 1-3) showed statistically comparable sizes that fit into the following grain size classes: 1) 0.5 –0.25 mm - 3–6%; 2) 0.25–0.16 mm - 35–40%; 3) 0.16–0.1 mm - 32–38%; 4) less than 0.1 mm - 16–30%. Grains are represented mainly by three granulometric classes belonging to fine-grained sandstones (0.1–0.25 mm) and siltstones (less than 0.1 mm). The proportion of medium-grained sand grains (0.5–0.25 mm) is greatly reduced. A method has been developed and implemented to prevent sand from the layer by injecting a curable resin that partially fills the pore space after curing, allowing an increase in pump operating time from 40 to 73 days and a decrease in the content of HDTV from 196.4 to 101 mg / l in 7 wells.

3 It is shown that the deposits of ASPW in the wells are mainly of the asphaltene type, and aromatic solvents remove the precipitation. It was established that Fores SA30 heated solvents accelerating the solvation of asphaltene molecules are among the most effective. The most effective inhibitors of ASV deposits were identified, which include an inhibitor of AFS EC 3019 “NALCO”, which allows inhibiting deposits at a dosage of 200 mg / l by 80%, as well as a depressant additive WES-410, inhibiting deposits by 60% at a dosage of 300 mg / l

4 It was experimentally established that corrosion in submersible well equipment proceeds through a carbon-dioxide mechanism. It was revealed that the presence of oxygen in samples from water wells and in samples for BKNS-2 and BKNS-4 in an amount of 0.2–1.0 mg / l indicates that water is pumped into the layers with a sufficiently high oxygen content, which at having good hydrodynamic coupling, can reach reactive production wells. It was experimentally revealed that the presence of sulfate reducing bacteria accelerates corrosion processes under precipitation by 2-3 times, while the corrosion rate of metal above sediment increases only 1.2-1.5 times

5 According to the method of de Waard - Lotz - Dagstad (de Waard, Lotz, Dagstad, 1995), taking into account the effect of water-cut downhole production, HCG speed, removal of mechanical impurities, corrosive aggressiveness of downhole products, the corrosion rate of the downhole equipment was calculated by the well depth. At the same time, the maximum corrosion rate for carbon and low alloy steels is observed in the temperature range from 50 to 100 ºC.

6 A comprehensive technology has been developed and implemented for removing various types of sediments from the surface of submersible equipment and tubing string using chemical reagents and coolant. The technology based on the use of a modified ESP check valve, temporarily opened for supplying agents to the tubing string and a submersible pump for reagent injection, was applied at wells No. Vankor field.

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