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Problems of corrosion protection during safe operation of pipeline systems and equipment of oil and gas industry

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Introduction. Organization of safety hydrocarbons transportation is one of the primary objectives for companies operating hazardous production facilities. Corrosion protection of field pipelines is still the most complex and multifaceted task. That is due to significant length of communication lines, branching pipeline networks, complex and heterogeneous composition of pumped liquids.

Problem Statement. The purpose of this research is the development of method of salinity control and the prevention of premature corrosion wear of oil pipelines by the use of inhibitors.

Theoretical Part. When transporting oil and petroleum products through pipelines, there is a high probability of synergistic risks arising from corrosion of the pipeline body material, including salt deposits. Salt formation affects the throughput, performance of pipeline systems, and equipment performance.

According to the result of in-line diagnostics analysis, more than 70% of pipes are subject to corrosion, with metal loss and changes in wall thickness. Corrosion also led to metal properties transformation, and degradation of its functional characteristics. Inhibitors are widely used during oil production and transportation to protect from the formation of salt deposits. With long-term operation of oil and gas pipelines it is not possible to ensure completely safe operation. Pipeline systems are constantly affected by the environment, external and internal pressure, corrosion and aging of the pipeline material.

Conclusion. The article presents a brief overview of the current state of oil pipelines, and a new method for protection from salt deposits. The composition of the salt deposition inhibitor, including citric acid, has been developed. It has been experimentally established that its use reduces the number of accidents. A brief analysis of the occurrence of accidents in the oil and gas industry is performed. The problems of safe operation of pipeline systems under the influence of non-stationary factors are determined. The necessity of creating a method for mathematical modeling of pipeline systems is confirmed.

Keywords: oil and gas pipelines, corrosion, citric acid, reduction of technology related risks, salt deposits, corrosion inhibitors, nonstationery risks, operational safety.

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Introduction. An urgent task in the operation of oil and gas pipelines is to protect pipes and equipment from corrosion. It is impossible to completely exclude corrosion phenomena, but it is possible to take timely measures for anticorrosion protection.

The most difficult issues remain protection from corrosion of field pipelines. In particular this is due to:

— significant length of communications,

— branching of pipeline networks,

— complex and heterogeneous composition of the pumped liquids,

— soil characteristics in the pipeline sections [1-3].

Salt deposition reduces safety of operation of the pipeline systems intended for transportation of hydrocarbons. This determines the relevance of the work. Processes of oil or gas extraction and transportation are often accompanied by undesirable formation of deposits of inorganic salts on the walls of the equipment and associated reservoirs. As pumping volumes increase, so do deposits.

The use of new technological and technical solutions for the transportation of flammable and combustible substances allows us to establish a higher level of industrial and fire safety of the operated dangerous object. This problem has been studied by many Russian and foreign authors [4-6].

Ensuring safe transportation of hydrocarbon media is one of the main tasks of organizations operating hazardous production facilities. The diagnostics of 600 technological and oilfield pipelines revealed unacceptable defects in 75 % of cases [7, 8].

Problem statement. The aim of this study is to develop a method for controlling salt deposition and preventing premature corrosion wear of oil pipelines by introducing inhibitors. Salt deposition on the walls of field pipelines affects their throughput and productivity. Salt formation is also one of the causes of metal corrosion. Therefore, to control salt deposition and prevent premature wear in the oil fields, inhibitors are introduced into the field pipeline system.

Theoretical part. The analysis of the pipeline diagnostics results of the main pipelines shows that the proportion of pipes with defects ranges from 9.6 to 21.8 % (indicators depend on the pipeline section, the presence of welds and shut-off valves). The percentage of pipes with dangerous defects is from 0.5 to 3.7 %. Of these, about 70% are pipes with metal losses and changes in wall thickness, including corrosion. During corrosion, the properties of the metal change and its functional characteristics deteriorate [9, 10]. One of the factors influencing the indicators of metal corrosion and wear is salt formation [11].

The safety of pipeline operation depends, in particular, on the pressure and physical and chemical properties of the pumped medium.

Accidents often occur due to aging of pipeline systems [12, 13]. It is not always possible to use well-known methods of in-line diagnostics to find out the cause of dangerous defects, measure them, and set the maximum value of the equipment's service life.

The difficulties of in-line diagnostics are caused by changes in cross-sections in pipeline systems and the formation of local resistances.

Salt deposition on the walls of pipelines affects the throughput, the performance of pipeline systems and the equipment operability, including those with moving parts.

Salt deposition and its consequences should also be taken into account when using a non-stationary system risk management system.

The introduction of inhibitors is widely used in oil fields and oil treatment sites in order to minimize the formation of salt deposits [14, 15].

The issues of salt deposition control and prevention of premature wear of oil pipelines were solved experimentally: the potential of a previously developed salt deposition inhibitor with the addition of citric acid was evaluated.

Experiment and results. The purpose of the laboratory experiment was to determine the effectiveness of the salt deposition inhibitor SNPKH 5312 grade C of different concentrations with the addition of citric acid. In the experiments, the reservoir water of modular cluster pump station (MCPS) of the oil treatment plant (OTP) of Bayteks LLC was used.

The samples were prepared in seven stages.

1. Seven conical flasks (250 ml) were filled with 100 ml of brine water.

2. In five of them, a salt deposition inhibitor with citric acid (CA, 0.3 mg) was added at concentrations of 10, 20, 30, 60 and 100 mg/dm^3, which corresponds to 0.2; 0.4; 0.6; 1.2 and 2.0 ml of the solution (table 1).

Table 1

Samples of reservoir water of MCPS OTP Bayteks LLC with the concentration of the corrosion inhibitor

Initial solution	No. 1	No. 2 (+ иinhibitor / + CA)	No. 3 (+ иinhibitor / + CA)	No. 4 (+ иinhibitor / + CA)	No.5 (+ иinhibitor / + CA)	No. 6 (+ иinhibitor / + CA)
Without temperature control	Brine water	0.2 mg /0.3 mg	0.4 mg /0.3 mg	0.6 mg /0.3 mg	1.2 mg /0.3 mg	2.0 mg /0.3 mg

3. The flasks were closed with lids. The first flask was a control one, it was not affected.

4. The remaining flasks were thermostated in the Memmert chamber drier at a temperature of 75 °C for 5 hours.

5. After 5 hours, the samples were cooled and filtered through a dense "blue ribbon" filter.

6. To determine the content of calcium ions in conical flasks, 10 ml of filtrate was selected with a Mohr pipette and 40 ml of distilled water was added.

7. Using murexide for Trilon B, the calcium hardness was determined (Table 2).

Table 2

The content of calcium ions in the reservoir water of BKNS UPN LLC Baytex with the addition of a salt decomposition inhibitor SNPH 5312 grade C and citric acid

	Initial sample	Sample no. 1	Sample no. 2	Sample no. 3	Sample no. 4	Sample no. 5	Sample no. 6
V_T^*, ml	12.94	11.76	12.04	12.2	11.8	12.3	12.08
X, ml×g/dm^3	1296.588	1178.352	1206.408	1222.4	1182.36	1232.46	1210.416
*T — titration. X — the content of calcium ions after titration.							

The results of calculating the effectiveness of the salt deposition inhibitor in brine water with the addition of citric acid are shown in Table 3.

Table 3

Effectiveness of the salt deposition inhibitor in brine water of BKNS UPN LLC Baytex with the addition of citric acid

	+ Inhibitor / + CA				
	0.2 mg / 0.3 mg	0.4 mg / 0.3 mg	0.6 mg / 0.3 mg	1.2 mg / 0.3 mg	2.0 mg / 0.3 mg
Effectiveness of the salt deposition inhibitor (ESDI,%)	93	71	85	58	54

The effectiveness of the salt deposition inhibitor (ESDI,%) is determined by the formula (1):

$$Э = (Cp – Cx / Co – Cx)\ 100, \quad (1)$$

where Cx — is the content of calcium ions in the sample without an inhibitor, mg/dm^3; Cp — is the content of calcium ions in the sample with an inhibitor after temperature control, mg/dm^3; Co — is the content of calcium ions in the initial solution, mg/dm^3.

The experiment and calculations showed that the inhibitor of SNPKH 5312 brand C with citric acid (3 %) effectively prevents the formation of salts in the technical devices of the Baytuganskoye field.

Measures to prevent accidents. The acute problem of corrosion of pipeline systems intended for transportation of hydrocarbon media requires high-quality and cost-effective solutions [16-19].

In this study, cases of ingress of pumped products into the external environment due to depressurization and damage to pipeline systems are considered. Their main reasons:

— uncontrolled metal corrosion of the inner and outer shell of the pipeline,

— hydro-and gas-abrasive wear,

— fatigue and aging of the metal.

The domestic level of technical support for pipeline systems with automation tools and high-quality materials lags behind the world level by 15-20 years [20, 21]. The material, diameter and thickness of the pipes do not always meet the design requirements. There are other reasons that affect the frequency of accidents and incidents in the operation of pipeline systems.

Figure 1 shows data on accidents at oil and gas industry enterprises in the Russian Federation in 2009-2017 [11].

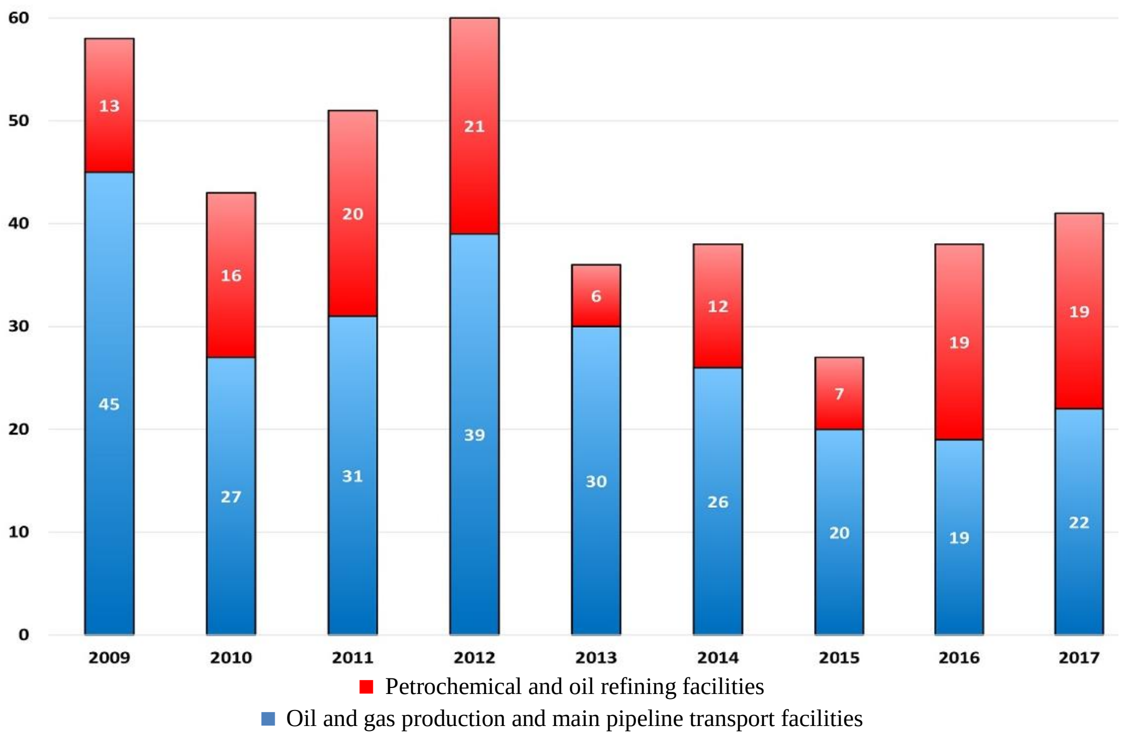

Fig. 1. Dynamics of accidents at the enterprises of oil and gas industry and oil and gas processing

With general patterns of accidents, each has its own distinctive features:

— time of origin and development,

— scale (depends on the energy potential of the equipment)

— pressure that leads to the destruction of technical devices and systems,

— explosions and fires

— release of substances that negatively affect the environment.

In view of the above mentioned, the following tasks are relevant:

— to determine the requirements for the formation of a methodology for early detection of pre-emergency situations and their prevention;

— to develop optimal parameters for online non-stationary risk management and emergency prevention.

Management of synergistic risks is laid down at the design stage of pipeline systems. During their operation, high-quality diagnostics and recognition of pre-accident and emergency situations are required, as well as precise compliance with the requirements of the technological regime. Measures to prevent emergency situations are also mandatory [22, 23].

The unsteadiness of the above-mentioned risks (environmental impact, external and internal pressure, corrosion and aging of pipeline material) reduces the efficiency and safety of the process of pumping oil, gas and their processed products. The lack of reliable systems for monitoring and accounting for non-stationarity is a serious drawback of the existing technologies for predicting and determining the probability of an emergency and possible consequences, especially when it comes to:

— the operation of the object under the conditions of the maximum service life;

— branched heterogeneous pipeline systems with different operating modes [24, 25].

Thus, the main tasks for mathematical and technical modeling of non-stationary pipeline systems are related to forecasting:

— maximum permissible maximum and minimum pressure values generated by pumping units;

— maximum permissible time intervals for alarm activation and protective equipment activation;

— unsteadiness of hydraulic resistances in branched and unbranched pipeline systems;

— unsteadiness of external influences on the pipeline;

— rate of corrosion wear of metal from non-stationary external and internal impact on the pipeline walls.

It is also necessary to create maps of pumping modes, to determine the procedure for switching on and off pumping units, and to specify the requirements for existing organizations for monitoring, managing technological processes and equipment with mandatory monitoring of non-stationary risks [26, 27].

For these tasks it is necessary to examine the occurrence of corrosion due to the effects of time-dependent factors by the method of spectral correlation analysis, and perform calculations of:

— changes of stress-strain state of pipeline design,

— change of hydraulic resistance fluid,

— internal and external influence of wave patterns of non-stationary variables on the characteristics of the pipelines.

Conclusion. The main reason for pipeline accidents is their unsatisfactory technical condition. Transportation of hydrocarbons involves constant risks arising from corrosion of the pipeline body material, including salt deposits.

The experiment revealed that citric acid can be used as a co-inhibitor to prevent salt deposits and corrosion.

You can prevent accidents or avoid catastrophic consequences by using models of the origin and influence of non-stationary risks on transportation processes.

The compliance with all safety conditions will allow you to manage the operation of pipeline systems for oil and gas transportation in real time.

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Contribution of the authors:

K. N. Abdrakhmanova and I. A. Diaghilev — experimental research and patent analysis; N. Kh. Abdrakhmanov — formulation of the main idea of research and article structure, editing; R. A. Shaybakov — literary, patent analysis and participation in theoretical research.