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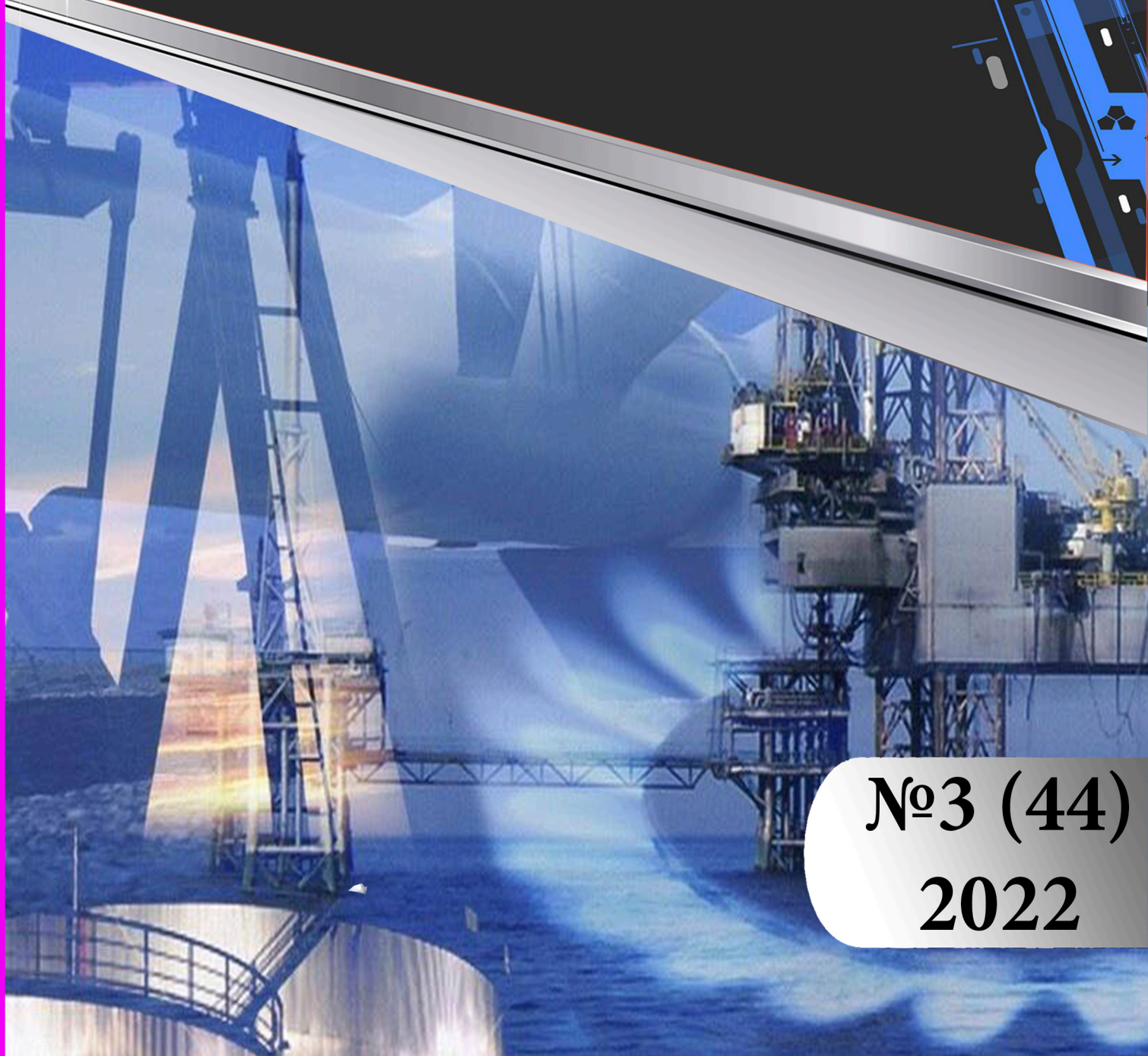

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CORROSION IN PIPES OF HEAT SUPPLY SYSTEMS AND CONDITIONS FOR ITS REDUCTION

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ABSTRACT

When the coolant passes through the pipes in the heat supply systems, difficulties arise that cause an in-crease in the consumption of electricity for heating the coolant. Such difficulties arise due to the formation of corrosion-scale deposits on the in nersurface of the pipe. The composition of such deposits is based on carbon-dioxide – CO_2, H_2CO_3, HCO_3^-, CO_3^{2-}, OH^-, H^+, Ca^{2+}. When considering the carbon dioxide equilibrium, taking into account the ions of alkalin-earth metals in the dissolved state, the ability of the coolant to form and precipitate of calcium or magnesium carbonate (scale) on the inner surface of the pipeline with OH^- and Fe^{2+} - ions simultaneously formed near the metal surface is observed. The resulting cathode and anode reactions can cause significant corrosion of the steel, i.e. the surface of the pipe. Due to corrosion, part of the mass of the iron pipe passes into the coolant solution significantly increases metal losses. The simplest and most effective, as well as in many cases economically feasible methods of preventing corrosion of pipelines, are inhibitor substances introduced into the composition of the coolant. The action of inhibitors is based on the formation of a film on the inner surface of a metal pipe with high protective properties.

Keywords: corrosion inhibitors, corrosion-scale deposits, coolant

INTRODUCTION

Using physical methods to eliminate stiffness, by boiling the coolant (water), it is impossible to prevent the process of scale formation.Scale formation can be prevented chemically by adding soda, phosphates, lime, silicates, chromates, dichromates, polyphosphates, nitrites, borates, organic compounds to the coolant)[1,2].

A simple, but effective and in many cases economically feasible method of eliminating rigidity and preventing corrosion of a metal pipe is the introduction of inhibitors into the coolant, substances whose introduction into the corrosive environment in small quantities significantly reduces the rate of corrosion. In practice, sodium silicate with a high modulus (m=3) is often used to protect the inner surface of pipelines, the concentration of which is selected depending on the characteristics of the water used. In such cases, a protective film is formed on the surface of the pipeline by constant dosing of sodium silicate. Impurities of phosphates, iron and manganese in elevated concentrations in water contribute to the formation of loose crumbling scale, in the case of copper content in the water, the formation of copper scale in the form of layered deposits on the walls of pipes, boilers, radiators is

possible. The coolant captures a highly dispersed sludge consisting of complex carbonates and phosphates, which is also involved in the processes of scale formation [3-5].

The coolant in heat supply systems contaminated with insoluble carbonates and iron oxides is difficult to remove with sodium silicate inhibitor. Acids are often used as inhibitors, reagents to eliminate scale and reduce corrosion of the metal surface: hydrochloric, sulfuric, sulfamic and others, the advantage of some of them is their cheapness and non-toxicity to the metal surface [6].

The authors have established a slowdown in the corrosion process of pipelines in heating systems associated with the formation of SiO_3^{2-}-ions, and the "survivability" time of the formed protective films for different values of the holding time has been established [7].

MATERIALS AND METHODS

The effect of various inhibitors on the corrosion rate was carried out on the surface of four steel tubes ($S = 0.2cm^2$ S = 0.2 cm^2), cleaned of fat with soda solution, decapitated with a solution of 10% sulfuric acid and weighed on analytical scales. Two tubes were immersed in a solution without an inhibitor, the other two tubes were immersed in a solution with an inhibitor –sulfamic acid and kept for three and five hours. The tubes were removed, washed, dried and weighed again. The results were entered in the table. The mass of iron removed from the tube surface was determined. The corrosion rate was calculated and the effectiveness of the inhibitor was determined by comparison. The effectiveness of the inhibitor (Z), in %, was determined by the formula:

$$Z = \frac{m_1 - m_0}{m_1}$$

where: m_1 is the mass of the tube before the experiment, g;

m_0 is the mass of iron removed from the surface of the tube, g.

The corrosion rate in $g/\left(m^2 \cdot h\right)$ was calculated taking into account the surface of the tube (S) and the mass of iron removed from the surface according to the formula:

$$V = \frac{m}{S \cdot \tau}$$

RESULTS AND DISCUSSION

In the calculations, the initial mass of the tube was used, equal to 0.081 g.

Table 1 shows the corrosion rates of steel tubes in coolant solutions without an inhibitor and with an inhibitor (sulfamic acid - $C_6H_5NH_3 \cdot H_2SO_4$).

Table 1- Quantitative indicators of iron mass and corrosion rate

Coolant solution, holding time	The mass of iron that has gone from the surface of the steel tube, g	Corrosion rate $g/\left(m^2 \cdot h\right)$	Corrosion losses per sample, mm/year
Coolant with out inhibitor, 3 hours	0.022	0.15	0.070
Coolant with out inhibitor, 5 hours	0.047	0.58	0.270
Coolant with inhibitor, 3 hours	0.062	0.27	0.060
Coolant with inhibitor, 5hours	0.074	0.12	0.030

Table 1 shows the calculated values of corrosion losse.

The effectiveness of the inhibitor was calculated by changing the mass of the tube surface:

$$Z = \frac{0.081 - 0.022}{0.081} \cdot 100\% = 27\%$$

$$Z = \frac{0.081 - 0.047}{0.081} \cdot 100\% = 57\%$$

$$Z = \frac{0.081 - 0.062}{0.081} \cdot 100\% = 74\%$$

$$Z = \frac{0.081 - 0.074}{0.081} \cdot 100\% = 91\%$$

The decrease in the corrosion rate on the surface of steel tubes in a coolant solution with an inhibitor can be explained by the formation of an effective protective film formed.The data for calculating the effectiveness of the inhibitor show that the most optimal conditions are – five hours of the inhibitor's action on the surface of the steel tube.

The influence of the holding time of steel tubes in a coolant solution with an inhibitor is investigated. The results are presented in table 2.

Table 2 - Indicators of the holding time in a coolant solution with an inhibitor- $C_6H_5NH_3 \cdot H_2SO_4$.

Exposure time, hour	Inhibitor concentration, *mg/l*	Weight of iron removed from the sample, *g*	Corrosion rate, $g/\left(m^2 \cdot h\right)$	Corrosion losses, *mm/year*
5	50	0.074	0.120	0.030
7	50	0.052	0.048	0.012

Table 2 continuation

9	50	0.021	0.027	0.0018
12	50	0.360	0.720	0.099
15	50	0.760	0.950	0.185

An analysis of the data in Table 2 suggests that an increase in the duration of treatment of the metal surface of the samples in a coolant solution with an inhibitor from 5 to 9 hours contributes to a significant reduction in iron losses, mm/g. However, as can be seen from the table, increasing the exposure time from 12 to 15 hours does not have a positive effect. As you can see, the mass of iron that has left the surface increases by an order of magnitude, hence the corrosion rate also increases. Apparently, an increase in the exposure time does not have a positive effect on the protective properties of the film.

Studies of higher (150 g/l) concentrations of the inhibitor and a longer holding time (17 hours and above) do not reduce the rate of corrosion.

Fig. 1 shows the appearance of the film formed on the inner surface of the pipe under the conditions of its treatment with an inhibitor for 5 hours, obtained using an electron microscope with energy dispersive microanalysis systems INSAenerguand HKL-Basic - structural analysis with a useful magnification of 300000.

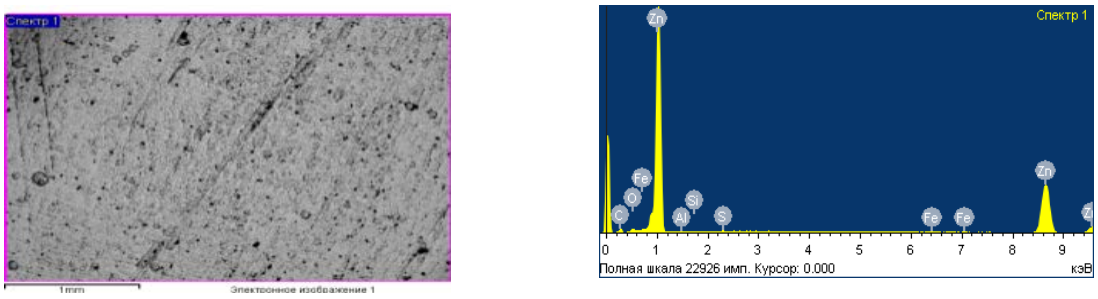

Fig. 1. Appearance of the formed inhibitor-proof film for 5 hours

Fig. 2 shows the appearance of the protective film formed by the inhibitor for 9 hours.

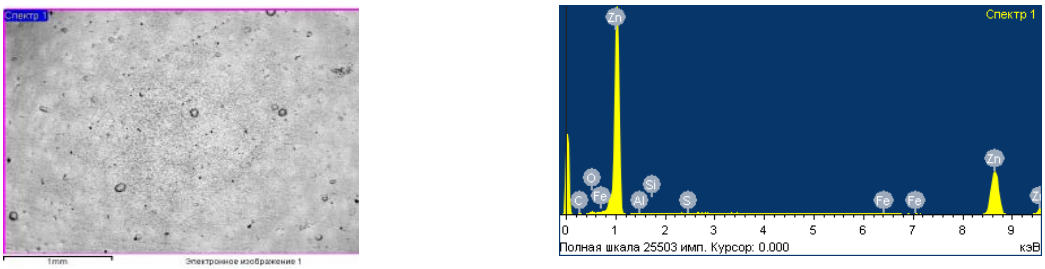

Fig. 2. Appearance of the protective film formed by the inhibitor for 9 hours

As can be seen from the drawings, the films are light, almost non-porous. Based on the results of the experiment, conclusions can be drawn.

CONCLUSION

Summarizing the results of the conducted studies on the effect of the inhibitor on the corrosion rate and the effectiveness of its action, we can draw the following conclusions:

1. A decrease in the rate of corrosion of the metal surface of the tubes in a solution with an inhibitor - sulfamic acid is shown.

2. The calculated values of the effectiveness of the inhibitor action show the possibility of using it to reduce the corrosion rate on the steel surface of the tube.

3. Electronic pictures of the resulting film show its high protective qualities.

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EVALUATION OF ERRORS OF VELOCITY MEASUREMENT BY A SATELLITE NAVIGATION SYSTEM WHEN TESTING AIRCRAFT

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ABSTRACT

Algorithms are proposed for estimating and correcting errors in measuring speed by a satellite navigation system when maneuvering an aircraft based on complex processing together with data from other onboard systems, primarily an inertial navigation system. The relevance of estimating errors in velocity measurements by a satellite system is determined by the fact that these data are used to solve a number of practically significant problems, such as improving the accuracy of determining aircraft orientation angles, estimating systematic errors in measuring angles of attack, slip and airspeed, and estimating three projections of wind speed in flight in the terrestrial coordinate system, as well as the identification of aircraft aerodynamic coefficients from flight data. To solve all these problems, methods of the theory of parametric identification of dynamical systems are used.

The paper presents the results of processing data from a flight experiment, which show that the proposed method provides an estimate of the errors in measuring three velocity projections by a satellite navigation system. The results show that with vigorous maneuvering, the errors of the satellite system increase significantly in comparison with rectilinear horizontal flight. The performed data processing of the flight experiment confirms the efficiency of the proposed solutions.

Keywords: satellite navigation system velocity measurement errors, inertial navigation system, complex data processing, parametric identification based on flight experiment data

INTRODUCTION

Satellite navigation systems (SNS) installed on board aircraft make it possible to determine with high accuracy the coordinates of an object, that is, latitude, longitude and altitude, as well as projections of flight speed relative to the earth's coordinate system. In addition, in recent years, a number of algorithms have been created that provide a solution to a wide range of problems based on measurement information coming from the SNS. For example, in [1, 2] methods for improving the accuracy of determining orientation angles are considered, in [3] an algorithm for estimating systematic errors in measuring angles of attack, slip and airspeed is presented, in [4, 5] algorithms for estimating wind speed are described, and publications [6, 7] are devoted to the identification of aerodynamic coefficients from flight data. The solution of all these problems is based on the application of methods of the theory of identification of dynamical systems [8-11]. At the same time, measurements of three projections of flight speed in the earth's coordinate system performed by the SNS are used as the metrological basis. Therefore, estimating errors in measuring velocity by a satellite system is an urgent task.

Currently, during flight tests of aircraft, satellite navigation systems (SNS) operating in the differential mode are used as a means of out-of-line measurements. As a rule, according to the technical description of the SNS, the measurement errors of the aircraft speed and its projections on the axes of a given coordinate system belong to the interval of 0.2 m/s with a confidence level of 0.95.

However, these results are valid mainly for the modes of level flight and limited maneuvering, when the number of navigation satellites whose signals are received by the SNS remains unchanged. During energetic maneuvering of the aircraft (for example, performing turns, spiral turns, etc.), the composition of the «constellation» of satellites changes. This leads to a significant increase in velocity measurement errors, which, according to preliminary estimates, can reach 8...10 m/s at time intervals up to 1...3 s.

In this regard, the problem arises of estimating and correcting the results of satellite external trajectory measurements of velocity and its three projections on the coordinate axes in maneuvering modes when the composition of the “constellation” of navigation satellites changes.

The solution to the problem can be obtained on the basis of the information redundancy available in the flight test data, by using the results of measurements performed by other onboard systems, primarily the onboard inertial navigation system (INS) and the integrated flight control system. In this case, it is necessary to take into account the nature of the errors inherent in these systems.

MATERIALS AND METHODS

Problem formulation. Let's specify the task. So, the SNS performs measurements in the normal coordinate system, the origin of which is associated with the aircraft and is located at the installation point of the receiving antenna. The vertical axis is directed upward along the normal to the surface of the ellipsoid, two horizontal axes are directed north and east along the tangents to the meridian and the parallel passing through the origin of the coordinate system.

Let us introduce the notation:

V_e, V_n, V_h - ast, north and vertical velocity components in the normal coordinate system described above, m/s;

$V = \sqrt{V_e^2 + V_n^2 + V_H^2}$ - aircraft full speed, m/s.

To assess the measurement errors of the SNS, it is advisable to use the measurements of the aircraft velocity components performed by the INS in the normal coordinate system described above. The eastern, northern and vertical components of the aircraft speed, measured by the INS, will be denoted $V_{e\text{-}b}, V_{n\text{-}b}, V_{h\text{-}b}$.

For verification, we will choose flight segments with a duration of 30 ... 150 s.

It is known that INS errors approximately change according to a harmonic law with an amplitude of up to 4 m/s and a period of 84.4 minutes (Schuler period), which significantly exceeds the duration of the processing section. Therefore, it is permissible to assume that in these areas the measurement errors of the INS flight speeds are constant. On the other hand, the SNS errors that occur during maneuvering are relatively high-frequency and have a period of approximately 1 ... 3 s. The specified separation of errors by frequency allows us to formulate the following two-stage estimation and correction procedure: at the first stage, the SNS data are used to find estimates of the constant errors of the INS measurements, at the second stage, the

velocity projections measured by the INS, corrected taking into account the obtained error estimates, are accepted as the final refined signals.

Problem solution algorithm Let us formulate the considered problem as a standard problem of parametric identification. As a model of the object, we choose the ratios connecting the velocity components in the normal coordinate system described above and the INS measurements. Let us take into account that the measurements are performed at discrete times . $t_i, i = 1,2,...,N$, where N – number of measurements in the processing area.

$$\begin{aligned} V_e(t_i) &= V_{e\text{-}b}(t_i) + C_{V_e}(t_i), \\ V_n(t_i) &= V_{n\text{-}b}(t_i) + C_{V_n}(t_i), \\ V_h(t_i) &= V_{h\text{-}b}(t_i) + C_{V_h}(t_i), \\ V(t_i) &= \sqrt{V_e^2(t_i) + V_n^2(t_i) + V_H^2(t_i)} \end{aligned} \quad (1)$$

where, C_{V_e} , C_{V_n} , C_{V_h} – constant errors of INS measurements of eastern, northern and vertical velocity components.

Let us formulate the model of observations:

$$\begin{aligned} z_1(t_i) &= V_e(t_i) + \xi_e(t_i), \\ z_2(t_i) &= V_n(t_i) + \xi_n(t_i) \\ z_3(t_i) &= V_h(t_i) + \xi_h(t_i) \\ z_4(t_i) &= V(t_i) + \xi(t_i) \end{aligned} \quad (2)$$

where $z^T(t_i) = [z_1(t_i) \quad z_2(t_i) \quad z_3(t_i) \quad z_4(t_i)] = [V_{e\text{-}CHC}(t_i) \quad V_{n\text{-}CHC}(t_i) \quad V_{h\text{-}CHC}(t_i) \; V_{CHC}(t_i)]$ – observation vector consisting of measurements made by the SNS;

$\xi_e(t_i), \xi_n(t_i), \xi_h(t_i), \xi(t_i)$ - random errors of SNS measurements (observation noise) of the east, north, vertical components and full speed. In accordance with the generally accepted assumption, we assume that they are sequences of normal independent random variables with zero mathematical expectation and known variances.

For the convenience of using parametric identification algorithms, we introduce additional vector notation:

state vector $y^T(t_i) = [V_e(t_i) V_n(t_i) V_h(t_i) \; V(t_i)]$,

vector of random errors $\xi^T(t_i) = [\xi_e(t_i) \quad \xi_n(t_i) \quad \xi_h(t_i) \; \xi(t_i)]$,

vector of identifiable parameters $a^T = [C_{V_e} \quad C_{V_n} \quad C_{V_h}]$.

Let us also introduce the vector of known time functions $u^T(t_i) = [V_{e\text{-}b}(t_i) \quad V_{n\text{-}b}(t_i) \quad V_{h\text{-}b}(t_i)]$, into which the measurements of the eastern, northern and vertical components of the velocity made by the INS are substituted.

Then the object and observation models (1) and (2) take the form

$$y(t_i)=\begin{bmatrix} u(t_i) \\ \sqrt{V_e^2(t_i)+V_n^2(t_i)+V_H^2(t_i)} \end{bmatrix}+\begin{bmatrix} a \\ 0 \end{bmatrix} \quad (3)$$

$$z(t_i)=y(t_i)+\xi(t_i) \quad (4)$$

When processing, we will include measurements made by the SNS in the observation vector: $z^T(t_i)=[V_{e-SNS}(t_i) \quad V_{n-SNS}(t_i) \quad V_{h-SNS}(t_i) \quad V_{SNS}(t_i)]$.

To find estimates of constant errors $a^T=[C_{V_e} \quad C_{V_n} \quad C_{V_h}]$ the functional is minimized:

$$J(a)=\sum_{i=1}^{N}\left(z(t_i)-\hat{z}_a(t_i)\right)^T\left(GG^T\right)^{-1}(t_i)\left(z(t_i)-\hat{z}_a(t_i)\right), \quad (5)$$

where, $\hat{z}_a(t_i)$ - observation vector prediction estimate, which is calculated by numerical solution of equations (3) and (4) with zero observation noise $\xi_e(t_i)=\xi_n(t_i)=\xi_h(t_i)=0, i=1,2,\ldots,N;$

G - diagonal matrix containing the r.c.d. measurement noise of the elements of the observation vector $z(t_i)$.

To numerically find estimates of the vector $a^T=[C_{V_e} \quad C_{V_n} \quad C_{V_h}]$, minimizing functional (5), the following identification algorithm is used (6) – (13), which is a modification of the classical Newton method [1,5]. In general, the algorithm is written as follows:

MM object $\dot{y}(t_i)=f(y(t_i),a,u(t_i))$. (6)

MM observations $z(t_i)=h(y(t_i),a,u(t_i))+\xi(t_i)$ (7)

Calculation formulas

$$\hat{a}_{k+1}=\hat{a}_k-\left[\nabla^2 J(\hat{a}_k)\right]^{-1}\left[\nabla^T J(\hat{a}_k)\right], \quad (8)$$

where

$$\nabla J(\hat{a}_k)=-\sum_{i=1}^{N}\left[z(t_i)-\hat{z}_{a_k}(t_i)\right]^T(G\,G^T)^{-1}\left[\nabla^T \hat{z}_{a_k}(t_i)\right], \quad (9)$$

$$\nabla^2 J(\hat{a}_k)=\sum_{i=1}^{N}\left[\nabla \hat{z}_a(t_i)\right]^T(G\,G^T)^{-1}\left[\nabla \hat{z}_a(t_i)\right], \quad (10)$$

$$\nabla \hat{z}_a(t_i) = \left[\frac{\delta \hat{z}_a(t_i)}{\delta a_1} \; \frac{\delta \hat{z}_a(t_i)}{\delta a_2} \; \ldots \; \frac{\delta \hat{z}_a(t_i)}{\delta a_p} \right], \tag{11}$$

$$\frac{\delta \hat{z}_a(t_i)}{\delta a_j} \approx \frac{\hat{z}_{a+\varepsilon e_j}(t_i) - \hat{z}_a(t_i)}{\varepsilon}, \tag{12}$$

where, ε - small number; e_j - is a vector of the same dimension as the parameter vector a, j -й whose th element is equal to 1, and all the rest are equal to zero.

Identification termination condition

$$\left\| \hat{a}_{k+1} - \hat{a}_k \right\| < 0.02 \left\| \hat{a}_k \right\| \tag{13}$$

Obtaining estimates of constant errors C_{V_e}, C_{V_n}, C_{V_h} completes the first stage of complex processing.

At the second stage, estimates of the constant errors of the C_{V_e}, C_{V_n}, C_{V_h} are added to the measured INS velocity components of the $V_{e\text{-}b}(t_i), V_{n\text{-}b}(t_i), V_{h\text{-}b}(t_i)$ and the corrected values of the components and the total velocity are calculated:

$$\begin{aligned} V_{e-corr}(t_i) &= V_{e-b}(t_i) + C_{Ve}, \\ V_{n-corr}(t_i) &= V_{n-b}(t_i) + C_{Vn}, \\ V_{H-corr}(t_i) &= V_{h-b}(t_i) + C_{Vh}, \\ V_{corr}(t_i) &= \sqrt{V^2_{e-corr}(t_i) + V^2_{n-corr}(t_i) + V^2_{H-corr}(t_i)} \; . \end{aligned} \tag{14}$$

RESULTS AND DISCUSSION

The performance of the proposed algorithms and the validity of the assumptions made were tested on examples of processing data from flight tests of one of the modern aircraft, obtained using an onboard measurement and registration system installed for the test period.

For processing, a flight segment with a duration of 87 s was selected, on which the aircraft performed a turn with a bank angle of 45 ... 55 degrees and a normal overload of 1.3 ... 1.7 units of overload (Fig.1). Time, s, is plotted along the x-axis on that and on all subsequent graphs.

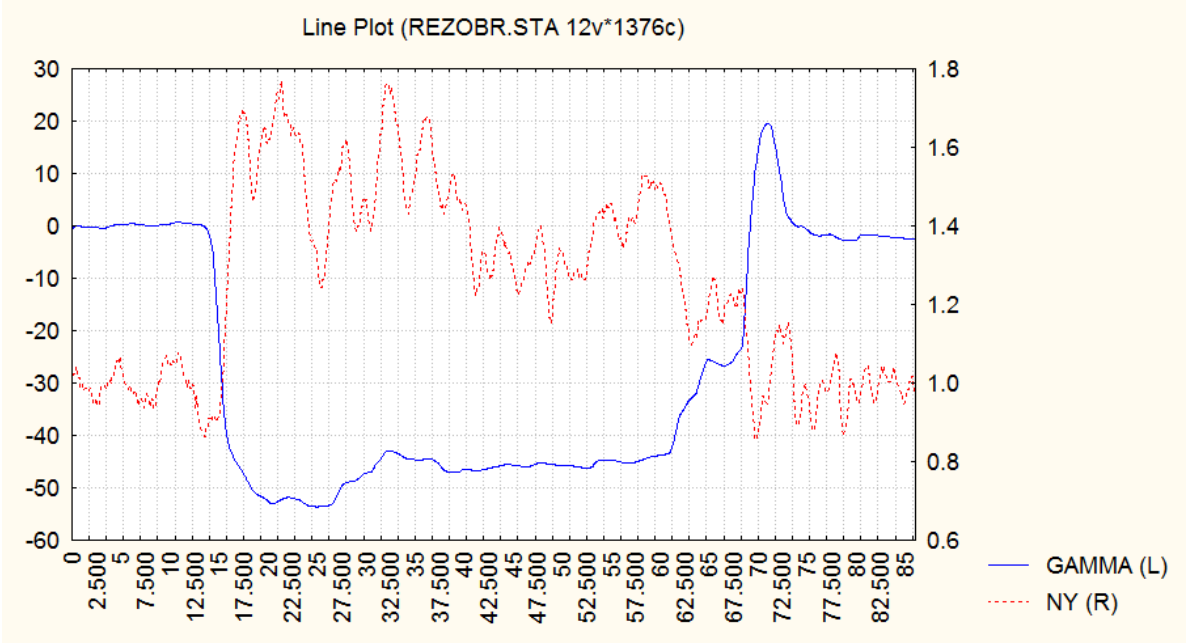

Fig.1.Change in the angle of roll (GAMMA, degrees, left y-axis) and normal overload (NY, unit of overload, right y-axis) in the processing area. On the abscissa - time, s.

The results of processing according to the algorithm of section 2 are shown in Fig.2.

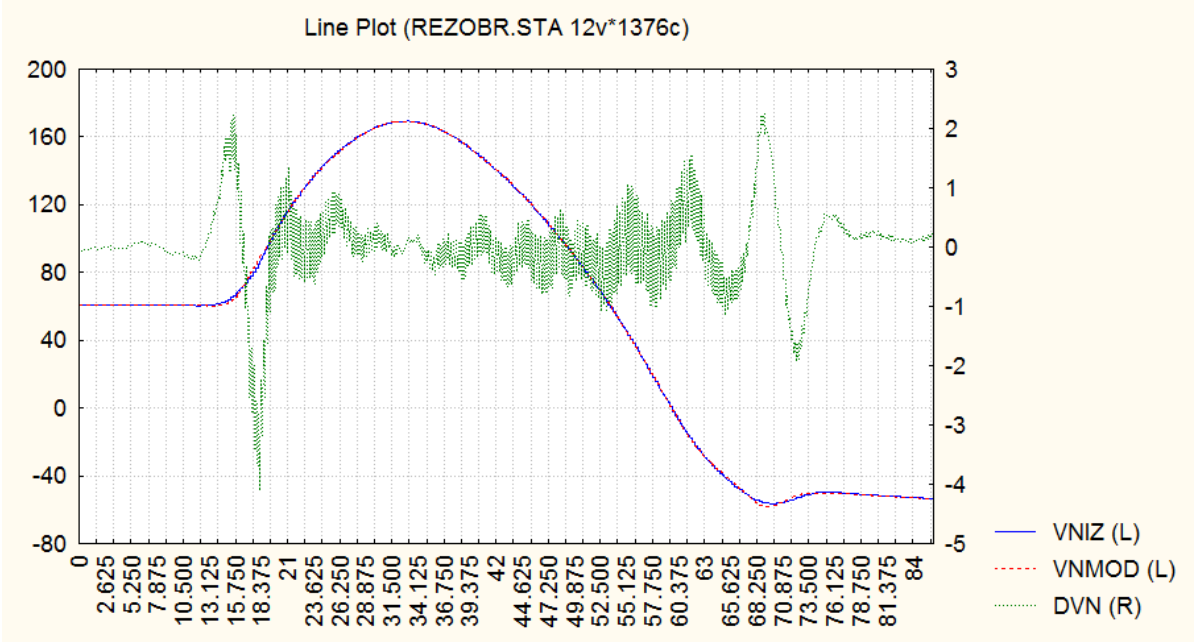

Fig.2. Northern velocity component measured by satellite navigation system and corrected (VNIZ, VNMOD, m/s, left y-axis) and estimation of its measurement error (DVN, m/s, right y-axis)

The measured SNS northern velocity component VNIZ and the corrected signal VNMOD (the northern component measured by the INS, to which a constant error estimate is

added) are visually indistinguishable on the graph, since the error is much less than the velocity values. The error of the SNS, which is estimated as the difference DVN between the signals VNIZ and VNMOD, is shown here on a larger scale (digitized along the right ordinate, m/s).

The graph shows that in straight flight sections with bank angles close to zero, the SNS errors do not exceed 0.2 m/s, which corresponds to the technical description. At the beginning and at the end of the maneuver, with a rapid change in the bank angle, the error briefly (by approximately 8 seconds) increases to (-4 ... 2) m/s. During a steady turn, the error also increases and is within ±1 m/s.

An analysis of information about the satellites used by the SNS shows that during the turn, the composition of the "constellation" of satellites from which the SNS receives signals is constantly changing, although their number always exceeds the minimum required 4 satellites. At the same time, the composition of the "constellation" remains constant in the segments of a rectilinear flight. This allows us to conclude that the reason for the multiple increase in the maneuvering error is transient processes in the SNS caused by the loss of signals from some satellites and the capture of others.

CONCLUSION

Algorithms are proposed that allow estimating and correcting errors in measuring the speed of a satellite navigation system when maneuvering an aircraft based on the use of information redundancy and parametric identification methods. The performance of the proposed algorithms is confirmed by the processing of the flight experiment data.

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STUDY OF PROCESS OF IRON OXIDE PIGMENTS

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ABSTRACT

The article describes the types of pigments used in the construction industry, and their role in human life. It is shown that pigments not only give color to building materials, but also contribute to their attractiveness. Described the physicochemical properties of pigments and factors affecting their quality. Describes such important parameters of pigments as their impact on the quality of application of paint, color intensity, hiding ability, compatibility with the painted material and others. In addition, the criteria for the selection of pigment in accordance with its resistance to strong light, heat and other weather conditions. The chemical composition of iron-bearing ores is assigned. Describes the method of obtaining pigments and the selection of optimal parameters. The optimal parameters of the firing process were determined. The dependence of the degree of roasting of ferruginous ore on the temperature and processing time has been studied. Besides, the chemical composition of the resulting pigment is given.

Key words: pigments, inorganic pigments, iron oxide pigments, lacquer production, enamel, iron-containing ore.

INTRODUCTION

Pigments are highly dispersible substances with a certain set of optical, mechanical and sorption properties, insoluble in water, organic solvents, film-forming agents and other dispersed media.

Pigments are solid components of composite paints and varnishes - paints, enamels, primers and powder compositions. By interacting with organic films, pigments form structural lines with them, increasing the strength and service life of coatings. Depending on the full or partial scattering of light, the pigments give color to the film. Needles and flaky pigments strengthen the film, reduce its gas and water permeability, increase the mechanical strength and weather resistance of paint coatings [1].

Kazakhstan's mineral resources are one of the key factors determining the country's development strategy. Kazakhstan is one of the richest regions in the world in terms of mineral resources and diversity. Mineral resources of Kazakhstan are an important guarantee of sustainable development and security of the national economy. The current state of the country's powerful mineral resource base has radically freed the country from dependence on mineral resources of the CIS countries, allowing Kazakhstan to export mineral resources and its processed products to the world market.

The reserves of iron ore are more than 8 billion tons. 80% of it is located in the Turgai iron ore basin. The largest deposits in the basin are Sokolov Sarybai, Kashar, Lisakov and Ayat. In the metallurgical process, in addition to iron ore, vanadium, aluminum oxide, phosphate slag are obtained. They are used as a mineral fertilizer.

Today, the development of paints and varnishes for the construction industry on the basis of local raw materials is a topical issue for Kazakhstan [2].

MATERIALS AND METHODS

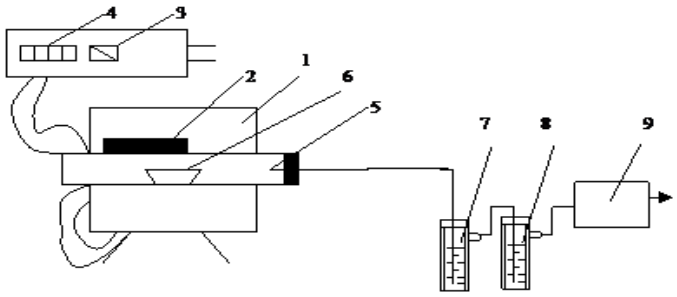
We studied the natural iron ore of the Altyntau mine. The chemical composition of the raw material was studied. The chemical composition of the original sample of iron-bearing ores is given in Table 1.

Table 1- Chemical composition of iron ore

Fe_2O_3	CaO	MgO	AI_2O_3	SiO_2	SO_3	Na_2O	K_2O	P_2O_5	TiO_2
5.12	4.088	2.46	17.74	48.25	2.77	0.36	5.8	0.31	0.94

Chemically, the ore contains mainly aluminum, silicon, calcium, iron, titanium, calcium, sulfides and other minerals[3,5].

The process of obtaining iron oxide pigments was carried out in the unit shown in Fig. 1. The ore, which has undergone the process of preparation and enrichment, is leached with a 20% solution of sulfuric acid containing iron in a ratio of 1:3 for 20-25 minutes at 60-70° C and infused for 8 hours. The precipitated solution is then filtered through a vacuum filter. The liquid solution is sent for disinfection. And the pigment is removed from the warehouse. The stock is dried in a drying oven at 100^0C until it reaches a constant weight and allowed to bake at 700^0C for 1 hour. Qualitative and quantitative analysis of the finished product.



Designation: 1. Tube oven; 2. Chromelalumel thermocouple; 3. Millivoltmeter; 4. Thermoregulator; 5. Reaction porcelain tube; 6. Boat; 7. Absorption glass; 8. Three-necked flask; 9. Water injection gas pump

Fig. 1. Example of an ore incinerator

The ore firiing unit consists of an electric furnace with a tube that can raise the temperature up to 1000^0C, a chromium alumel thermocouple that controls the temperature, a millivoltmeter, a thermal relay MKU-2 that maintains the set temperature, a porcelain tube inside the furnace, and a boat with a specific number of ore. One side of the tube is open for air to enter, and the other side is connected to a water-pump to pump the gases from the furnace through the absorption vessels. The solution in the first three necks of the flask should be titrated with an alkaline solution through a burette, and the second glass is placed to monitor the absorption process. Fill the absorption flask – 100, the beaker – 50 ml, 5-10% - a solution of hydrogen peroxide neutralized with a vertical methyl orange indicator [4,6,7].

According to known methods, the ore is leached with 20% sulfuric acid in a ratio of 1:3.

RESULTS AND DISCUSSION

When the ore is leached with sulfuric acid, its compounds are converted into sulfate. The following reaction occurs during leaching.

$$Fe_2O_3+3H_2SO_4 \rightarrow Fe_2(SO_4)_3+3H_2O \quad (1)$$
$$Na_2O+H_2SO_4 \rightarrow Na_2SO_4+H_2O \quad (2)$$
$$Al_2O_3+3H_2SO_4 \rightarrow Al_2(SO_4)_3+3H_2O \quad (3)$$
$$K_2O+H_2SO_4 \rightarrow K_2SO_4+H_2O \quad (4)$$
$$CaO+H_2SO_4 \rightarrow CaSO_4+H_2O \quad (5)$$
$$TiO_2+H_2SO_4 \rightarrow TiO(SO_4)+H_2O \quad (6)$$

Table 2 – Chemical composition of iron ore after leaching with 20% sulfuric acid, %

№	Fe_2O_3	MgO	Al_2O_3	SiO_2	SO_2
1	74,17	1,07	2,6	19,27	2,89

In order to enrich the iron-bearing ore, it is leached with water and, as shown in the table, the amount of iron oxide in the ore increases. Then 20% sulfuric acid is added in a ratio of 1:3, and the compounds soluble in sulfuric acid in the ore are dissolved. Iron, aluminum, silicon, magnesium and sulfur compounds remain in the ore. That is, the composition of the original ore varies significantly.

At the end of the preparation process, the iron ore is sent for firing. Firing was studied at a temperature of 700-1000^{0}C for 15-60 minutes. The results of the study are shown in the following table. The results of the study are presented in Table 3.

Table 3 – The process of firing iron ore depending on temperature and time.

Firing temperature, ^{0}C	Firing time	Fe_2O_3 content in raw materials, g		Degree of firing, %
		Before firing	After firing	
700	15	29,8	21,45	72,39
	30	30	22,5	75,01
	45	29,99	25,19	84,09
	60	28,7	24,96	87,77
750	15	33,7	22,24	66,14
	30	35,6	26,34	74,07
	45	32,1	25,32	78,99
	60	33,4	26,72	80,23
800	15	30,5	17,69	58,37
	30	29,9	18,08	60,65
	45	27,19	18,21	67,14
	60	28,4	21,18	74,62
850	15	29,69	16,92	57,36
	30	27,7	17,17	62,21
	45	27,6	19,3	69,96
	60	30,6	22,64	74,02

Table 3 continuation

900	15	34,9	19,54	56,4
	30	32,74	18,98	57,99
	45	31,2	19,65	63,39
	60	32,65	23,69	72,58
950	15	31,7	15,53	49,13
	30	29,6	15,68	52,98
	45	34,5	18,52	53,7
	60	30,54	20,76	68,01
1000	15	28,52	13,01	45,65
	30	29,85	15,51	51,97
	45	31,78	18,75	59,28
	60	32,4	21,06	65,03

The formula for calculating the degree of firing of ore:

$$\alpha = \frac{m_1 - m_2}{m_1} \cdot 100\%$$

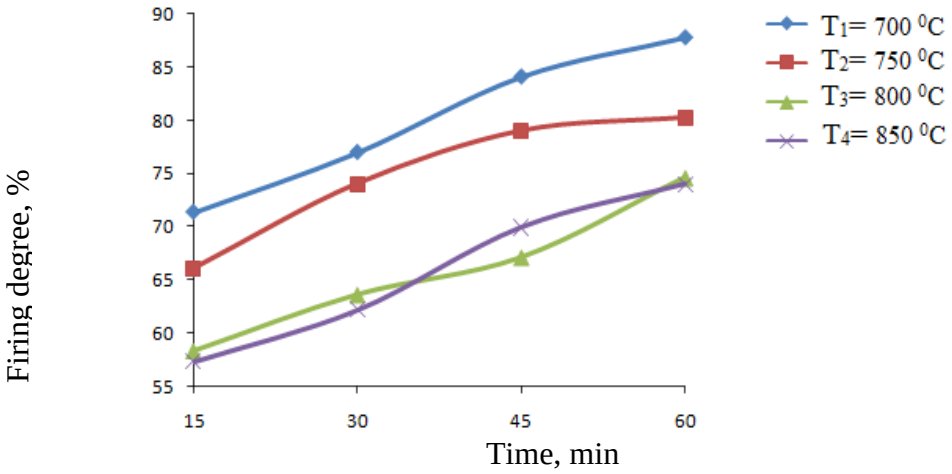


Fig. 2 - Dependence of the degree of firing on time and temperature

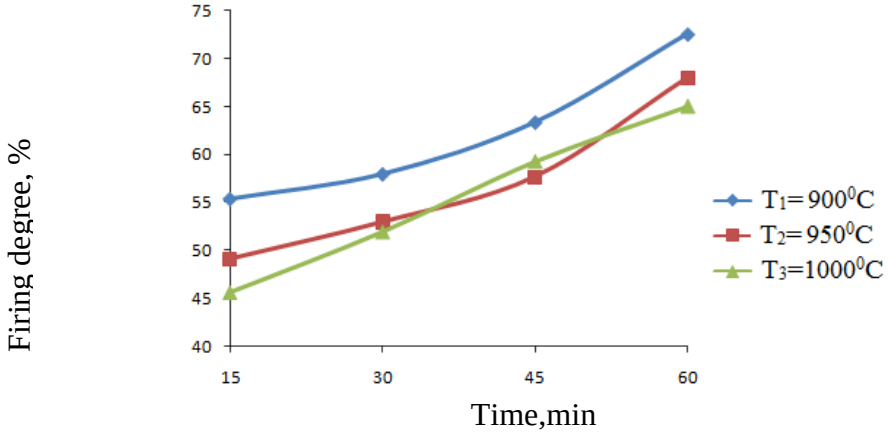


Fig. 3 – Dependence of the degree of firing on time and temperature

The process of roasting iron ore is a complex process consisting of chain and parallel chemical reactions. When the ore is heated to 500^0C, the dissociation of pyrite forms iron (II) sulfide and sulfur. Sulfur burns rapidly in the gas phase and turns into sulfur gas. As the temperature rises further, it oxidizes to iron sulfide. Therefore, the firing process was carried out in the range of 700-1000^0C.

The image of the pigment obtained as a result of the study is given below. The pigment sample obtained in the laboratory was studied by special methods used in the paint industry. The chemical properties of the pigment are shown in Table 4.

Fig. 4 – Laboratory pigment

Table 4 – Results of the study of the obtained pigment sample and comparison with standard grades of iron oxide pigments

Name of the indicator	Pigment grade			
	Higher	K-0	K-1	Actual (according to research results)
1. Mass fraction of iron compounds is not less than Fe_2O_3, %	90.8	90.5	90.0	87.9
2. Mass fraction of insoluble residue in hydrochloric acid, %, not more	0.7	0.7	0.7	0.57
3. Mass fraction of volatile substances, %, not more	0.5	0.5	1.0	0.2
4. Mass fraction of water-soluble substances, %, not more	0.58	0.7	1.0	0.62
5. pH of water extract	5 - 9	3 - 7	3 - 7	6.7
6. Oil capacity, g/100g pigment, not more	45	45	45	13.8
7. Residue in a sieve with a mesh of 0.063 mm, %, not more	0.1	0.3	0.5	0.3
8. Coverage, g/m, not more	7	7	9	7

The red iron oxide pigments obtained by the results of the studies shown in the table are close to the quality requirements (TU 2322-001-33437841-2001) and belong to the red iron oxide pigments.

CONCLUSION

According to the results of the study, the degree of firing of iron ore is – 72.39-87.77%. The dependence of the degree of firing of iron-bearing ore on the temperature and processing

time was studied. According to the results of the study, the effective technological parameters of roasting of iron ore are as follows: temperature – 700^0C, time – 60 minutes.

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ANALYSIS OF THE CURRENT STATE OF THE INNOVATIVE POTENTIAL OF THE REPUBLIC OF KAZAKHSTAN

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ABSTRACT

In modern Kazakhstan, the priority areas of innovation and technological development in our country are clearly defined, the need for the formation of a single national innovation system is ensured, which ensures the effective use of the existing innovation potential and creates incentive for its growth.

The innovative development of the economy is determined both by the requirements of the time and the priority of increasing the competitiveness of the national economy. The most important direction for ensuring innovative development in modern conditions is the implementation of sustainable economic changes associated with this process. At the same time, the identification of the main criteria for innovative development, the formation of a structure for a holistic assessment of the level of innovative development of the region and mechanisms for their improvement in order to effectively manage the level of innovative development of the region are of particular importance. The article provides a comparative analysis of the essence of the innovation potential, its main components, the main indicators of innovative activity in the Republic of Kazakhstan, the volume of innovative products over the past 5 years and the level of innovative activity of enterprises. At the end of the work, the results were summarized and the main factors affecting the development of innovation potential were identified.

To create an innovative environment in the regions of Kazakhstan, it is necessary to strengthen integration processes that contribute to the effective implementation of innovation potential within the framework of a regional innovation system between public administration bodies, educational, industrial enterprises and research institutes of various subjects of the Republic of Kazakhstan.

Keywords: innovation, innovation potential, product, innovative development, competitiveness, innovation

INTRODUCTION

The concept of "innovative potential" began to develop in the early 1980s and has become a conceptual expression of the concept of innovative activity. In order to determine the rational amount of innovative potential that should be present in an effective functioning macroeconomic system, as well as to assess the impact of innovative potential on the development of the national economy, it is necessary, firstly, to clearly define the concept of innovative potential, and secondly, its composition. Currently, in the economic literature, quite a lot of attention is paid to the problems of forming innovative potential, however, the available information is of a contradictory nature and does not have a homogeneous

formulation. For example, in individual cases, the innovative potential is equated with the scientific and technical potential. Such an analogy does not take into account the fact that a novelty becomes an innovation in the face of its diffusion and commercialization. And only the scientific and technical component of the innovation potential is responsible for the emergence of a novelty.

In the development of modern society, the main factor in the strategic growth of the economy is innovation. Companies that are inefficient users of their innovative potential will certainly free up their niche in the market to advanced enterprises. And companies that can effectively use their innovative potential, using new ideas, innovations, will be able to reduce production costs and make additional profits, strengthen their competitive advantages and increase it, while maintaining their share in the market [1].

Thus, innovative potential is a set of characteristics of a socio-economic system (Enterprise, City, Region, country) that determine the ability to create, implement and disseminate new ideas, technologies and products.

MATERIALS AND METHODS

The concept of "innovation potential" consists in determining its main resource interrelated components, as well as indicators characterizing its level.Today, the concept of" innovation potential " can be considered as an integral part of the scientific, personnel, technical, financial and economic potential and information and communication potential, which ensure innovative activities and determine the competitiveness of the region's economy.

In the economic literature, there are many ways to explain the concept of innovative potential, for example:

1. a set of various types of resources necessary for the implementation of innovative activities;

2. ability of the system to switch to a new state in order to meet needs (personal, Market, etc.);

3. a structure that combines the three components of potential: resource, internal and productive, which predict and define each other in interaction;

4.the ability to create innovations, the willingness to accept innovations at the level corresponding to the world for the implementation, subsequent effective use of innovations.

The value of innovative potential is a parameter that allows you to assess the possibilities of innovative activity of the region and determine the strategy for innovative development. Management decisions on the choice and implementation of an innovation strategy depend on the state of innovation potential, as a result of which it is necessary to conduct a comprehensive assessment[2].

RESULTS AND DISCUSSION

Currently, the creation of an innovative economy is a strategically important direction for Kazakhstan. In order to transfer the country's economy to the path of innovative development, it is necessary to develop a mechanism that will allow restructuring all spheres of public relations in order to promote the development of an innovative economy. The transition to a knowledge economy requires the formation of an integral system in the country and, accordingly, in the regions, which effectively converts new knowledge into new

technologies, products and services that find their real consumers in national or World Markets[3].

Regions - all over the world are considered the engine of innovation and development of the entire country. It is important to strengthen the regional dimension of innovative development. At the same time, it is necessary to achieve coordination of the actions of the government, science, education, business, financial instruments in the form of regional banks and the involvement of federal banks and the media.Therefore, today it is necessary to support the regions involved in investing in innovative development, as well as those that are characterized by the selectivity or limitation of innovation. More attention should be paid to innovation zones. In this regard, innovative services are carried out in the Republic of Kazakhstan by region. The main indicators of innovation activity in 2021 are shown in Table 1.

Table 1 - Key indicators of innovation activity in the Republic of Kazakhstan for 2021, units

	Number of enterprises, units	From those with innovation
The Republic of Kazakhstan	28 203	2 960
Akmola	1 155	67
Aktobe	1 114	139
Atyrau	1 046	106
West Kazakhstan	795	55
Zhambyl	732	67
Karaganda	2 199	285
Kostanay	1 366	163
Kyzylorda	645	72
Mangystau	1 070	67
Pavlodar	1 092	57
North Kazakhstan	992	112
Turkestan	814	85
East Kazakhstan	1 854	207
Astana city	3 668	494
Almaty city	6 527	747
Shymkent city	1 435	100
Note: https://www.stat.gov.kz/[4]		

As shown in Table 1, according to the report for 2021, there are a total of 28,203 enterprises in the Republic of Kazakhstan. Of these, there are a total of 2960 innovations of the enterprise. According to the regions, Almaty is the leader in the number of enterprises and innovative activities. It has 6,527 enterprises, including 747 enterprise innovations. The second place is occupied by Astana, where 494 out of 3,668 enterprises have innovations. In Karaganda, 2,199 enterprises, including 285 enterprises, are engaged in innovative activities. In total, there are 1,854 enterprises in East Kazakhstan, including 207 innovative enterprises. There are 163 innovative enterprises in Kostanay and 139 in Aktobe. In total, 112 enterprises of 992 enterprises in northern Kazakhstan are engaged in yin and yang. In Atyrau, the number of enterprises engaged in innovative activities is 106, in Shymkent-100 enterprises engaged in innovative activities. As we have seen, the city of Shymkent occupies the 9th place in terms of innovation activity. According to the schedule, in other cities, the number of enterprises

engaged in needlework is less than 100. Next, the volume of innovative products (goods, services) by region is shown in Table 2.

Table 2 – 2017-2021. Volume of innovative products (goods, services) of the Republic of Kazakhstan, mln.tenge

	2017	2018	2019	2020	2021	Growth rate in 2021 /2017., %
The Republic of Kazakhstan	844734.9	1064067.4	1113566.5	1715500.1	1438708.5	1.7 ece
Akmola	15721.9	25644.6	17793.0	56366.5	112279.2	7.1 times
Aktobe	39442.0	44299.9	51421.7	59026.1	86445.2	2.2 times
Atyrau	5768.0	8819.8	7536.3	402420.3	40422.1	7 times
West Kazakhstan	18122.1	23398.7	24713.4	21671.3	19774.1	109.1
Zhambyl	50854.7	66782.3	77092.5	67430.7	77650.2	152.7
Karaganda	32048.0	54778.0	74007.0	145720.6	246050.8	7.7 times
Kostanay	91502.6	124014.9	211088.3	349012.4	378988.5	4.1 times
Kyzylorda	5 505.8	6401.7	16425.2	19925.7	33111.2	6 times
Mangystau	294.9	651.0	7971.3	5317.2	4233.2	14.4 times
Pavlodar	177881.5	250032.0	44 503.7	96984.4	97164.0	54.6
North Kazakhstan	13804.9	9396.5	8652.1	26066.0	25196.4	1.8 times
Turkestan	13140.0	13375.7	13797.5	14847.6	14177.3	107.9
East Kazakhstan	80472.0	174068.8	223618.8	116747.0	37549.2	46.7
Astana city	149277.5	112146.2	129468.7	67314.0	41456.4	27.8
Almaty city	26183.3	30228.4	48948.4	56491.2	62846.8	2.4 times
Shymkent city	112091.6	101678.0	136084.8	150588.3	95024.9	84.8
Note : https://www.stat.gov.kz/[4]						

According to Table 2, the volume of innovative products in Kazakhstan increased by 1.73 times in 2021 compared to 2017. That is, in 2017 it amounted to 844,734.9 million tenge, in 2021-1,438,708. 5 million tenge. In 2021, Mangistau, Akmola, Atyrau, Karaganda, Kyzylorda, Kostanay have significantly more growth rates than in 2017. In 2021, the volume of innovative products (goods, services) in Mangistau is leading compared to 2017 with an increase of 14.4 times. In the cities of Akmola and Atyrau, the volume of innovative products increased almost 7 times, in Karaganda-7.68 times, in Kyzylorda-6 times, in Kostanay-4.14 times. However, there is no growth in all cities of the Republic of Kazakhstan. In Republican cities, including Astana and Shymkent, the volume of innovative products decreased significantly compared to 2017. Accordingly, the volume of innovative products in Astana in 2017 amounted to млн 149,277.5 million.in tenge, in 2021, over 5 years, it decreased by 72% with a total volume of 41,456.4 million."no," he said. And the city of Shymkent decreased by 15%, that is, in 2017 it amounted to 112,091.6 million.tenge, and in 2021 it decreased to 95,024.9 million tenge. In other cities, there is a decrease in the growth rate of innovative products. In Pavlodar by 45%, in East Kazakhstan by 55%[5-6].

The innovative potential of the Republic of Kazakhstan is directly related to the innovative activity of enterprises in the regions. Fig. 1 below shows the level of inovation activity of enterprises located in the Republic of Kazakhstan and in the cities of the Republic.

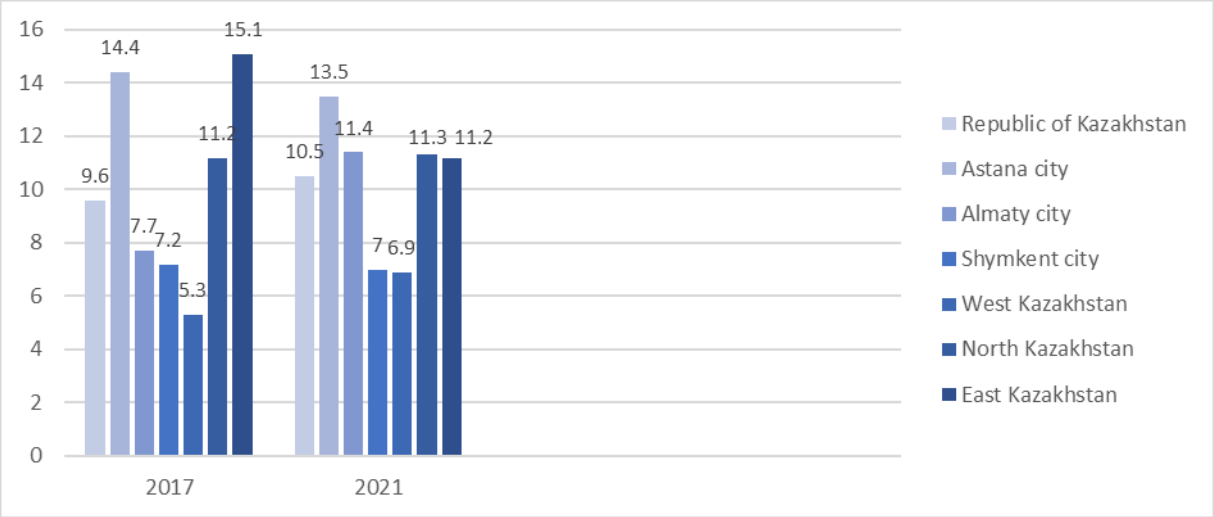

Fig. 1. 2017-2021. The level of innovation activity of enterprises in the Republic of Kazakhstan for all types of innovation, % [4]

As can be seen from Fig. 1, the level of innovation activity of the Republic of Kazakhstan in 2017 was 9.6%, and this figure reached 10.5% in 5 years. Astana was 14.4% in 2017, but its activity level in 2021 decreased by 0.9% compared to 2017 and amounted to 13.5%. The level of activity in Almaty has increased significantly. That is, in 2017 it was 7.7%, and 5 years later the level of activity increased by 3.7% and amounted to 11.4%. The level of Shymkent decreased from 7.2% to 7%. The level of activity in western Kazakhstan increased from 5.3% to 6.9%. The level of innovation activity in northern Kazakhstan in 2017 was 11.2%, and in 2021 it increased by 0.1%, that is, 11.3%. There is a significant change in the level of innovation activity in East Kazakhstan. In 2017, the level of activity was the highest in comparison with other cities, 15.1%. But in 2021, the level of activity decreased by 3.9% to 11.2%.

CONCLUSION

The competitiveness of the national economy directly depends on the growth of innovative potential in society. This means that economic growth should be carried out mainly through industrial and innovative achievements, the introduction of scientific and technological progress, the use of computer, resource-saving technologies. That is, the transition of the economy of Kazakhstan to the path of innovative development is one of the main priorities of the state policy aimed at ensuring the stability of the national economy in the context of global competition.

The necessary legislative and institutional framework and infrastructure have been created to systematize work to increase the share of innovative goods, works and services, to promote the development of technological entrepreneurship. On the basis of the best international experience, constant work is underway to improve legislation.

In the Global Innovation Index ranking, Kazakhstan improved its position by 77 places (79th place in 2019). According to the Global Competitiveness Index of the World Economic Forum in 2019, Kazakhstan took the 95th place in terms of the "innovation potential" factor (no assessment was carried out in 2020). In addition, in 2020, Kazakhstan returned to the Bloomberg Innovation Index (60 Best Countries) and took the 59th Place[5].

We believe that the main condition for increasing the innovative potential of the Republic of Kazakhstan is to increase the competitiveness of innovative enterprises of the regions. Therefore, in order to increase the innovative potential of the Republic of Kazakhstan, it is necessary, first of all, to develop the innovative potential of the regions. To do this, it is possible to identify the main factors that affect the regional innovation potential, form its scale and determine the directions of use:

1. innovation policy pursued by regional authorities;
2. innovative strategy of economic entities operating in the relevant territory;
3. policy of financial and credit institutions operating in the region;
4. changing customer preferences;
5. nature of competition;
6. current level of development of territorial innovation infrastructure;
7. the presence of certain knowledge and scientific and technical developments accumulated within and beyond a certain territory and which can be attracted in the interests of the socio-economic development of a particular territory.

Thus, we can conclude that in order to increase the effectiveness of the development of innovation activities in each region, it is necessary to introduce a flexible financial support mechanism that simultaneously takes into account the investment needs and investment potential of the innovation industry.

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THE RESULTS OF EXPERIMENTAL RESEARCH THE VIBRATION OF THE AIRCRAFT ON THE CONCENTRATION ANTI-WATER-CRYSTALLIZATION LIQUID IN AVIATION KEROSENE

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ABSTRACT

In this article, we consider the results of experimental studies describing the influence of the vibrational effect of an aircraft on the concentration of anti-liquid crystal liquid in jet fuel. The order of carrying out the full factorial experiment, the multidimensional regression model, as well as information sources for constructing the multidimensional regression model, the mathematical model are described. A preliminary experiment is considered in which the temperature of the beginning of the crystallization of the tested fuels is determined, and the limitations (lower and upper limits) of the factors and the hypothesis about the presumed form of the regression equation are then revealed. The adequacy of the obtained model of statistical communication and the values of unknown coefficients are analyzed. Based on the theory of experiment planning, a method for calculating the parameters of a full-factor experiment has been developed, according to which experimental studies have been carried out for various brands of fuel. Based on the study, the author proves the relationship between three factors: the frequency of vibration, the temperature of the mixture of fuel for jet engines and anti-wax liquid, the temperature of the beginning of the crystallization of fuel for jet engines.

Keywords: vibration, anti-water-crystallization liquid, fuel for jet engines, experiment.

INTRODUCTION

The practical benefits of scientific research largely depend on the methods of their implementation and the form in which the results are presented. The use of modern effective research technologies through productive electronic computing and appropriate mathematical software can significantly reduce the period of implementation of the results, which leads to savings in time and money.

With the help of traditional research methods, it is difficult to ensure the required modernization of old or design of new technical means. Therefore, in science, technology and production, effective research methods are used to solve various problems. At the same time, close attention is paid to process models and methods of their construction.

For an effective analysis of the mechanism of phenomena and process control, it is necessary to identify the relationships between the factors that determine the dynamics of the process and present them in quantitative form, i.e. in the form of a mathematical model.

A mathematical model is a mathematical representation of the most significant aspects of the process. The mathematical model construction scheme shown in Fig. 1 is a set of equations, conditions (constraints) and algorithmic rules and allows:

- receive information about the processes taking place in the object of research;
- calculate systems, i.e. analyze and design them;
- receive information that can be used to control the simulated object [1].

During the preliminary experiments [2,3], a functional relationship was established between the frequency of vibration exposure and the mixture of anti–water crystallization liquid (AWCL) with jet engine fuel (hereinafter referred to as fuel) and the fuel brand.

It is most expedient to associate this factor with differences in the hydrocarbon composition of the tested fuels, namely, with the temperature of the beginning of crystallization, since it is this quality indicator that integrally combines the most significant differences in the group hydrocarbon composition of various types of fuels.

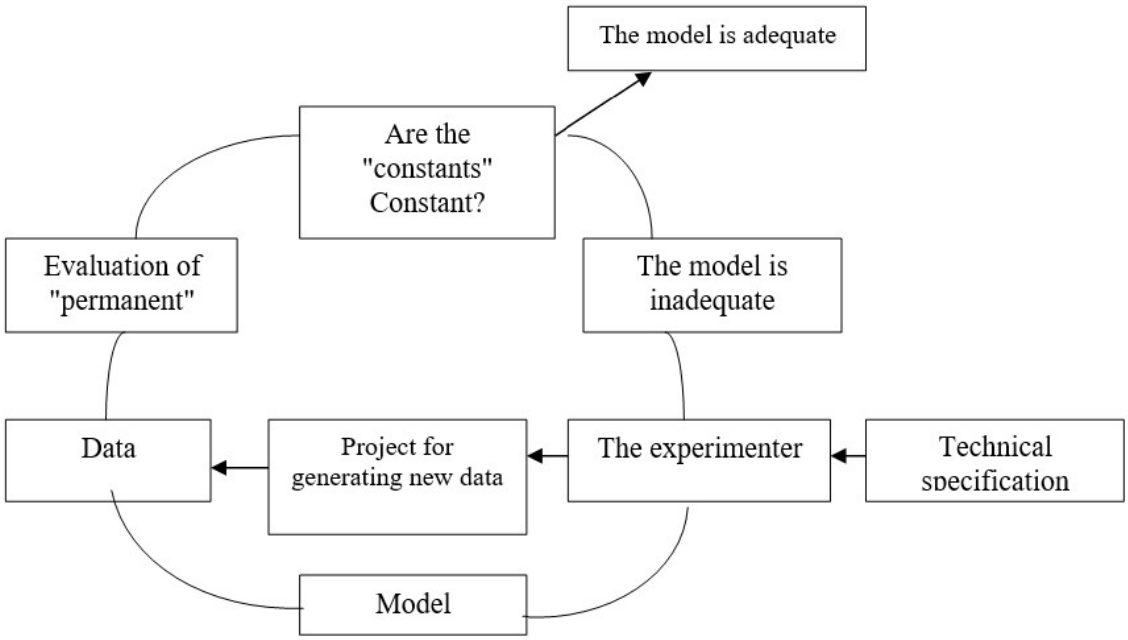

Fig.1. Diagram of the construction of a mathematical model

So, the procedure for planning and conducting experimental studies of the dependence of the concentration of AWCL in the fuel on the magnitude of the frequency of vibration action on the fuel, its temperature and the temperature of the beginning of fuel crystallization is considered below.

In our case, experiment planning is understood as a procedure for selecting the number and conditions of experiments necessary and sufficient to solve the task with the required accuracy and reliability.

MATERIALS AND METHODS

The method of solving the problem. The purpose of planning the experiment [4,5] is to obtain a mathematical model of the dependence of the content of HCL in the tested fuels depending on the three influencing factors mentioned above.

When drawing up a mathematical model, we will be guided by the general principles schematically shown in Fig. 2.

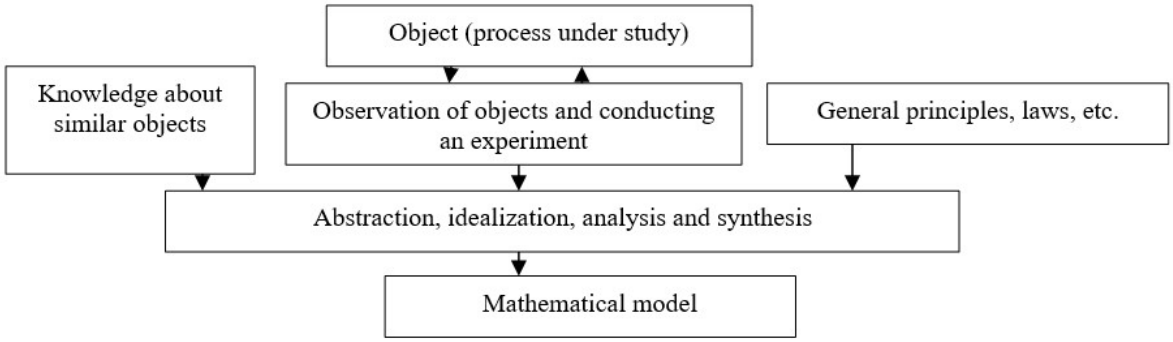

Fig. 2. Sources of information for building mathematical models

When planning an experiment, we will present the object under study in the form of a «black box» (cybernetic model), which is affected by factors x1 ...xk, shown in Fig. 3.

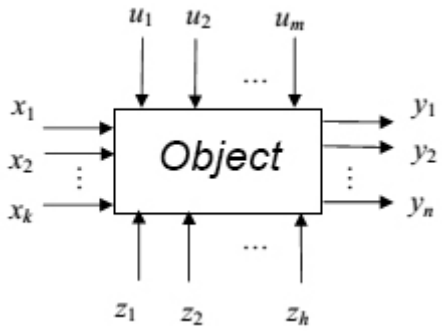

Fig. 3. General scheme of the cybernetic system

where: $x_1 \ldots x_k$ – independent control (input) variables that can be purposefully changed during the experiment – experimental factors; $u_1 \ldots u_m$ – controlled disturbing effects that cannot be changed during the experiment; $z_1 \ldots z_h$ – uncontrolled and uncontrollable disturbances, unknown to the researcher, slowly changing in time randomly; $y_1 \ldots y_n$ – controlled or calculated parameters that characterize the state of the object.

Since the experiment is multifactorial, the mechanism of factors is unknown, then polynomial mathematical models (algebraic polynomials), i.e. regression equations, are used.

The purpose of the preliminary experiment was to determine the temperature of the beginning of crystallization of the tested fuels and then identify the limitations (lower and upper limits) of the factors and hypothesize about the assumed form of the regression equation [5,6].

During the preliminary experiment, it was found that the temperatures of the beginning of crystallization of the tested fuels of the RT, TS-1 and Jet A-1 brands were the following values presented in Table 1.

Table 1 - Values of temperatures of the beginning of crystallization of the tested fuels

No.	Brand of fuel for jet engines	The value of the temperature of the beginning of crystallization, °C
1.	RT	-68
2.	TS-1	-60
3.	Jet A-1	-48

Determination of the temperature of the beginning of crystallization was carried out in accordance with the standard method according to GOST 5066 – 91 [3].

Thus, based on a priori data, the following restrictions were chosen for this factor (in ^{0}C): $-68 \le T_{HK} \le -48$.

The following limits are selected for the frequency of vibration exposure (in Hz): $100 \le \nu \le 200$.

The following restrictions are selected for the temperature of the fuel (that is, a mixture of kerosene and AWCL) (in °C): $-40 \le T \le 0$.

Below is the procedure for conducting a complete factor experiment (CFE), in which one parameter is investigated and all possible combinations of factor levels are implemented.

Three levels were selected for each factor – upper, lower and intermediate. The choice of three levels of factors was carried out from the following considerations: if the model serves the purpose of finding optimal working conditions for a product or system, then it is sufficient to have factors at two extreme levels – maximum and minimum; if the model is designed to clarify the mechanism of phenomena, i.e. determining the influence of factors in the range of their changes, then two extreme levels are not enough and intermediate values.

So, the above limitations (variation intervals) were the basis for planning a complete three-factor experiment at three levels. The conditions for encoding variables for the Benkin-Box plan are shown in Table 2.

Table 2– The order of encoding variables

No.	Factors	Designation of factors	Levels			Range of variation
			-1	0	+1	
1.	Frequency of vibration exposure, Hz	X_1	100	150	200	50
2.	The temperature of the fuel mixture for RD and AWCL, °C	X_2	0	-20	-40	20
3.	The temperature of the beginning of crystallization of fuel for RD, °C	X_3	-50	-60	-70	10

Let's find the number of experiments, knowing the number of factors k = 3 by the equation (1):

$$N = 3^k, \quad (1)$$

where 3 is the number of levels, k is the number of factors.

Thus, the number of experiments will be 27.

The planning matrix for the three-factor PFE is shown in Table 3.

Verification of symmetry with respect to the center of the experiment, the conditions of normalization and orthogonality are indicated in Table 3.

Table 3 – Three-factor PFE planning matrix

Experience Number	Factors								
	X_1	X_2	X_3	X_1X_2	X_1X_3	X_2X_3	X_1^2	X_2^2	X_3^2
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	-	-	-	+	+	+	+	+	+
2.	0	-	-	0	0	+	0	+	+
3.	+	-	-	-	-	+	+	+	+
4.	-	0	-	0	+	0	+	0	+
5.	0	0	-	0	0	0	0	0	+
6.	+	0	-	0	-	0	+	0	+
7.	-	+	-	-	+	-	+	+	+
8.	0	+	-	0	0	-	0	+	+
9.	+	+	-	+	-	-	+	+	+
10.	-	-	0	+	0	0	+	+	0
11.	0	-	0	0	0	0	0	+	0
12.	+	-	0	-	0	0	+	+	0
13.	-	0	0	0	0	0	+	0	0
14.	0	0	0	0	0	0	0	0	0
15.	+	0	0	0	0	0	+	0	0
16.	-	+	0	-	0	0	+	+	0
17.	0	+	0	0	0	0	0	+	0
18.	+	+	0	+	0	0	+	+	0
19.	-	-	+	+	-	-	+	+	+
20.	0	-	+	0	0	-	0	+	+
21.	+	-	+	-	+	-	+	+	+
22.	-	0	+	0	-	0	+	0	+
23.	0	0	+	0	0	0	0	0	+
24.	+	0	+	0	+	0	+	0	+
25.	-	+	+	-	-	+	+	+	+
26.	0	+	+	0	0	+	0	+	+
27.	+	+	+	+	+	+	+	+	+

The symmetry with respect to the center of the experiment is calculated by the formula:

$$\sum_{j=1}^{N} x_{ij} = 0, \tag{2}$$

where i - is the factor number, j - is the experiment number, N - is the number of experiments.

In our case , we have the following dependency:

$$\sum_{j=1}^{27} x_{ij} = 0 \tag{3}$$

Thus, the condition of symmetry with respect to the center of the experiment is fulfilled.

Now the normalization condition is checked (the sum of the squares of any column must be equal to the number of rows) by the formula:

$$\sum_{j=1}^{N} \left| x_{ij} \right| = N \tag{4}$$

In our case , the equation will have the form:

$$\sum_{j=1}^{27} \left| x_{ij} \right| = 27 \tag{5}$$

As can be seen from equation (5), the normalization condition is met.

The orthogonality condition (the sum of the products of any two columns must be zero) is checked by the equation:

$$\sum_{j=1}^{N} x_{ij} x_{fj} = 0 \tag{6}$$

where $i \neq f$.

In our case, the orthogonality condition is satisfied.

So, since in our case the three-factor PFE planning matrix satisfies the conditions of symmetry, normalization and orthogonality, we can conclude that this matrix is optimal.

RESULTS AND DISCUSSION

The experimental study was conducted in order to determine the optimal content of AWCL in the tested fuels, depending on the selected three factors.

Randomization of the sequence of experiments was used to reduce the influence of the external environment and uncontrolled factors within each series of points of the factor space. The results of the experiment are presented in Table 4.

Using experimental data, we investigate the influence of the following three factors on the concentration of AWCL: the frequency of vibration exposure (Hz); the temperature of the

test fuel in a mixture with AWCL (°C); the temperature of the beginning of fuel crystallization (°C).

To do this, we use the data in Table 4 with the results of experimental studies.

A multidimensional regression model (or multiple regression model) is a generalization of a linear regression model with two variables. Let n - be the number of measurements of the values of factors X_1, X_2, ..., X_K and the corresponding values of the variable Y. It is assumed that

$$y_i = \beta_o + \beta_1 x_{i1} + ... + \beta_k x_{ik} + \varepsilon_i, \; i=1,\ldots n, \tag{7}$$

(the first index x_{ik} of the value refers to the observation number, the second to the factor number); here ε_i (i=1,...n) are uncorrelated normally distributed random variables such that

$$M\varepsilon_i = 0, \; M\varepsilon_i^2 = \delta^2, \tag{8}$$

where M – the mathematical expectation operator of a random variable.

Table 4– Results of experimental studies

Experience Number	Factors			Parameter
	X_1	X_2	X_3	
1	150	-20	-50	0.108
2	200	0	-50	0.117
3	150	-40	-50	0.095
4	200	-40	-50	0.085
5	100	-20	-50	0.115
6	200	-20	-50	0.107
7	100	-40	-50	0.102
8	150	0	-50	0.118
9	100	0	-50	0.120
10	150	-40	-70	0.125
11	200	-20	-70	0.118
12	200	-20	-60	0.117
13	100	-40	-60	0.115
14	100	-40	-70	0.128
15	100	0	-60	0.128
16	200	0	-60	0.123
17	150	0	-70	0.132
18	150	-40	-60	0.107
19	100	0	-70	0.135
20	150	-20	-70	0.128
21	100	-20	-70	0.132
22	200	-40	-60	0.102
23	200	-40	-70	0.113
24	150	-20	-60	0.120
25	200	0	-70	0.122

26	150	0	-60	0.125
27	100	-20	-60	0.122

The assumptions described above can be accepted as a working hypothesis. Therefore, theequation of statistical connection can be constructed in the first approximation in the form:

$$y_i = \beta_0 + \beta_1 \cdot x1_i + \beta_2 \cdot x2_i + \beta_3 \cdot x3_i + \varepsilon_i \quad (9)$$

where i=1…3.

Analysis of the adequacy of the obtained model. The adequacy of the proposed model [7] and estimates of unknown coefficients in the regression equation are determined using the STATISTICA statistical package [8]. In the Multiple Regression module, a file is created and data is entered into a spreadsheet using the results of the experiment from Table 5.

In order to visualize the evaluation of the initial data, three-dimensional graphs of the evaluation function Y for factors X1, X2, X3 are constructed in order to find the main dependence.

The results of the study are shown in Fig. 4-6.

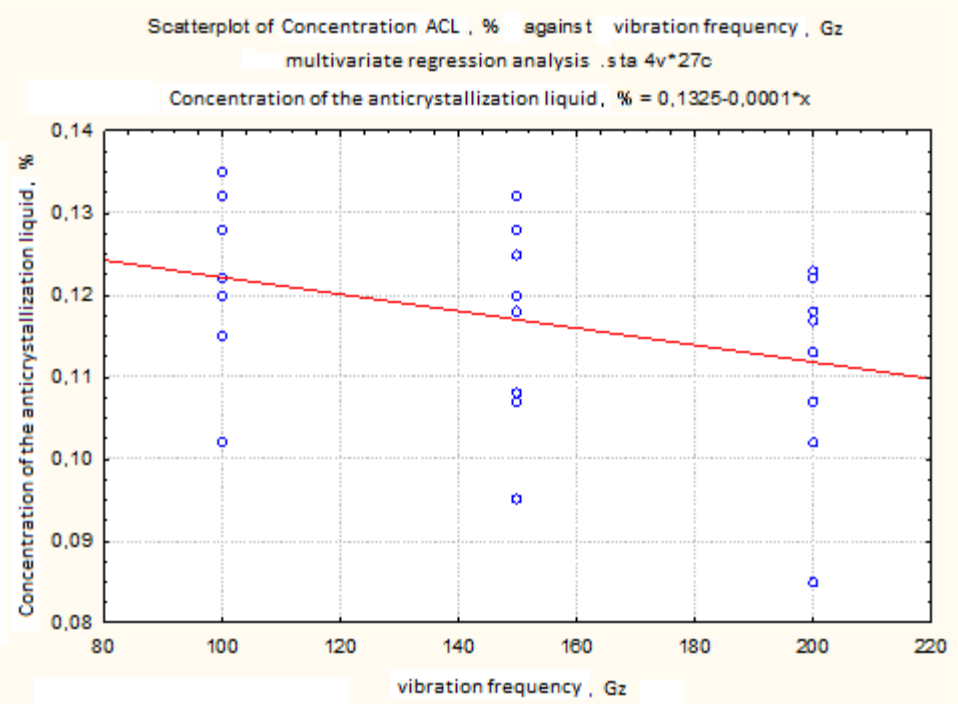

Fig. 4. Graph of the evaluation

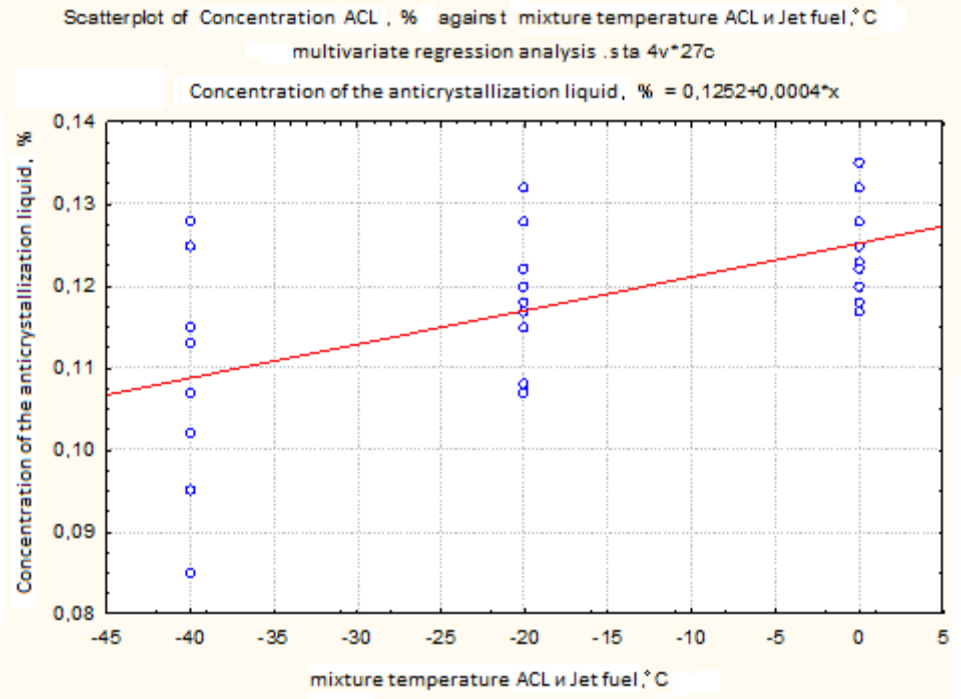

Fig. 5. Graph of the evaluation function Y for factor X2

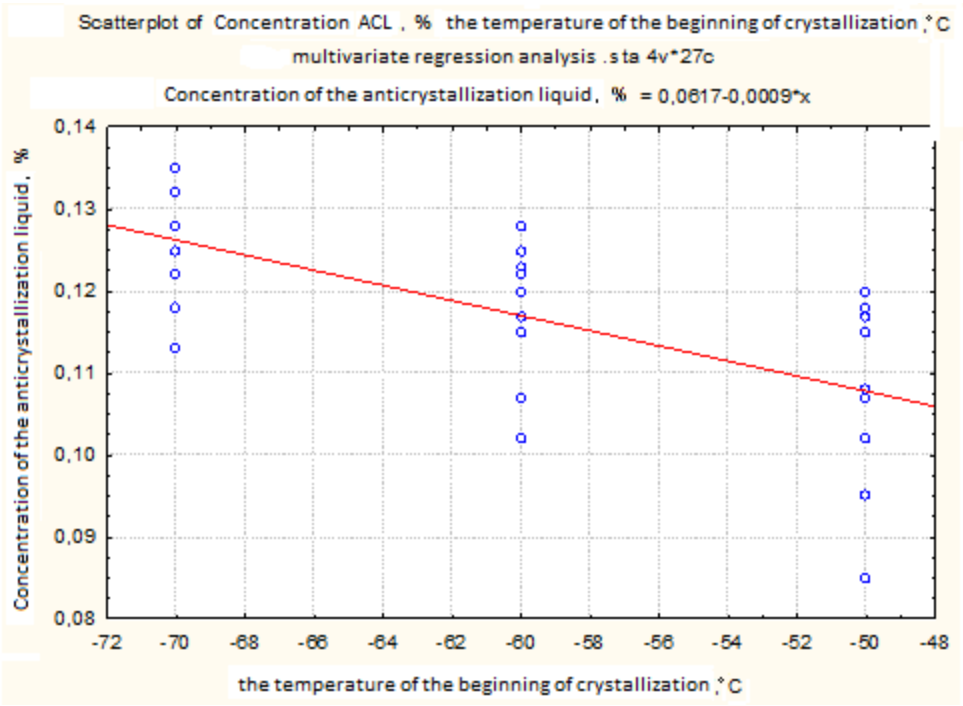

Fig. 6. Graph of the evaluation function Y for factor X3

As can be seen from Fig. 4-6, the main relationship between each of the three factors and the independent variable can be traced quite well and is linear. To test this hypothesis in further calculations, the "Multiple Regression" option of the STATISTICA package is used (shown in Table 6).

Table 6 – Summary multiple linear regression of the dependent variable

№ п/п	Statistics	Statistical values
1	Multiple correlation coefficient R	0,94253
2	Fischer 's Criterion F	61,003
3	Coefficient of determination R2	0,88835382
4	Number of experiments	27
5	Corrected coefficient of determination R2	0,87379127
6	Significance level P	0
7	Standard error	0,00420

From the appearance of the scattering diagrams (Fig. 4-6), it is clearly seen that for all three factors there is a dependence close to linear.

It is obvious from Table 6 that the adjusted coefficient of determination R2 is 0.9. This suggests that the proposed model describes 90 percent of the variation of the independent variable Y, the value of the forecast error is extremely insignificant and is equal to S = 0.004.

The value of Fisher's statistics for testing the hypothesis H_0 about the absence of a linear relationship between the variable Y and the set of factors F=61,003 corresponds to the significance level $p=10^{-5}$. Since $p<0.05$, we reject the hypothesis H0.

Let's evaluate the adequacy of the calculated model, i.e. the assumed linear relationship between the parameter and the factors.

After processing the experimental data in the STATISTICA 8 program, the following results were obtained, presented in Table 7.

Table 7 – Coefficients of paired correlation of factors X1, X2, X3 for parameter Y

Variable	Correlations (multidimensional regression analysis)			
	Vibration frequency, Hz	Mixture temperature ACL Jet fuel, °C	Crystallization onset temperature, °C	Concentration ACL, %
Vibration frequency, Hz	1.000000	0.000000	-0.000000	-0.363625
Mixture temperature ACL Jet fuel,°C	0.000000	1.000000	0.000000	0.578673
Crystallization onset temperature, °C	-0.000000	0.000000	1.000000	-0.649052
Concentration ACL, %	-0.363625	0.578673	-0.649052	1.000000

Let's analyze the matrix of paired correlations: it can be seen that the greatest correlation is observed between the pairs "temperature of the mixture of AWCL and fuel, ° C – Concentration of AWCL, %" (correlation coefficient 0.5787) and "temperature of the beginning of crystallization, °C – concentration of AWCL, %" (correlation coefficient -0.6491). Vibration affects the average concentration of AWCL in the fuel to a lesser extent.

Thus, based on the above, we can conclude that the proposed linear model of multiple regression is workable.

Based on the analysis of the values of the Student's statistics and the significance level of the deviation of the null hypothesis H0, we conclude that the factors «Frequency of vibration exposure, Hz», «Temperature of the mixture of fuel and HCL, °C», «Temperature of the beginning of crystallization, °C» can be included in the proposed refined statistical model.

CONCLUSION

The problem of assessing the state of aviation fuel from the point of view of the content of abnormal impurities in it is formulated. It is shown that the most important parameter in this case is the concentration of the anticrystallization liquid in the fuel.

According to the results of the analysis, the main factors affecting the concentration of the anticrystallization liquid in the fuel are identified, which include the frequency of vibration exposure, the temperature of the mixture of fuel and anticrystallization liquid, the temperature of the beginning of crystallization.

Based on the theory of experiment planning, a method for calculating the parameters of a full-factor experiment has been developed, according to which experimental studies have been carried out for various brands of fuel.

The reliability of the obtained regression model was evaluated by mathematical statistics methods and the statistical significance of the model parameters was confirmed.

The conducted studies allowed to identify the most significant factors affecting the state of aviation fuel, and also showed the efficiency of the proposed methodology for assessing the properties of aviation fuel.

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PROBLEMS OF GAS PRODUCTION CAUSED BY THE PRESENCE OF HYDROGEN SULFIDE

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ABSTRACT

The presented article is devoted to the analysis of the problems of gas production in field containing hydrogen sulfide. The technological criteria for evaluating technological schemes are considered step by step, with an analysis of the disadvantages of existing gas purification technologies from hydrogen sulfide and specifying the requirements for the technology of fields gas desulfurization. The energy costs of gas purification from hydrogen sulfide are analyzed and a conclusion is made about the most preferred method. Technical solutions for the use of hydrocarbon solvents in the gas purification from sulfur compounds at coal mining are proposed.

Keywords: gas, hydrogen sulfide, industrial purification technology, energy costs, technical solutions, criteria.

INTRODUCTION

The gas that is extracted from the well during its production by an industrial way can contain a lot of different components, which include water, mechanical impurities, acidic components, helium with nitrogen, as well as heavy hydrocarbons with acidic components. Specified impurities contribute to the activation of corrosion processes and the formation of hydrates, which lead to a decrease in the throughput capacity of the entire gas transportation system [1-3]. Because the entire system of field gas treatment is necessary for its further transportation, the effectiveness of such preparation will affect the operation of the entire gas transportation system (GTS). Considering it as one of the most capitalintensive industries for extraction and transportation of gas and gas condensate, it becomes obvious the importance and value of raw materials extracted and supplied as valuable chemical raw materials. Foreign experience has shown the advantages of deep extraction and processing of heavy hydrocarbons from gases with their further use how raw materials and fuel. The petrochemical raw materials and motor fuel obtained from them are more often much efficient than the use of petroleum products.

MATERIALS AND METHODS

Consider the technological criteria for evaluating technological schemes, which make it possible to approach this problem more objectively. Technological criteria make it possible in some cases to give an objective assessment of a number of processes. However, their use nevertheless makes it possible to make a preliminary analysis of the effectiveness of various technologies to find out their disadvantages. Table 1 demonstrates the effectiveness of the

analysis on the possibilities of using various technologies used in the treatment of gases with a low sulfur content in the field (Table 1).

Table 1 - Disadvantages of existing technologies of gas purification from hydrogen sulfide

technological indicator	gas treatment method				
	A	I-H	C	Chr	FeL
low concentrations of the absorber due to					
-corrosion processes	+	-	-	-	+
-precipitation of the solid phase	-	+	-	+	-
-losses of the absorbent	+	+	+	+	+
high energy consumption at the regeneration	+	+	+	+	+
the susceptibility to corrosion of well equipment	+	+	+	+	+
plumes, which requires the use of special materials and inhibition					
the presence of hydrogen sulfide in the hydrocarbon condensate and reservoir water separated in the inlet separator	+	+	+	+	+
atmospheric pollution with sulfur compounds due to the possibility of hydrogen sulfide utilization at Klaus furnaces	+	-	+	-	-
low capacity for hydrogen sulfide	+	+	+	+	+
the resulting sulfur is not sold as a commodity	-	-	+	+	+
the impossibility of using emulsifying nozzle absorbers	+	+	+	-	-
Note - A-amine method, I-H iron hydroxide, C-cyolite, Chr - chromates, FeL - ferro-nylon complex					

The analysis of the data presented in this table allows you to conclude that there is no reliable technology that allows purify gases with a low sulfur content. The specified weak points give the right to develop the basic requirements for technological schemes and absorbers used in the treatment of gases with a low sulfur content in the field conditions given in Table 2.

The considered requirements, formulated taking into account technological criteria, showed that they are the most possessed only by technologies that implement oxidative absorption and absorption by cations that form sulfides that are slightly soluble in water.

Table 2-Requirements for the technology of field gas desulfurization

Requirement	Amin	Solutions of alkalis	Solutions of oxidizing agents	Gaseous oxidizing agents	Adsorption	Formation of insoluble sulfides	Physical absorption
Possibility of application for the purification of gases with a low concentration of hydrogen sulfide	-	-	+	+	+	+	+
the possibility of using emulsifying mass transfer devices	-	-	+	-	-	+	+
the depth of purification from hydrogen sulfide is up to 7mg/m^3	+	+	+	-	+	+	-
selective extraction H_2S in the presence of CO_2	-	-	+	+	-	+	-
exception the formation of hydrates	-	-	-	+	+	-	+
carrying out purification at normal temperature	+	+	+	+	+	+	+
ensuring ecological safety	-	-	+	+	-	+	-
elimination of acidic regeneration gases	-	-	+	+	-	+	-
reagents for gas purification should be cheap	-	+	-	-	-	+	+
low metal consumption	-	-	-	-	-	+	+
low energy consumption		-	+			+	

Consider the energy criteria for analyzing technological schemes. The final choice of technology is characterized by an assessment of the energy costs performed additionally, since the available technical and economic indicators used for the selected technologies are subjective.

Table 3 demonstrates the comparative energy costs (electricity, steam, fuel gas, water) required for the implementation of the process of gas purification from H2S using different methods.

Table 3-Energy costs for gas purification from hydrogen sulfide

Purification method	**energy costs, MJ/h**
Diethanolamine (alkaline)	555.8
Vacuum-potash (alkaline)	390.0
Tricalium phosphate (alkaline)	311.6
Arsenic-soda (oxidation)	36.9
Precipitation of iron sulfide II	21.6

Based on this table, it should be concluded about the preferred methods that are energy-efficient for purification gases with a low sulfur content in industrial conditions: a) oxidative absorption of H2S; b) precipitation of sulfides.

Based on an in-depth analysis of various schemes for both oxidation and conversion of H2S into low-soluble type sulfides, it became possible to develop a concept of technological requirements necessary for effective gas purification from H2S at the Tasbulat gas treatment plant, which are as follows:

- the use of designs of simple emulsifying mass transfer devices that implement the H2S absorption process;
- the ability to perform gas purification at high and low pressures;
- perform gas purification in a wide temperature range;
- do not use water-based absorbents;
- cheapness and availability of the applied absorbent;
- reliability and simplicity of the equipment in the technological solution of the absorbent regeneration unit;
- inability of the absorbent to provoke corrosion of the equipment;
- inability of the absorbent to provoke the formation of hydrates.

RESULTS AND DISCUSSION

Taking into account the requirements for the technology of gas purification from H2S at this gas treatment plant, the implementation of both described technologies will be complicated by hydrate formation.

Fig. 1 shows the conditions of formation of hydrates in natural gas. Taking into account the location of the gas purification plant from sulfur to the BTS (at the beginning of the technological scheme), occurs conditions for the formation of hydrates if aqueous solutions of absorbents are used. This makes it necessary to refuse to use aqueous solutions of oxidizing agents and cations on Tasbulat gas treatment plant, which form sulfides that are hardly soluble in water. Figure 1 shows the process of hydrate formation in the range P= 8.0-12.0 MPa and T=15-20 °C.

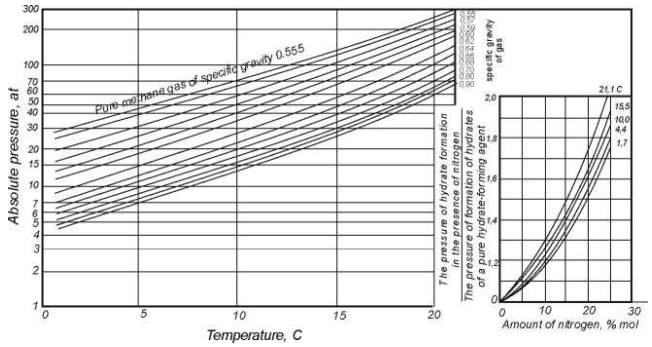

Fig. 1. Conditions of hydrate formation of natural gases

The problem of hydrate formation at a field sulfur purification plant in the conditions of the Tasbulat deposit is solved only when creating an absorbent with a new composition that will be available and have a low price. Gas purification from H2S in the field conditions of the Tasbulat field is realized by technology that uses hydrocarbon condensate as an absorbent material.

CONCLUSION

Based on the literature analysis were found technical solutions of using hydrocarbon solvents on the purification of gas from sulfur compounds at the coal mining. Gas oil and others related to light hydrocarbon liquids are used as an adsorbent substance used in sulfur purification plants [4]. This technology is simple in terms of technological support, the use of simple mass transfer equipment, works at low and high pressures, works steadily in conditions of gas and liquid overloads. Thus, it is quite effective in conditions of low H2S capacities.

As the main equipment, this technology provides a separator, an absorber, tanks, pumps and pipelines. The operation of the installation for purification from sulfur, which is part of the field UCP, updates the requirements for the equipment in operation:

high degree of H2S extraction from gas;
low specific reagent costs;
stability and reliability of operation under changes in gas and liquid loads;
low weight and bulkiness of hardware design;
the ability to assemble devices in a block design;
low energy consumption;
minimization of technological operations by quantity.

The emulsifying absorber according to its design is the most suitable for the above requirements, as well as for working under pressure. The stability of the hydrodynamic modes of this equipment is provided at gas velocities from 0.3 to 10 m/s and liquid from 0.4 to 2 m / s [5-8].

At the Tasbulat field, it is most rational to implement gas purification in an emulsifying absorber with a flooded nozzle.

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