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ABSTRACT

of the dissertation for the degree of Doctor of Science

RESEARCH OF TECHNICAL, TECHNOLOGICAL AND ENVIRONMENTAL ASPECTS OF INCREASING THE EFFICIENCY OF NATURAL GAS PREPARATION FOR TRANSPORTATION

Speciality: 3354.01 - Construction and operation of oil and gas pipelines, bases and storage facilities

Field of science: Engineering

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MAIN CHARACTERISTIC OF THE WORK

Relevance of the topic. The use of gases from offshore oil and gas fields requires the development of highly efficient technologies for drying them from water vapor, removing acidic components, condensate and other impurities that meet modern requirements in order to ensure unhindered gas transportation. The results of the studies show that water vapor, harmful components, mineral salts and other impurities contained in gases during transportation in oil field conditions, along with the formation of hydrates in the process system, lead to the deposition of salts in various parts of the installations for complex gas preparation for transport, to corrosion of oil and gas equipment and other complications.

Development of highly efficient, environmentally friendly complex absorbents based on domestic chemical products for cleaning gases produced from gas condensate fields from acidic components, drying from water vapor, i.e. gas preparation according to requirements is essential. Therefore, the creation and application of new innovative, including nanotechnologies, as well as gas drying devices that meet modern technologies to ensure gas transportation without losses, is one of the urgent problems that need to be solved.

In order to reduce costs in the preparation and transportation of gases, to increase the efficiency of technologies used to achieve quality indicators up to international standards, it is expedient to improve the technologies for transporting low-pressure associated gases, taking into account the complexity of the relief of their transportation lines, and to use nanotechnological compositions. At the same time, the solution of environmental problems, the development of environmentally friendly inhibitors to protect transport lines from corrosive wear is one of the priority problems.

Object and main objectives of the study. The object of research in the dissertation are devices and reagents for storing, cleaning, drying and transporting natural gas, as well as models and algorithms that describe these processes, as well as environmental problems of these processes.

The main goal of the work is to study and develop mathematical models, innovative devices, new reagents - complex inhibitors based on nanotechnology, coatings for corrosion protection of underground and offshore gas pipelines to improve the efficiency of natural gas storage, purification, drying and transportation technologies, and determination the directions for data development. technologies.

The problems to be solved within the framework of the dissertation work are as follows:

- analysis of existing technologies and relevant mathematical models for storage, purification, drying and transportation of natural gas;
- development of innovative technologies, reagents and mathematical models;
- improvement of facilities for storage, purification, drying and transportation of natural gas;
- research of technology of compressors and gas installations;
- development of a set of measures to improve the efficiency of underground gas storage facilities;
- development of inhibitors based on nanotechnology to protect gas pipelines from corrosion;
- increasing the efficiency of protection against corrosion of underground structures.

The scientific novelty of the researchs are:

1. Proposal of absorbents based on polypropylene glycol and its oligomers to improve the efficiency of natural gas transportation.
2. Development of a complex effective nanocomposition using local raw materials to prevent hydrate formation and attrition.
3. New modified insulating coatings are proposed to improve the efficiency of microbiological protection of underground equipment.
4. Determination of reasons for the formation of condensate during the transportation of low-pressure gases and the development of methods for their elimination.
5. The principle of operation and design of a highly efficient gravitational gas dehydration separator are presented.

6. A new innovative technological scheme of a gas dehydration unit has been developed to improve the efficiency of gas treatment technology from underground gas storage facilities.

The main provisions for defense:

1. Hydrate formation was studied using polypropylene glycol and its oligomers to improve the efficiency of natural gas transportation in laboratory and field conditions.

2. A comprehensive effective nanocomposite composition was developed using the products of local chemical plants for hydrate formation and erosion, and the effect on the process of natural gas transport under the influence of various factors in laboratory and field conditions was studied.

3. The method of selection of inhibitors in the preparation of gases for transport, the influence of a constant magnetic field on the formation of hydrates and the regulation of the corresponding consumption rate have been solved.

4. To increase the effectiveness of microbiological protection of underground facilities, the effect of modified bitumen-polymer-based insulation coatings on rupture was studied, the effectiveness and efficiency of an effective inhibitor to protect equipment from hydrogen sulfide and electrochemical corrosion were determined by laboratory tests.

5. The provision of unhindered transportation of low-pressure gases between GMOs and the reasons for the formation of condensate on the transportation lines of fields equipment have been studied.

6. Based on the analysis of the results of research and development work carried out in connection with the reconstruction of the existing separation equipment, the design and principle of operation of the new gravity-cyclone separator are proposed.

7. Study of an innovative technology that allows increasing the active volume of gas injected into UGS facilities based on the analysis and study of the current state, technological and thermodynamic parameters of all wells and field equipment in underground gas storage facilities.

The practical significance of the work. The results of research on transportation equipment, inhibitors and mathematical models of natural and associated gas can be applied to corrosion protection of pipelines used in the production, storage, treatment, transportation and distribution of gas to consumers, environmental protection and the development of new innovative technologies.

Approbation of work. The main results of the dissertation were presented and discussed at various domestic and international conferences:

- Scientific practical conference "Caspianoil-gasfield" "RIGP OG and K" (Baku, 24-25 december 2014);
- International scientific conference "Modern technology in oil-gas business" (Ufa, 2016).
- The 7th International Conference on Control and Optimization with Industrial Applications. 26-28 August, 2020. Baku, Azerbaijan.
- 11th International Conference on Theory and Application of Soft Computing, Computing with Words, Perception and Artificial Intelligence. ICSCCW-2021. Antalya, Turkey. 23-24 August 2021.
- 2nd International Conference on Information Technology, Advanced Mechanical and Electrical Engineering (ICITAMEE). Yogyakarta, Indonesia, August 25-26th 2021.

Publications. The main results of the dissertation are reflected in 57 scientific papers, including 18 articles in reputable scientific journals abroad (5 in Web of science, Scopus and 12 in INSPEC), 3 abstracts, materials of republican and international conferences (including 2 abroad).

The structure and scope of the dissertation. The dissertation consists of an introduction, 6 chapters, a conclusion, a list of references in 224 titles and an appendix. The work consists of 308 pages, including the main text, 62 figures, 45 tables and an appendix on one page.

SUMMARY OF THE WORK

The introduction of the dissertation substantiates the relevance of the topic, the main goals and objectives of the study defined, outlines the scientific novelty of the work, its practical significance and the main provisions of the dissertation, as well as a summary of the main sections of the dissertation.

The first chapter considers the current state of natural gas transportation, problems of its collection and transportation, environmental aspects and prospects for the preparation and transport of natural gas, establishes the factors affecting the efficiency of these processes, and directions of research in the thesis, and given of setting of the problems that need to be solved.

The efficiency of main gas pipelines depends on the quality of the transported gas.

Using these advantages of gas-hydrate deposits, it should be noted that storage of natural gases in the form of hydrates in gas reservoirs is of greater interest. It is known that its volume decreases 150-200 times when the gas changes into hydrate form. At present, up to 150 mud volcanoes have been identified in the South Caspian basin, which has created conditions for the discovery of many gas-hydrate deposits in the southern water area of the sea. As a result of multi-year scientific and research works conducted in these deposits, great experience has been gained, which can be used in the future in the development of deposits in the Caspian Sea water area. Calculations show that most of the total gas produced in this field so far has been obtained due to hydrate cracking. So, according to calculations, the formation pressure in the field should drop from 78 MPa to 2 MPa during the 35-year operation period. However, the formation pressure here is equal to 60 MPa, which proves that additional gas has entered the formation due to hydrate splitting. For this reason, taking into account these properties of hydrate, it is of great interest to carry out the processes of storing natural gas in the form of hydrate in small-volume gas reservoirs and transporting it in the form of hydrate, which are actual and very complex processes that require solving.

If the preparation of natural gas for transport does not meet the requirements, liquid (water and hydrocarbons) and other aggressive components entering the main gas pipelines together with natural gas lead to a decrease in the productivity of the gas pipeline, to the formation of corrosion, the deposition of salts in the pipeline, to other complications and to some environmental issues.

Depending on the number of components in natural gas, the climatic conditions of the region and other factors, the process of gas transportation in accordance with the requirements of current regulations is carried out in several stages. Natural gases contain from 75 to 99% methane, ethane - is usually 2-4%, and sometimes 7-8%, propane - 0.1-4.0%, butane - 1-2%, heavy hydrocarbons (C_5+) - 2- 3%.

The presence of water, mineral salts and acidic components (H2S, CO_2, hydrate compounds, corrosion deposits and salts) in the production of gas and gas condensate fields, especially offshore gas fields, leads to technological complications in the system. This, in turn, disrupts the operation of gas transmission facilities and main gas pipelines, and in some cases leads to accidents and large gas losses.

Depending on the number of components separated from the gas when absorbents are used, the gas preparation process is conditionally divided into the following groups:

- physical absorption - extraction of acidic gas components by liquid organic absorbers. This method makes it possible to carry out complex purification of gases from acidic components and organic sulfur compounds;

- chemical sorption - based on chemical bonds between the absorbent and the absorbed components;

- combined absorbents are used for complex purification of gases from acidic components and drying from water vapor.

The inhibitor absorbs water vapor contained in the gas in an equilibrium state. Part of the inhibitor dissolves in the gas phase, and part - in the liquid phase extracted together with gas, in free formation water and liquid hydrocarbon condensate.

Due to the change in thermodynamic and technological parameters of gas produced from gas condensate fields and withdrawn from underground storage facilities, it is expedient to apply a systemic control of the accuracy of calculating the consumption rate of the inhibitor.

Environmentally friendly and economical, new inhibitors must meet the following requirements: be soluble in the aqueous phase in all proportions, freeze at low temperatures and have low viscosity, not form corrosion in the process system and at the same time not enter into a chemical reaction with natural gas, hydrocarbon condensate, the aqueous solution of the inhibitor in the system must be regenerated and have a large production base based on local chemical products.

Until recently, diethylene glycol (DEQ), ethylene glycol (EQ) and triethylene glycol (TEQ) have been widely used in the process of gas drying to prevent the formation of hydrates. Although these substances are effective reagents and inhibitors, they have a number of technical and technological disadvantages: high viscosity, freezing at high temperatures, a complex regeneration unit, while they are expensive and toxic, lack of a production base in the country, mainly purchased from foreign countries in foreign currency, etc. On the other hand, to increase the concentration of DEQ and TEQ to 95-99%, it is necessary to use vacuum devices, which in turn, increases the cost of transporting gas several times.

Based on this, the dew point temperature of the dried gas was determined at various concentrations and contact temperatures of local absorbents, consisting mainly of monopropylene glycol (MPG) and polypropylene glycol (PPG), it was found that MPG and PPG have high gas drying properties, at the same concentration and at contact temperature. The temperature of the gas dried using MPG and PPG is several degrees lower than with DEG and TEG; DEG and TEG in the oil and gas industry can be replaced by MPG and PPG. One of the main indicators of new absorbents - MPG and PPG - is the regeneration of its solution saturated with water vapor.

Studies and analysis of production performance at the Kalmaz and Garadag UGS facilities, taking into account the economic efficiency of creating UGS facilities mainly at depleted oil and gas fields, shown that the low-temperature separation method during gas transportation to the storage facility is effective and has technological advantages. If the gas taken from the storage facilities is exported to foreign countries, then it is expedient to use gas dehydration for gas transportation, and for which it is necessary to reconstruct and improve the operation of these devices.

Dew drops on the outer surface of pipelines are a serious problem in the operation of offshore structures. One solution to this problem is to cover large metal surfaces with a cost-effective heat-insulating material.

A comprehensive study of technological schemes and features of the processes of preparing natural gas for long-distance transport can make it possible to establish mathematical models for the processes of formation and movement of hydrates in gas pipelines and in mass transfer devices for absorption dehydration of natural gas, and thereby find the optimal values of the main parameters of these processes. For a more effective solution of this problem, it is also necessary to develop a methodology for assessing the formation of a condensed phase during the movement of natural gas. The use of all these technologies and recommendations will make it possible to determine the duration and reduce the cost of overhaul, improve the quality of work, and taking into account the two-dimensional effect of hydrate formation - to clarify of the beginning of hydrate formation in pipelines.

The development of a methodology for assesment of releasing of a condensed phase during the movement of natural gas through the gas and condensed phases, the calculation of particle trajectories in process equipment, the determination of abrasive wear of flow parts or the determination of the condensed phase are the basis for increasing efficiency.

As a result of the analysis of various approaches to solving given problems, the problems that need to be solved to improve the efficiency of these processes and devices and directions of research defined.

Thus, in order to solve the above problems, prevent complications in the production, transportation and storage of gas, improve the efficiency of operation of gas lines and gas pipelines, as well as ensure environmental safety, the following issues are resolved in the dissertation:

- study of existing technologies and relevant mathematical models for storage, purification, drying and transportation of natural gas;

- development of new innovative technologies and mathematical models;
- improvement of equipment for storage, purification, drying and transportation of natural gas;
- development of a set of measures to improve the efficiency of underground gas storage facilities;
- development of inhibitors based on nanotechnology to protect gas pipelines from corrosion;
- increasing the efficiency of microbiological protection of underground structures.

In the second chapter, the issues of developing a composite inhibitor for preparing gas for transport, preventing environmental pollution during the operation of wells with intense sand formation, choosing an inhibitor for preparing gases for transport and determining the consumption rate are considered and resolved.

To solve the problem for drying the gas and preventing hydrate formation and protecting lines from erosion-shock wear, a complex effective composition is fed into the line. consisting of pyrocondensate, heavy gasoline fraction and clay nanoparticles, in the following proportions, in %:

- pyrocondensat	68-71
- heavy gasoline fraction	28,9-31,9
- clay	0,1

The complex composition for natural gas transportation consists of pyrocondensate (68-71), heavy gasoline fraction (28.9-31.9) and clay (0.1) with nanoparticles 10-9m in the amount of 53.06% by weight. The composition of the heavy gasoline fraction with pyrocondensate is obtained as an intermediate product at the Sumgayit Organic Synthesis Plant. The viscosity of the proposed mixture at a temperature of 20°C is 1.1-1.2 mPa·s, the density of the mixture is 840-870 kg/m^3, the initial boiling point is 85-90°C, and the end point is 115-120°C.

Viscosity of pyrocondensate at 20°C is 0.85-1.2 mPa.s, density is 845 kg/m3, octane number is 90, initial boiling point is 40°C, end point is 120-140°C. In this case, the viscosity of the heavy gasoline fraction at 20°C is 27.5 mPa.s, the density is 920 kg/m3, the initial boiling point is 250-270°C, and the final boiling point is 310-340°C. C. Pyrocondensate in the proposed composition absorbs water in the gas and dries it, preventing the formation of hydrates. The heavy gasoline fraction in the composition hydrophobizes mechanical impurities in the transported gas, reducing its abrasive properties and thereby protecting the highway from wear, nanoparticles in the composition reducing the temperature of hydrate formation due to the drying of of the gas composition and are increased of the stability of the mixture provides protection against erosion. The influence of the ingredients on the temperature of hydrate formation and corrosion at 2 mPa·s at a flow rate of 20 g/1000 m3 of various compositions was studied and the following results were obtained.

To prevent of arisen of the complications - the precipitation of mineral salts and hydrates in the process of extraction and transportation of gases in various technological parts, methyl and isopropyl alcohols, and other inhibitors containing ethylene and glycol are introduced into the gas stream.

The issues of replacing expensive absorbents DEQ and TEQ, which have a number of technical and technological shortcomings, of the development of efficient, environmentally friendly absorbents with a production base, have been studied. Taking into account the shortcomings outlined in the previous chapter, new absorbents and inhibitors must meet the following requirements:

- to have high drying capacity and low viscosity;
- effectively reduce the initial temperature of hydrate formation in gases;
- the regeneration process should be stable and simple;
- have a large production base, etc.

For this purpose, samples of various chemical reagents were taken from chemical plants, their physicochemical and technological parameters were studied in the laboratory (Fig.1).

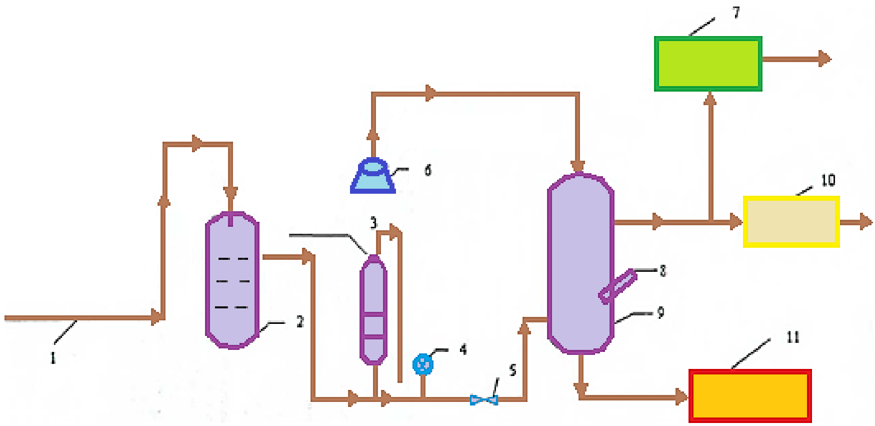

Fig.1. Schematic diagram of a laboratory device for drying and purifying natural gas
1 - sour gas; 2 - barbater; 3 - rotameter; 4 - pressure gauge; 5-control valve; 6 - absorbent supply pump; 7-hydrometer "Baikal-3"; 8 - cavity for thermometer; 9 - absorber; 10 - chromatograph LKhM-80; 11 - container for absorbent saturated with water vapor

Depending on the concentration of PPG and the temperature of contact with the gas, the dew point (DP) temperature of the dried gas was determined. In experimental and test work, a laboratory device with a mirror system was used. The results of the study showed that, PPG (Fig.2) is the most effective for drying gases among the investigated reagents. The temperature of the gas dried using PPG at the same concentration and temperature is several degrees lower than that of DEG and TEG, and it can be used as a new dryer, instead of DEG and TEG.

The results of testing aqueous solutions of DEG, TEG and PPG, carried out at the regeneration unit, are shown in Fig.3. It can be seen from the graphs that the density of regenerated PPG compared to DEG and TEG at low temperatures (403-413^{0}K) is 99-99.5% of the mass.

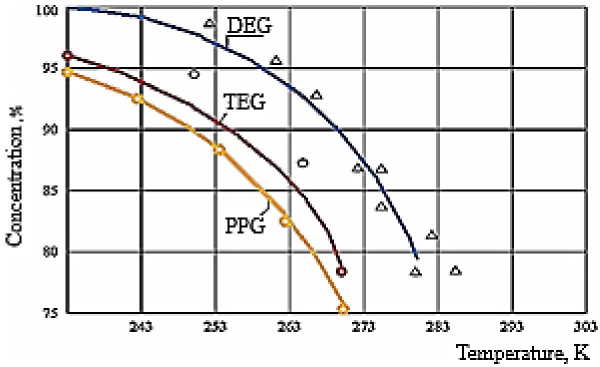

Fig.2. Dependency of concentration of glycol on temperature

The concentration of DEG and TEG is 92-97% of the mass.

Industrial tests and application of a new absorbent - polypropylene glycol in a gas drying device operated in the gas compressor station No.2 of the company "Bahar energy operation" were carried out, the following optimal technological mode of operation was selected for the new absorbent.

Concentration of regenerated PPG, wt. % - 98-98.8
density, kg/m3 - 1030-1033
Concentration of PPG saturated with water vapor, wt% -93-95

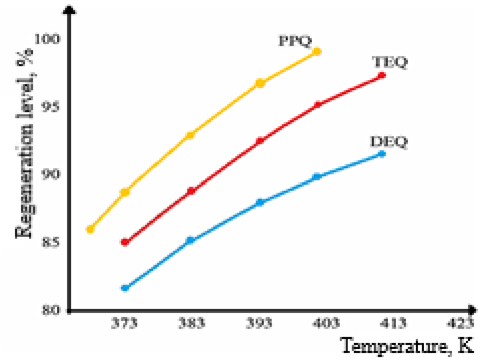

Fig 3. Test results in regeneration unit

PPG regeneration temperature, K - 403-413
Temperature of gas contact with absorbent, K - 303-308
Dry gas temperature, K - 268-263
The flow of supplied absorbent, kg/1000 m^3 - 13-15
Losses of absorbent in the general system, g/1000 m^3 - 70-100

At present, the company has 2 gas drying devices, the gas capacity of the units is 1.0-1.1 million m3 per day.

When using PPG, the disadvantage of using a composition with surfactants with a mixture of alkane DE-202 as a filler is an increase in its abrasiveness due to the dissolution of paraffin-tar compounds on the surface of the solid phase of the transported gas, the alcohols present in its composition, which intensifies metal erosion (equipment). Therefore, along with drying gases to the required level and preventing the formation of hydrates in transportation lines, in order to solve the problem of creating a composite inhibitor to protect metal equipment from impact erosion, a composition was studied by complex action, consisting of pyrocondensate (68-71) %, of heavy gasoline fraction (28.9-31.9) % and clay (0.1) with nanoparticles 10^{-9} m in size in the amount of 53.06% mass.

Clay from the Khirdalan, Gekmali and Bulbulya deposits was used in the studies as nanodispersed clay. The results of measuring clay fractions with an electron microscope are shown in Table 1. The pyrocondensate in the composition of the proposed composition dries the gas, absorbing water in it, and prevents the formation of hydrates. The heavy gasoline fraction included in the composition reduces the abrasive properties of the transported gas due to the hydrophobization of mechanical impurities in the transported gas, thereby protecting the transport line from wear. Thus, the nanoparticles in the composition reduce the temperature of hydrate formation due to drying of the gas and at the same time ensures the stability of the mixture and increases the protection of the main lines from erosion by increasing the hydrophobicity of the solid phase.

After entering the composition in the gas under test, the temperature of crystal hydrate formation was determined by adding to the gas the composition proposed in the prototype at the rate of 10; 15; 20 and 25 gr. for every 1000 m^3.

Table 1. Sizes of clay fractions

Clay deposit	Size (m) and amount of fraction in the composition of clay, %					
	Quartz sand	$(25\text{-}5)10^{-5}$	$(5\text{-}2)10^{-6}$	$(2\text{-}1)10^{-9}$	$(1\text{-}0{,}5)10^{-7}$	10^{-9}
Hokmali	2,70	2,80	6,00	36,51	51,99	no
Khirdalan	1,21	1,91	2,00	41,82	1,00	53,06
BuleBula	5,20	51,4	20,00	23,40	No	No

Table 2. Results of the study

Composition	Pressure, MPa	Influence of the consumption of the composition in the gas mixture (g/1000m3 gas) on the temperature of crystalline hydrate formation (±°C)				
		0	10	15	20	25
Gas mixture without composition	*2*	+8				
	4	+7				
	6	+6				
	8	+6				
Existing (prototip)	*2*		-8	-12	-16	-19
	4		-9	-12	-17	-20
	6		-11	-13	-18	-21
	8		-12	-13	-19	-21
Proposed	*2*		-10	-14	-18	-21
	4		-12	-14	-19	-23
	6		-13	-15	-21	-24
	8		-14	-17	-21	-24

It can be seen from this that hydrate crystal formation without applying the composition in the transport of the tested gas at pressure 2; 4; 6 and 8 MPa , respectively it occurs at temperature 8, 7 and 6°C. At the same pressure, as the consumption of the composition per 1000 m3 of gas increases, the crystal hydrate formation temperature decreases, and this temperature tends to decrease as the pressure increases; under the same conditions, the temperature of hydrate formation decreases more with the proposed composition than with the prototype. For example, if the consumption of the prototype in the gas is 10; 15; 20 and 25 g/1000m3, the temperature of hydrate formation at 2 MPa is respectively -8°C; -12°C; -16°C; -19°C, when process is carried out with the proposed composition this temperature will be -10°C ; -14°C; -18°C and -21°C. The same similar result is obtained when the study is carried out at a pressure of 6 MPa. For example, if the hydrate formation temperature for the prototype respectively is -9; -12; -17 and -20°C at a pressure of 4 MPa and at 10; 15; 20 and 25g/1000m3, for the proposed compo-sition, this temperature respectively is -12; -14; -19 and -23°C.

The results of the study are shown in table 2.

As can be seen from the table, the use of the proposed composition against hydrate formation under the same conditions increases the efficiency of the operation by 10-15% compared to the existing inhibitor, and the highest efficiency is achieved at a composition flow rate of 25 g per 1000 m^3 of gas.

Table3. Hydrate ormation temperature in pipeline and wear time

Composition	Pressure, MPa	Composition con-sumption, g/1000m^3	Number of nanoparticles in the composition, %	Influence on the temperature of hydrate formation, ±°C		Influence on wear time, hour	
				M1	M2	M1	M2
Existing (prototip)	8	25	0 0,01 0,05 0,1 0,15	-21 -25 -30 -33 -33	-21 -24 -28 -31 -31	1,5 1,7 2,1 2,6 2,6	1,5 1,6 2,0 2.4 2.4
Proposed	8	25	0 0,01 0,05 0,1 0,15	-24 -33 -42 -54 -54	-24 -30 -39 -46 -46	6 24 36 56 56	6 14 26 34 34

Adding the prototype composition to the gas reduces the time of erosion-impact wear of the metal pipe relative to the non-composite case due to the dissolution of paraffin compounds in the PPG mixture in the composition of the prototype composition (Table 3).

Unlike the prototype, the addition of the proposed composition to natural gas during transportation significantly increases the erosion-impact wear time of the metal. For example, if the amount of solids in the transported composition is 30 g/1000 m3 at a pressure of 2; 4; 6 and 8 MPa erosion-impact wear time of the metal is for the prototype, respectively, 3; 2.5; 2 and 1.5 hours, and for the proposed composition; 12; 10; 8 and 6 hours, i.e. the proposed composition increases the metal wear time by 400%.

One of the main issues in the application of all types of inhibitors and absorbents is the determination of their consumption in the process, its regulation as time changes and other factors and parameters - thermodynamic indicators. The thermodynamic parameters of UGS at the beginning and end of the gas injection process in 2019 are given in Table. 4.

Table 4. Thermodynamic parameters in UGS at the beginning and end of the gas injection process

№	Thermodynamic indicators	Pressure at the beginning of injection, MPa	Pressure at the end of injection, MPa
1	Inlet pressure of CS	3,5-3,6	3,8-4,0
2	Outlet pressure of CS	10,1-10,4	10,5-10,6
3	Wellhead pressure	8,2-8,3	10,4-10,5
4	Internal reservoir pressure in storage	11,5-11,7	11,5-11,9

In addition, the following factors should be considered when choosing an inhibitor:

- initial component composition of gas;

- the amount of moisture in the gas, which is in equilibrium;

- DP temperature for water vapor in gas prepared for transportation;

- concentration of used and unused inhibitors;

- selection of the regeneration temperature of the aqueous solution of the inhibitor;

And when calculating the consumption of MPG used at the Garadagh UGS, it is necessary to take into account the following other factors:

- the amount of equilibrium moisture in the gas at the start and end points of the gas pipeline;
- concentration of unused and used inhibitor - glycol injected into the gas flow;
- the amount of free water coming along with the gas flow;
- the amount of inhibitor to absorb water vapor in the gas phase.

When calculating the inhibitor consumption rate, it is necessary to take into account losses in the process system due to following reasons:

- loss of glycol inhibitor when dissolved in liquid hydrocarbons;
- mechanical loss of glycol in the gas flow;
- loss of glycol during filling and emptying.

Thus, the above losses should be added to the rate of consumption of the inhibitor, obtained as a result of the calculation based on the actual field performance. The amount of water vapor in the gas on humidity is calculated by the following formula:

$$W = b_1 - b_2$$

where b1 and b2 - the amount of water vapor in the wet and dry gas; W is the amount of water absorbed from the gas, kg/1000 m3.

Taking into account the gas indicators, the consumption rate of the inhibitor is calculated as follows:

$$G = \frac{WX_2}{X_1 - X_2}$$

where G is the total amount of inhibitor; X1 - concentration of the initial inhibitor; X2 is the concentration of the already used inhibitor.

Based on the modification, the model used includes secondary visual coefficients and additional parameters characterized by the compression ratio of gas mixtures at high pressure. Parameterization of the modifyied equation shows that when calculating the volatile components of natural gas, an error of 1-2% occurs, which is more accurately calculated using the Peng-Robinson equation.

The advantage of the modified equation of state is that it is easy to introduce additional changes due to secondary coefficients in case of new tests, and the disadvantage is the increased values of the parameters. This is characterized by an increase in the accuracy of determining the Hibbs energy in the gas phase.

The range of effective use of the equation: at a temperature of -40°C-(+100-150) °C and a pressure of 0.1MPa-(12-14) MPa.

At a pressure of 100 MPa and above at a negative or positive temperature in the ambient temperature range, the method of thermodynamic extrapolation of three-phase equilibrium test data is used. We write the dependence corresponding to the approximated data in given coordinate system in the following form:

$$Y = A + \frac{B}{T} + C \cdot \ln(T)$$

where A, B, C are the coefficients that describe the data at control points in more detail and allow extrapolating the obtained dependence both to negative and to positive over a wide temperature range. The equilibrium pressure at a given temperature is determined by the following formula:

$$A + \frac{B}{T} + C \cdot \ln(T) = \ln f - \frac{p \cdot \Delta V}{(v_1 + v_2)RT} + \frac{\ln(x_{H_2O})}{(v_1 + v_2)}$$

For a more detailed study of the initial stage of the process of separating the hydrated part of methane, a three-phase calculation of the hydrated part of methane with a water phase at a low temperature (272.95°K) was considered.

It should be noted that one of the main parameters of the conservation effect is the temperature, the increase of which in the studies is carried out in the appropriate sequence aimed at the surface separation of the hydrate in the network of three-phase balance lines: "gas - hexagonal ice - hydrate" and "gas - chilled water - hydrate". In network "gas - chilled water - hydrate", hydrate is converted into chilled water.

The consumption rate of the inhibitor in individual sections is determined by the following formula:

$$H_{T,i} = G \cdot K$$

where G is the minimum required (theoretical) specific consumption of the inhibitor; K - safety factor within 1.05-1.25 for unaccounted factors. K is the coefficient of phase distribution of components in non-isothermal and non-stationary flow of a gas-liquid mixture and is determined experimentally. To accurately calculate the phase imbalance in the field, the amount of volatile or non-volatile components of the gas phase, including CO_2, H_2S, N_2, H_2O and methanol, must be calculated accurately:

$$G = \frac{G_i \cdot (X_2 - X_1) + G_1^{recycle}\left(X_2 + X_1^{recycle}\right) + (W_1 - W_2) \cdot X_2}{X - X_2} +$$

$$+ \frac{100 - X_2}{X - X_2} \cdot [(Q_2 - Q_1) + (q_2 - q_1)]$$

$$G_2 = \frac{X}{X_2} + \frac{G_1 \cdot X_1 + G_1^{recycle} \cdot X_1^{recycle} + 100 \cdot [(Q_2 - Q_1) + (q_2 - q_1)]}{X_2}$$

G - the minimum specific consumption of the inhibitor, X - density , kg/1000 m3; G_1 - the specific amount of the "liquid-water" phase entering the point 1 of the technological chain from the previous technological area of the inhibitor, kg/1000m3; $G_1^{recycle}$ - the specific amount of recirculating aqueous solution of the inhibitor given to the point, kg/1000 m3; G_2 - the specific amount of the aqueous liquid phase of the inhibitor supplied to the point 2 of the technological chain, kg/1000m3; X_1, X_2 - the concentration of the water phase of the inhibitor at points 1 and 2, respectively, in mass %; X - concentration of the inhibitor given to point 1, mass %; $X_1^{recycle}$- concentration of the used inhibitor given to point 1, mass %; W_1, W_2 - humidity capacity of gas at points 1 and 2 (equilibrated with aqueous liquid phase), kg/1000m3; Q_1, Q_2 - amount of inhibitor in the gas phase at points 1 and 2, kg/1000m3; q_1, q_2 - amount of inhibitor in hydrocarbon condensate at points 1 and 2, kg/1000m3. G_1; $G_1^{recycle}$, X_1, X_2, $X_1^{recycle}$ are taken as known quantities; G and G2, and their values are found by calculation.

In order to increase the efficiency of the LPS device and improve its technology, in process of preparation gas to transportation at the Garadagh UGS facility, the following changes were made to the technological scheme of the equipment (Fig.4):

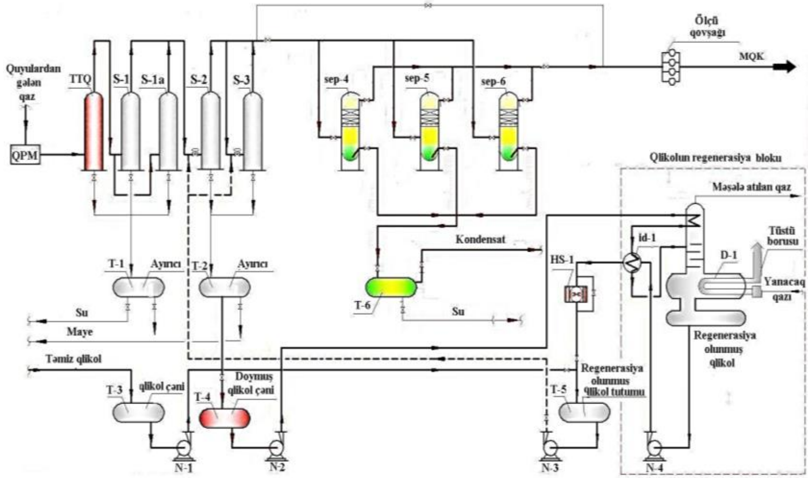

Fig.4. Principal flow diagram of the device for preparing gas for transportation in the Garadagh UGS

- before installing the LPS, "catching devices" must be installed to trap dust, sand and other mechanical impurities in a free liquid mixture entered with a gas flow, that meet modern requirements and take into account the daily performance of the equipment;

- to increase the efficiency of liquid phase separation in stage II and III separators and prevent them from entering the main gas pipelines, it is required to install two “phase separation devices”;

- the complex of equipment must be provided with automated control and measuring devices that meet modern requirements;

- to prevent hydrate formation in the process system, it is expedient to inject glycol into the gas flow at the inlet to stage II and III separators;

- for the regeneration of the glycol solution used in the technology, saturated with water vapor, it is necessary to enter to operation of the built "regeneration unit" in the underground storage facility.

This chapter also discussed the issues of developing a methodology for determining PPG in natural gas using a chromatograph, studying the effect of the composition of the transported gas on the reliability of the gas pipeline in order to study the impact of the operation of gas supply systems on the environment, organizating of environmental protection of the gas supply system and minimizing environmental damage.

In order to obtain a new reagent, the physicochemical properties of a number of reagents were studied and experimental studies were carried out. Table 5 presents the results of studies of the composition as an inhibitor of salt deposition.

Table 5. Effectiveness of applying of inhibitor composion

Amount of composition in reservoir water, mg/l	The amount of precipitation on mass-exchange surfaces, gr.	Protective effect, %
0	0,442	—
10	0,142	68,5
20	0,084	81,0
30	0,064	85,5
40	0,058	86,8

As can be seen from the table, the use of the composition makes it possible to achieve a high protective effect by preventing the deposition of salts in wells, individual parts of gas treatment plants and on the heat exchange surfaces of gas dryers.

It has been established that lowering the temperature does not lead to a sharp increase in the viscosity of the composition, which makes it possible to use it for processing natural gas in field conditions at relatively low temperatures.

The third chapter is devoted to improving the efficiency of microbiological protection of underground structures, the use of nanocomposition against hydrate formation and erosion in gas pipelines, the study of the effect of a stable magnetic field on hydrate formation in a gas pipeline, the study of the effect of cathodic polarization on the peeling of insulating coatings on a bitumen-polymer basis, and to development of an effective method to prevent of hydrate formation and corrosion during transportation of natural gas.

Despite the presence of modern types of insulating coatings among a wide range of insulating materials (polyurethane, polyepoxide, triple polyethylene), in the oil and gas complex is dominated by less effective in terms of operational and anti-corrosion performance, but cheaper oil bitumen based on mastics and mastic-tape coatings (Fig.5).

In addition to mechanical corrosion, damage to pipes in oil and gas pipelines is affected by biological components of the environment (soil, sand), destruction of the protective coating of pipes under the influence of soil microorganisms.

This leads to the formation of corrosion cracks, the loss of transported products and, in most cases, significant environmental pollution.

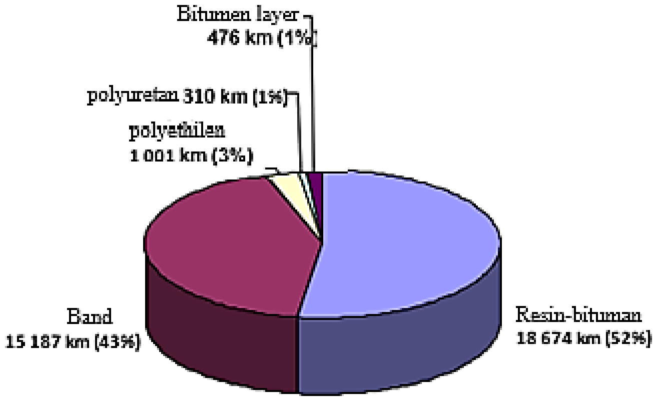

Fig.5. Distribution of types of insulation coatings

The number of microorganisms around the pipeline decreases depending on the distance from the pipe, and chemical processes are the factors that initiate the biological corrosion of the metal, and then ensure the continuation of the corrosion process. Thus, these two processes complement or mutually reinforce each other in the overall corrosion process.

During long-term operation of pipelines with bitumen coating under the conditions of the main line, the degradation of the insulating coating occurs with the loss of dielectric properties and gradual cracking. During the operation of pipelines in saline and highly mineralized areas containing more than 3-4% of soluble CO_2 and H_2S, due to the rapid penetration of iron into the liquid and the formation of hydrogen ions, corrosion processes occur in the cracks of the protective coating. The penetration of hydrogen into the steel surface leads to a sharp decrease in the strength of the metal structure and accelerates the corrosion process.

Studies show that microorganisms, namely sulfate-reducing bacteria, cause up to 80% of all corrosion losses.

Based on the analysis of existing methods and methods of biocorrosion protection, depending on the composition of the soil, climatic conditions, types of microorganisms, dielectric properties of insulating materials, the following main areas of biocorrosion protection of pipelines can be noted:

- the use of inhibitors that reduce the impact and activity of microorganisms;
- development of various composite materials;
- application of cathodic protection;
- periodic control and monitoring of the condition of pipelines to detect the activity of microorganisms,
- reducing the activity of sulfate-reducing bacteria under appropriate conditions, fighting hydrogen sulfide corrosion.

Biocorrosion and biodegradation are two of the most serious problems for systems and equipment in direct contact with the water environment. One of the ways to solve this problem is the modification of insulating coatings obtained from oil-bitumen mastic, which makes it possible to prevent electrochemical corrosion, together with corrosion inhibitors that improve physical and mechanical properties and increase their biological properties.

The adding of corrosion inhibitors to the base composition of bitumen-polymer mastic makes it possible to obtain mastics with high physical and mechanical properties and increased plasticity.

Bitumen-polymer mastic produced in Azerbaijan was taken as raw material. One of the important quality indicators of bitumen-polymer mastics is water absorption, which determines its hydrophobicity and, as a result, the dielectric properties of the insulating coating. Therefore, it is necessary to consider the water absorption capacity of base and modified mastics in a wide range of inhibitor saturation rates from 0.05% to 2.0% of mass.

Three types of experiments were carried out to study the water absorption of base and modified mastics with inhibitors of the class of amines and quaternary ammonium salt in distilled and sea water (Fig. 6).

When a sample of base mastic is kept in distilled water, it becomes brittle, and a gray mold forms on it. At the same time, the modified mastic samples retain their plasticity under those conditions, and no deposits are observed on them. The gray cast on the base mastic sample is most likely the result of desorption of water-soluble components of the mastic.

The nature of the dependences of water saturation in seawater is analogous to the dependences obtained for distilled water. At the same time, it should be noted that the water saturation of base and modified mastics in seawater is much lower than in distilled water. The rectilinear nature of the mass change kinetics of mastics is characteristic only for basic mastics, while the water saturation of mastics from the class of amines and modified with ammonium salts inhibitors reaches a maximum and remains practically unchanged after that.

After a three-month storage of prototypes in appropriate nutrient media, it was found that the developed mastics are biologically resistant to corrosive microorganisms and can be used to insulate pipelines in problem areas of the route: in swamps, silty soils, salt marshes, in soils with high humidity and high risk of microbiological corrosion. It was found that amines are multifunctional inhibitors of class A and quaternary ammonium salts (Fig.7). Thus, they have an inhibitory effect both on the electrochemical corrosion of metals and on microorganisms that are corrosive.

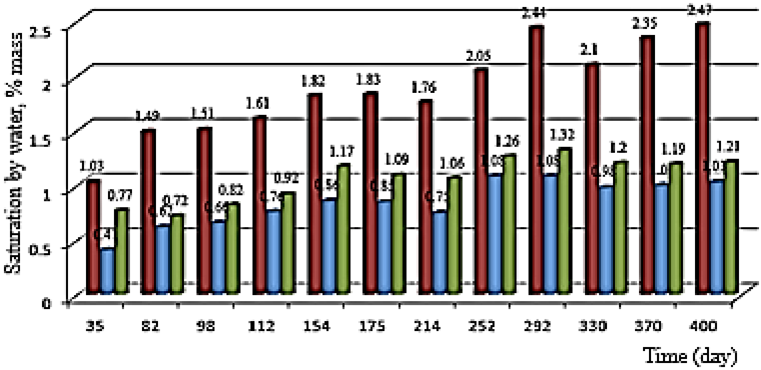

Fig. 6. Study of water absorption of mastic

As can be seen from the graph, type B inhibitors are most effective against sulfate-reducing (CRP) bacteria.

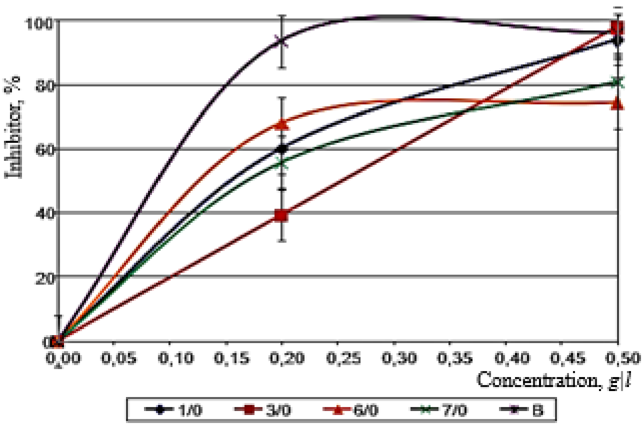

Fig. 7. Multifunctionality of inhibitors

For the reliability of a microbiological corrosive environment, it is very important not only to stop the growth rate of bacteria and the rate of corrosion, but also the mechanism of coverage by the environment. It has been shown that inhibitors 1/0, 3/0 and 7/0 meet the increase in CRP activity as a competitor, while inhibitors 6/0 and B cover this process by a non-competitive mechanism.

Inhibitor "B" is the most effective agent against corrosion from compounds containing quaternary ammonium salts. The effect of this inhibitor on sulfate-reducing bacteria corresponds to the minimum manifestation of the inhibitor constant, i.e., the maximum requirements for the presented inhibitors of corrosion biocides.

Since offshore gas pipelines run along the bottom through areas with different topography, various complications are observed in the gas transportation system. The technical condition of the gas and liquid lines entering the Hovsan KSM from the oil and gas storage on the offshore foundations No.1 and 3 of the Bahar field was investigated, the technical and technological indicators of the lines were analyzed, the influence of the magnetic field of a permanent magnet based on alloys was studied. Neodium-iron-boron and samarium-cobalt, on the physicochemical parameters and hydrate formation, of formation water coming along with the gas flow (Fig. 8).

The principle of operation of the laboratory installation is as follows: formation water separated from the gas condensate taken for

Fig.8. Laboratory apparatus

is poured into a 3-liter glass vessel and, using a pump connected to an electric motor, is passed through pipes at a speed of 0.5 m/s through a permanent magnetic inductor.

Thus, the water is circulated by the pump for 5 hours and passes through the magnetic field.

Analysis of the results showed that:

- at the formation water freezing temperature of minus 269-268.5°K, the freezing temperature of formation water treated in a magnetic field at a voltage of 350 mT or 280 kA/m drops to 265.5°K;

- it is possible to decompose of hydrate compounds formed in the technological system by exposure to an electromagnetic field;

- the impact of the electromagnetic field used to prevent the formation of hydrate compounds depends mainly on the dielectric properties of the medium and the magnetic field strength.

Formation water taken from the oil primary separation tank located in the oil preparation and transportation shop of "Bahar energy operation" company was selected as the research object. At the beginning of the study, a chemical analysis of the produced water was carried out and the obtained results are given in table 6. It can be seen from the table that the research object is a hydrocarbon-based formation water with high mineralization.

In our research, the influence of the magnetic field of different voltages on the freezing temperature of formation water was studied. It was determined that among the studied magnetic samples with different voltages (B±50, ±150, ±250, ±350 and ±450), there were samples with a magnetic field strength of 350 and 450 mT, which had an effective effect on the freezing temperature of formation water.

The analysis of the obtained results showed that as a result of the decrease of the conductivity of formation water, the concentrations of the ions in it, their equivalent concentrations (mg. eq/dm3), the equivalent percentage, the classification results on Palmer and Sulin, the freezing temperature of the formation water sample processed by the two selected magnetic fields strength of 350 mT or 280 kA/m drops considerably (table 7).

t = 298^0K, density; ρ = 1.04. Bohm number: B_{e15}=5.73, pH= 8.0.

Table 6. Results of experiments (without magnets)

Name of ions	**Consentration of ions, mg/dm^3**	**Equivalent consentration of ions, mq.ekv/dm**	**Consentration of ions, m.mol/d**	**Equivalent %**	**Classification of water on Palmer and Sulin**
Total hardness		10	5		
Carbonate hardness		10	5		S=69,41624
Dry residue	60540				
Na^{+}+K^{+}	20476,88	853,20		49,42	S_2= 0
Ca^{2+}	80,16	4	2	0,2317	
Mg^{2+}	72,96	6	3	0,3475	A=29,42528
Sum of cations Σ		863,20		50,00	
CL^{-}	20561,00	580,00		33,60	a= 1,158476
SO_4^{2-}	921,76	19,20		1,1123	
CO_3^{2-}	150,00	5,00		0,2896	II type
HCO_3^{-}	15799,00	259,00		15,0023	
NT	0,00	0,00		0,0000	
HB_4O_7	0,00	0,00		0,0000	
Sum of anions Σ		863,20		50,00	
Fe^{2+}					
Fe^{3+}	927,09	49,68			
Total mineralization	58061,76				

Cathodic corrosion protection is also used in the operation of underground structures. In practice, according to regulatory documents, the minimum protective potential for the $Cu/CuSO_4$ electrode is -0.85 V. This potential value is based on theoretical calculations of the electromotive force (EMF) of the iron oxidation reaction in the presence of water in a neutral environment. In this case, the following reactions take place:

t = 298^{0}K, density; ρ = 1.04. Bohm number: B_{e15}=5.73, pH= 8.8.

Table 7. Results of experiments (with magnets)

Name of ions	**Consentration of ions, mg/dm^3**	**Equivalent consentration of ions, mq.ekv/dm^3**	**Consentration of ions, m.mol/dm^3**	**Equivalent %**	**Classification of water on Palmer and Sulin**
Total hardness		8	4		
Carbonate hardness		8	4		S,=75,22794
Dry residue	59060				
$Na^{+}+K^{+}$	21025,46	876,06		49,55	S_2= 0
Ca^{2+}	40,08	2	1	0,1131	
Mg^{2+}	72,96	6	3	0,3393	A=23,86714
Sum of cations *Σ*		884,06		50,00	
CL^{-}	22865,25	645,00		36,48	a= 0,904915
SO_4^{2-}	962,91	20,06		1,1346	
CO_3^{2-}	1110,00	*37,00*		2,0926	II type
HCO_3^{-}	11102,00	182,00		10,2934	
NT	*0,00*	0,00		0,0000	
HB_4O_7	0,00	0,00		0,0000	
Sum of anions *Σ*		*884,06*		50,00	
Fe^{2+}					
Fe^{3+}	134,12	7,19			
Total mineralization	57178,66				

Anod reaction

$$2Fe^0 \rightarrow 2Fe^{+2} + 4e \qquad \varepsilon^0 = 0,44V$$

Cathod reaction

$$O_2 + 2H_2O + 4e \rightarrow 4OH \qquad \varepsilon^0 = 0,4V$$

Result reaction

$$2Fe^0 + O_2 + 2H_2O \rightarrow 2Fe(OH)_2 \qquad \varepsilon^0 = 0,84V$$

Sulphate reduction in soil corrosion occurs as a result of bacterial activity, and oxidation occurs according to the classical scheme of cathodic depolarization without access to atmospheric oxygen:

$4Fe^0 \rightarrow 4Fe^{2+} + 8e$ (on the anod parts of metall)

$8H^+ + 8e \rightarrow 8H$ (on the cathod parts of metall)

$SO_4^{2-} + 8H \rightarrow S^{2-}\ 4H_2O$ (cathodic depolarization of SRB).

The total EMF of the cathodic depolarization reaction is 0.60 V. Thus, if sulfate ions are reduced, the recommended cathodic protection potential is -0.24 V higher than the resulting EMF. This leads to an increase in the corrosive activity of SRB.

One of the important technical indicators characterizing the quality of the insulating coating is the peeling radius of the coating under the influence of cathodic polarization. Peeling of the coating from the protected metal occurs as a result of the following reaction with the formation of hydroxide ions, and the decay rate, at the same potential, high at the initial stage, gradually slows down:

$$\frac{1}{2}O_2 + H_2O + 2e = 2OH$$

The peeling rate of coating is determined as a function of coating thickness and soil-coating interaction.

For research, 18 samples of 200x200 mm in size, cut from the main pipeline, were prepared, the surface of 9 samples was treated with metal brushes, and the surface of the remaining samples was treated with a sand jet in the optimal mode. After that, three types of bitumen-polymer coatings were applied to the surface of the samples. Connected to the negative pole of a direct current source, the samples were kept in an electrolyte solution for 30 days at a temperature of (20±2) °C under cathodic current (Fig.9).

Analysis of the results (Table 6) shows that the performance characteristics of the proposed protective and insulating coatings meet the requirements of the current standard, and the resistance of coatings to cathodic separation is affected by both the method of cleaning the metal surface and the properties of the inhibitor contained in the modified mastic.

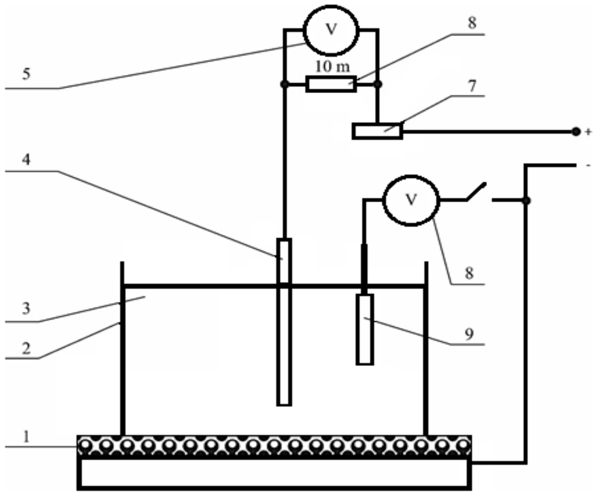

Fig.9. Schematic diaqram for testing samples of modified mastic coatings to determine the radius of the gap using an inert anode.

1 - a sample of the studied coating; 2 - polyethylene tube: 3 - electrolyte; 4 - inert anode; 5 and 8 - voltmeters; 6 - reference resistance; 7 - reostat; 9 - reference electrode.

The introduction of inhibitors G and J into the base mastic increased the resistance of the modified mastics to peeling, in the case of inhibitor G - more than 11%, and in the case of inhibitor J - up to 22% during sandblasting of the metal surface. Sulfuric acid, sulfur trioxide and oleum are used as sulfiding agents.

To determine an effective inhibitor that provides comprehensive protection of equipment from hydrogen sulfide and electrochemical corrosion, sulfates have been laboratory tested.

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Table 8. Radius of peeling of coatings at cathodic polarization

Brend of mastic	Sample surface treatment method	Duration of storage in electrolyte, days	Peeling radius, mm
Basic (МБП1Д)	By metall brush	30	10 ± 0,40
МБП1М1-Д	By metall brush	30	9 ± 0,25
МБП1М2-Д	By metall brush	30	8 ± 0,30
Basic (МБП1Д)	By sand jet	30	9 ± 0,25
МБП1М1-Д	By sand jet	30	8 ± 0,20
МБП1М2-Д	By sand jet	30	7 ± 0,25

The resulting sulfate compounds were tested both separately and in combination with dimethylethanolamine (DMEA) in an aggressive environment to protect against various types of corrosion. The corrosion process was studied for 20 hours. The time dependence of the corrosion rate in CO_2 medium is shown in Fig.10 (where 1 - no inhibitors, 2 - Na + sulfate, 3 - Na + sulfate + DMEA).

With the introduction of sodium sulfate in an aggressive environment, the protection efficiency in the first hour of the process was 68.43%. However, with an increase in exposure time, the level of protection against corrosion increases, respectively, to 79.66%.

Sulphonates were tested as inhibitors under laboratory conditions to determine the most effective for comprehensive protection against hydrogen sulfide and electrochemical corrosion of equipment. The obtained sulfate compounds were tested in an aggressive environment to protect against various types of corrosion both separately and in combination with dimethylethanolamine (DMEA).

The combination of Na+ sulfates with DMEA demonstrates a high corrosion protection effect even at low concentrations, due to the synergistic action of the components. The proposed sulfate compositions can be successfully used as multifunctional CO_2 and H_2S corrosion inhibitors.

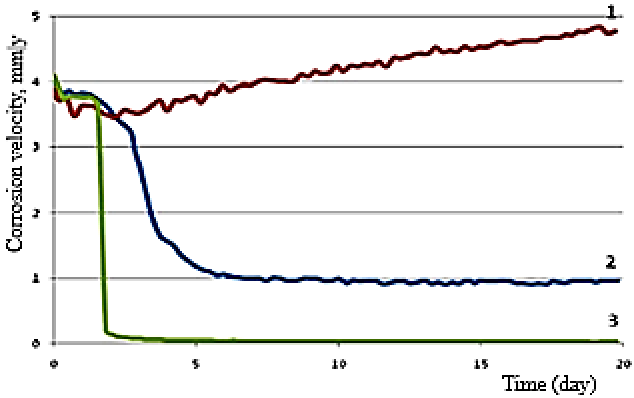

Fig. 10. Time dependence of corrosion rate in CO_2 environment

As can be seen here, the corrosion process was studied for 20 hours. When Na sulfonate was added to the corrosion environment, the protection efficiency was 68.43% in the first hour of the process. However, with the increase of exposure time, the degree of corrosion protection increases accordingly to 79.66%.

The protection efficiency of compositions based on DMEA and sodium sulfonate within 20 hours was 99.5%, while the corrosion rate decreased from 4.09 to 0.02 mm/year, respectively.

In the fourth chapter considered with the development and application of innovative technologies for gas transportation, regarding this, the problems of developing new methods and technologies and scientific and technical proposals for cleaning gases from harmful components, improving the technology for collecting and transporting low-pressure gases between offshore platforms are considered.

Liquid sorbents are widely used in world practice for purification of acidic components of natural and associated gases (H_2S; CO_2, etc.) and their dehydration from water vapor. Depending on the number of components extracted from the gas with the help of absorbents, the process is conventionally divided into the following groups:

- physical absorption - extraction of acidic gas components by liquid organic absorbers. This method makes it possible to carry out complex purification of gases from acidic components and organic sulfur compounds;

- chemical sorption - based on chemical bonds between the absorbent and the absorbed components;

- combined absorbents are used for complex purification of gases from acidic components and drying of water vapor.

The results of the study showed that the absorbent with the best performance has the following composition: PPQ or MPQ - 75%; MEA - 20%; water - 5%. The experimental study of the new complex absorbent in the laboratory was carried out according to the following method.

Natural gas containing 1.5% H2S, 4-4.5% CO2 and saturated with water vapor enters the absorption column at a rate of 20-40 m^3 per hour, where the gas comes into contact with the proposed complex absorbent. For every 1000 m^3 of gas flow, 18-20 kg of complex absorbent is injected. During the experiment, the gas pressure in the absorber was 5.0-5.5 MPa, and the contact temperature of the gas+absorbent was 25-35°C.

Physico-chemical parameters of the proposed absorbent are as follows:

Density, 20°C, kg/m^3	- 1022-1046
Viscosity, 20°C,	-28-30 mm^2/s
Freezing temperature	- minus 60-65°C.
Boiling temperature, °C	- 190-195
medium pH	- 6.8-7.0

When using a new complex absorbent, the DP temperature of the gas relative to water vapor is minus 20-22 °C, and the degree of purification from harmful components is 90-95%, the absorption capacity is significantly reduced if the amount of water in the absorbent is more than 10%.

The main factors that determine the efficiency of gas separators are the internal diameter of the separator, the operating pressure and the gas velocity in the diametrical section of the separator. When gas moves from the separator through the pipeline, the liquid phase released from the gas because of changes in its temperature and pressure leads to the occurrence of technological complications in the system.

Regarding this, the design of the internal elements of operated separators has been improved. This separator consists of the following elements (Fig.11): 1 - vertical cylindrical body; 2 - leading pipe; 3 - vortex-forming pipe coil, 4 - central pipe for removing purified gas, 5 - branched pipes connected to the lower part of the separator; the outlet line of the purified gas in the upper part of the separator body - 6, and in the lower part the outlet line of the liquid phase (water + C_5+) - 8.

Here $D_1 = 3D_2$: - the diameter of the central tube. D_2 is the sum of the diameters of the branched tubes. The separator works with the following technology; the gas containing liquid and other particles enters the vortex generator through the leading tubes and creates a centrifugal force as a result of the movement of the gas in the tube. As a result of the centrifugal force, small liquid particles are separated from the gas stream, which later merge and turn into large liquid drops.

As a result of the reduction of the radius of the element inside the separator, the energy of the moving gas flow decreases, and as a result, heat exchange occurs in the system and the gas temperature decreases. As a result of this process, the water and condensate vapors separated from the gas condense, turn into liquid and are fed into the liquid line, the gas separated from the flow exits the spiral and enters the low pressure area. This condition arises due to the fact that the diameter of the central tube is larger than the inlet diameter of the vortex creator.

For this reason, the gas purified from the liquid mixture moves to the upper part of the separator through the central pipes. The center tube is designed to fit into the outlet line at instant speed. In order to prevent undesirable mixtures (water, condensate, oil droplets) from falling into the line with the gas flow, a line with a diameter smaller than the diameter of the central pipe is sometimes located in the body of the separator. As a result of the gas and liquid phase falling to a low pressure level in the separator, due to the decrease in the gas flow rate, the liquid drops are directed towards the wall of the tank through the branched pipes located below under the influence of their mass. As a result of this, intensive separation of liquid droplets from gas is observed due to the additional effect created in the system.

The principle of operation of the separator is as follows: gas containing liquid and other particles enters the vortex generator through the guide pipes, and as a result of the movement of gas in the pipe, centrifugal acceleration occurs.

As a result of its action, small liquid particles are released from the gas flow, which then combine and turn into large droplets. As the radius of the element inside the separator decreases, the energy of the moving gas flow decreases, which leads to heat exchange in the system and a decrease in the gas temperature. As a result of the pressure drop of the gas and liquid phases to a low level, due to a decrease in the gas flow rate in the separator, liquid drops under the

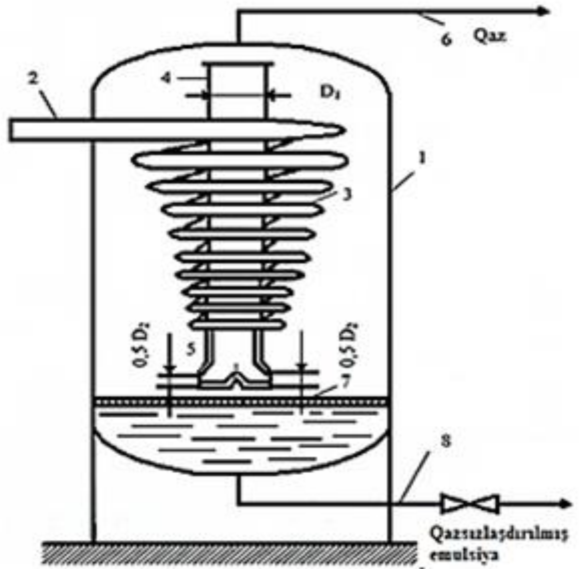

Fig.11. Separation unit

action of their mass are directed to the tank wall along the branched pipes located in the lower part.

As a result, due to the additional effect in the system, an intensive separation of liquid droplets from gas is observed.

The efficiency of collecting and processing low-pressure (0.1-0.5 MPa) oil and gas at offshore oil and gas fields is low, which leads to large losses of associated gas, makes it difficult to transport gas to gas treatment plants on land and further to the consumer. The effective application of existing technologies for the collection, preparation and transportation of low-pressure gas in deep-sea foundations is very difficult and difficult for technical and technological reasons. For this purpose, calculations were carried out to improve the efficiency of the low-pressure gas transport system at offshore oil and gas fields, the equipment used, pipelines and operating modes of compressor stations were studied.

The amount of gas supplied to the flare at the Guneshli field, i.e., losses by years are shown in Table 7.

Table 7. The amount of gas supplied to the flare, by year

Year	2015	2016	2017	2018	2019
Losses of associated gas (defined), mln.m^3	623	740	895	1058	1310
Oil gas entering the flare	1365	1570	1420	1365	1035

Let us determine the pressure required to clean the gas from the liquid accumulated during transportation through the pipeline on the seabed.

First option. To ensure the normal transportation of low-pressure gas through offshore gas pipelines, it is necessary to find the optimal working gas pressure to squeeze out of the liquid precipitated from the gas.

Let us consider the worst-case scenario for the transportation of low-pressure petroleum gas, when the system (pipeline) is completely clogged with a liquid mixture. The pipeline diagram for calculating the working gas pressure is shown in fig. 12.

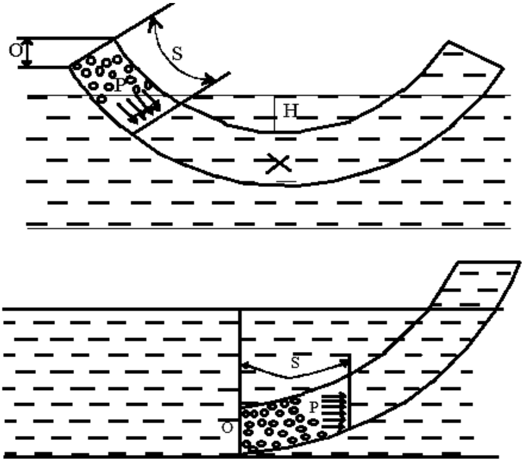

Fig. 12. Scheme of the pipeline

The movement of gas through a pipeline under the condition of an incompressible liquid can be described as follows:

$$m\frac{dv}{dt} = P \cdot f - 2\pi R(l - S) \cdot \tau - \rho g s f \sin\varphi \qquad (1)$$

where m - is the mass of the liquid; S - pipe section; ρ - is the density of the liquid; *l*, *R* and *f* - are the length of the pipe, the radius of the inner pipe and the cross-sectional area, respectively; τ - is the friction stress between the liquid and the inner surface of the pipe wall.

Assuming that the fluid velocity is negligibly small, and not taking into account the friction stress, from expression (1) we got the following equation:

$$\rho\pi \mathrm{R}^2(\mathrm{l} - \mathrm{S})\frac{dv}{ds} \cdot V = P \cdot f - \rho g s f \sin\varphi$$

Integrating the differential equation, we obtain the following equation:

$$P = \frac{\rho V^2}{2ln2} + \frac{\rho g l \sin\varphi(\ln 2 - \frac{1}{2})}{ln2} \qquad (2)$$

In the second variant, the calculation is performed in the following sequence. To determine the pressure required to lift the liquid when its level in the pipe drops to height H, we write the equation of motion of the liquid in the pipe as follows:

$$m\frac{dv}{ds}\cdot V = P\cdot f - \rho g f(H - s.\sin\varphi) \qquad (3)$$

After integrating equation (3), taking into account the mass of the liquid - m=ρf(*l*/2-s), we obtain:

$$P = \frac{\rho V^2}{2ln2} + \rho g(Hln2 + \frac{l}{4}sin\,\varphi - \frac{l}{2}ln2\,sin\,\varphi)\frac{1}{ln2} \qquad (4)$$

Calculations based on the expressions obtained showed that the working pressure required to squeeze out the liquid collected in the pipe passing through the seabed should be P = 1.5-2.0 MPa.

Based on the research results, the following scientific and technical proposals have been prepared:

-in accordance with the technological scheme of the high-pressure gas pipeline used in the gas lift system, to ensure unhindered gas transportation in the deep-water part of the Guneshli field, lay an additional pipeline with a pressure of P=1.5-2.0 MPa and connect it to the low-pressure gas system;

- improve the internal design of existing separators;

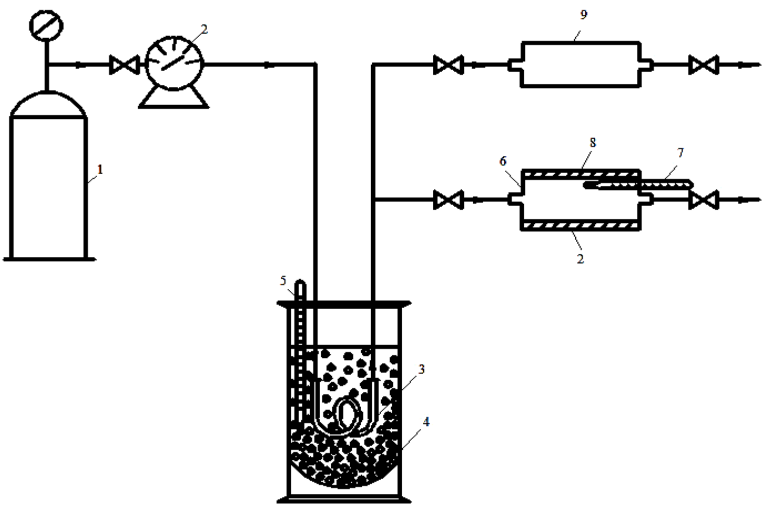

Fig.13. Diagram of a laboratory device for testing thermal insulation coatings.

1 - source of gas; 2-gas meter; 3-heat exchanger; 4 - dewar vessel; 5, 7 - thermometer; 6 - a sample of an insulated metal pipe; 8 - heat-insulating cover, 9 - uninsulated metal pipe.

- gel and mechanical balls should be used to displace the liquid phase in the low-pressure pipeline;
- based on locally produced chemicals, develop of the foaming systems with different compositions.

One way to eliminate the complications caused by dew drops on the outer surface of pipelines is to cover large metal surfaces with thermal insulation materials. To study this problem, laboratory experiments were carried out with heat-insulating materials with different compositions (Fig.13).

In the first version, before insulating the pipe, its surface was cleaned with a sandblasting machine or metal shot, after wiping with a solvent and the following composition of the insulating material was applied to the dry surface.

Covering large metal surfaces with heat-insulating materials is one of the economically efficient ways to overcome this problem. For this purpose, preliminary experiments with heat insulation materials in several compositions were conducted in laboratory conditions.

When conducting experiments, 2 main options were taken into account.

In I variant, before insulating the pipe, its surface is cleaned with sandblasting or metal scraps, wiped with a solvent, and insulating materials are applied to the dry surface. For this purpose, the following examples have been prepared:

In II variant, the surface of the pipe is not cleaned with sandblasting, only the corrosion products and paint residues on the surface of the pipe are cleaned by a mechanical method with a metal brush, and the insulating coating is applied to the wet surface. In this case, the coatings with the following composition were experimentally tested in laboratory conditions:

In option II, the surface of the pipe is not cleaned by sandblasting, corrosion products and paint residues on the surface of the pipe are cleaned only mechanically - with a metal brush and an insulating coating is applied.

Initially the experiments were carried out without applying an insulating coating to the metal pipe. Thus, the gas temperature inside the metal pipe gradually decreased from 25°C, when the gas temperature inside the pipe reached 6-8°C, a dew layer was observed on the pipe surface.

In this case, the following coatings were tested:

Then the experiments were continued by isolating the outer surface of the pipe. First, the proposed coatings according to Option I were applied to the surface of the pipe one by one, and the temperature of the gas inside the pipe gradually decreased to minus 2-3°C. Then the proposed samples were tested in the same mode for option II.

In both cases, positive results were obtained for the first 3 compositions (composition 1, 2 and 3), i.e. no dew layer was observed on the insulating coatings.

The purpose of the creation of UGS facilities is to increase the reliability of the gas supply system and regulate the seasonal fluctuations in gas consumption in the country and the industry.

Composition 1. Epoxy; Fiberglass + Epoxy; Interlayer-1 + Epoxy; Fiberglass + Epoxy;	**Composition 2.** Epoxy; Interlayer-1 + Epoxy; Fiberglass + Epoxy;
Composition 3. Epoxy; Fiberglass + Epoxy; Intermediate layer with one-sided aluminum foil	**Composition 4**. Epoxy; Intermediate layer with one-sided aluminum foil
Composition 1. Composition of plastic; Fiberglass + Epoxy; Interlayer-1 + Epoxy; Fiberglass + Epoxy;	**Composition 2.** Composition of plastic; Interlayer-1 + Epoxy + Composition of plastic Fiberglass + Epoxy;
Composition 3. Composition of plastic; Fiberglass + Epoxy; Intermediate layer with one-sided aluminum foil	**Composition 4.** Composition of plastic; Intermediate layer with one-sided aluminum foil

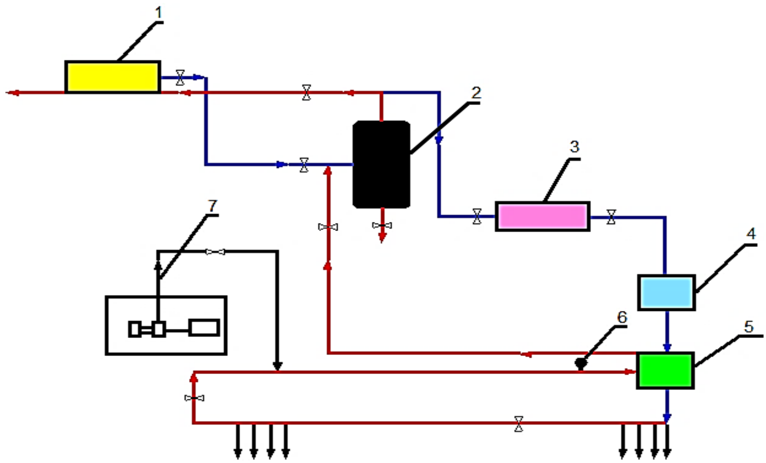

Fig. 14. Gas preparation unit at Kalmaz UGS.
1 - main gas pipeline; 2 - separator; 3 - compressor station;
4 - cooler; 5 - gas measuring device; 6 - nozzle; 7- reagent

During the cold months of the year, UGS facilities should cover 15-20% of the uneven gas consumption in the country. In this regard, at the Kalmaz UGS facility, the technological regimes of the gas transportation preparation unit were analyzed (Fig.14).

Ensuring the dew point of the dried gas in accordance with the requirements of the industry standard during the period of gas extraction depends on the correct selection of the optimal parameters of the complex absorbent and the absorption gas dehydration device. Based on the results of the research, the parameters of the complex absorbent were preliminarily selected and the main technological scheme of the gas dehydration unit was proposed to improve the efficiency of the gas preparation taken from the Kalmaz UGS facility (Fig.15).

The use of an absorbent in the gas treatment system on taking gas from the Kalmaz UGS facility allows achieving the following goals:

- the DP temperature taken from the underground storage and dried gas on humidity will meet all the requirements of the industry standard;

- gas losses due to the formation of hydrates in the system will be excluded;

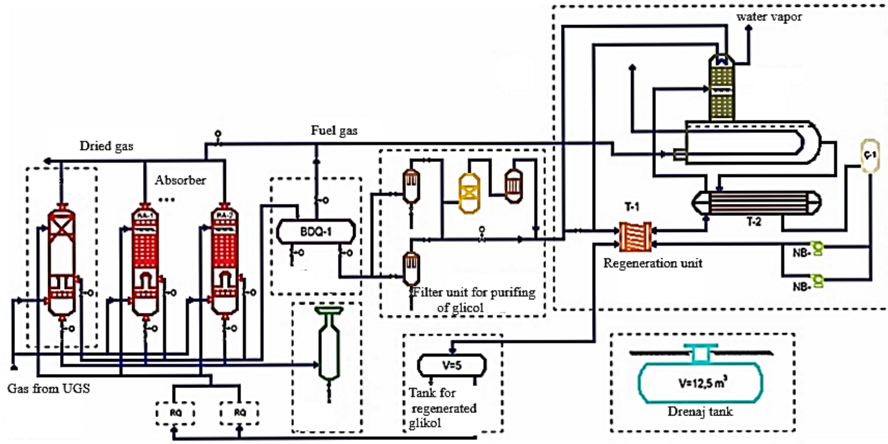

Fig. 15. The main technological scheme of the gas drying plant

- the ingress of the liquid phase into the main gas pipeline will be prevented, as a result of which the efficiency of the transport network will increase and its technological regime will stabilize;
- pollution of the formation and bottomhole of the well during gas injection will be prevented, on the basis of which an increase in their productivity is expected;
- the cost of transportation of gas to consumers will be significantly reduced;
- the use of a complex absorbent based on local petrochemical products for gas preparation for transportation will make it possible to exclude the purchase of imported chemicals.

In the fifth chapter is devoted to the development of a gravitational cyclone separator with a combined design based on a comparative analysis of the effectiveness of various separator designs: gravity, inertial, centrifugal, centrifugal-vortex type and separator filters and the study of equipment operated in UGS.

Produced and transported gas is necessarily purified in separators. Changes in operating conditions and instability of the inlet flow parameters have a negative impact on the quality of gas treatment in existing gas separators. As a result, residual liquid accumulates in the gas flow, on narrow and uneven areas of the pipeline, which in turn leads to a decrease in pressure in the pipeline and an increase in operating and exploitation costs.

The separator diameter is determined by the amount of gas passing through it and the average allowable gas flow rate according to the following formula:

$$D_B=\sqrt{\frac{Q_H P_0 Z T_{sep}}{64824 v_{or} p_1 T_0}} \quad (3)$$

where D - is the inner diameter of the separator, m; Q_H - separator capacity, m^3/day; P_0 - absolute atmospheric pressure, N/m^2; Z - compression ratio; T_{sep} - gas temperature in the separator, K; v_{av} - average optimal gas velocity, m/s; p_1 - is the pressure in the separator; T_0 = 293°K.

The use of the average speed as the main separation force allows not only to control the separation process, but also to significantly reduce the dimensions of the separation units. In this case, the main separation force is determined by the following formula:

$$T = \frac{4\pi \cdot R^3(\rho_1-\rho)v^2 t}{3r} \quad (4)$$

where r - is the radius of the drop trajectory; v - is the tangential (tangential) component of the drop velocity; R - is the radius of the drop; ρ_1 and ρ - are the density of the liquid and environ.

As can be seen from the formula, with a decrease in the diameter of the separator, the separating force acting on the drop increases, which leads to a decrease in the size and lighting of the weight of separators of these types.

To purify natural gas from mechanical and liquid mixtures, as well as to prevent the formation of drops, a gravity cyclone separator with a combined design with mesh elements was developed (Fig. 16).

The separation unit consists of three parts, the main cleaning is carried out at the 2nd stage, and the fine (final) cleaning is carried out by dripping in the section with mesh elements. For laboratory tests, a design of a gravitational vertical cyclone separator with a volume of V = 8.5l with mesh elements was developed. Cyclone separators developed by us produced and intensively are still applied. The separator is for cleaning gas and compressed air streams from mechanical additives, suspended liquid droplets and other undissolved additives. A cyclone gas separator does not have:

- filters that require frequent replacement;
- complex internal structural elements that cause difficulties during operation, repair and internal inspection of the apparatus, as well as pressure drops during the movement of gas-liquid flow inside the separator;
- other such deficiencies that prevent the efficient operation and use of the separator.

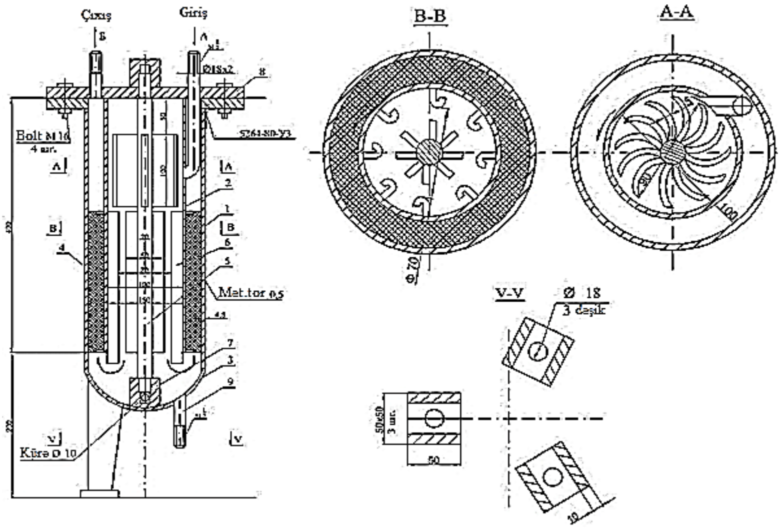

Fig. 16. Gravitational cyclone separator

1 - outer case; 2 - inner case; 3 - lower elliptical base; 4 - mesh sleeve; 5 - rotating shaft with a propeller; 6 - partition; 7 - bearing body; 8 - removable top cover; 9 - fitting for draining condensate; 10 - branch pipes "A" and "B" for gas inlet and outlet

That is why the repair costs of them are low. The separator consists of a body, an elliptical base, a cylinder that rotates depending on the gas pressure, a chromium-plated mesh with high cleaning properties and nozzles A and B for gas inlet and outlet.

The supplied gas moves due to the rotation of the shaft with the blades set at a certain angle inside the separator. Then the gas flow, separated from the main liquid, is directed to the compartment with mesh elements, where, for additional separation of liquid droplets from the gas flow, it passes through a fine mesh located between the outer and inner casings. The filter compartment with mesh elements is designed for fine cleaning, preventing droplet entrainment. The purified gas is discharged through the outlet fitting B, and the separated liquid is discharged into the lower part of the separator through the condensate outlet.

Fig.17 shows a process flow diagram for the separation of natural gas in a gravity cyclone separator.

Natural gas containing the liquid phase enters the C-1 compressor inlet and then goes to the S-1 separator. To test the separator's performance and the efficiency of gas purification, the pentane-hexane fraction (C5; C6) is introduced into the gas stream to separate the liquid mixture from the raw gas before entering the S-1 separator, the gas-liquid flow enters in S-1 separator. During contact of the gas-liquid flow with separation devices, the main part of the liquid phase (hydrocarbon condensate and mechanical impurities) is separated from the raw gas.

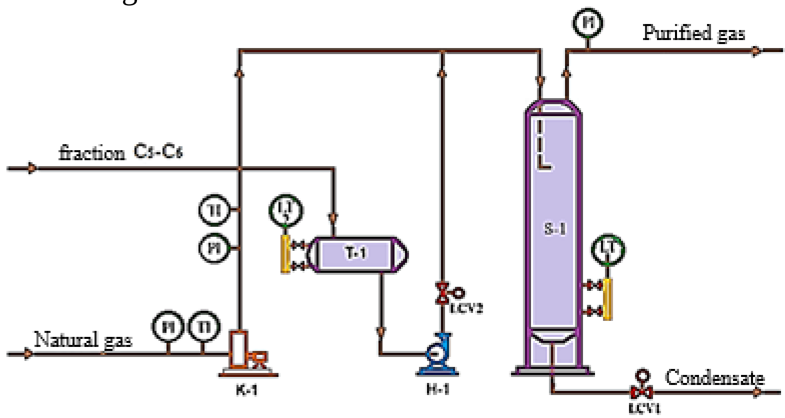

Fig. 17. Technological scheme of gas separation

Then, to prevent droplet entrainment, the gas in the compartment with mesh elements is subjected to fine (final) cleaning. The purified gas is withdrawn through the purified gas pipeline through the “B” fitting, and the condensate is discharged from the bottom of the separator through the level control valve.

The proposed cyclone separator has the following advantages:

- there is no need to frequently change the mesh filter elements;
- of complex internal structural elements that impede the operation, maintenance and internal inspection of the device are absent;
- no pressure drop during the movement of the gas-liquid flow inside the separator;
- increasing the degree of purification from mechanical and liquid mixtures;
- prevention of irretrievable losses (entrainment) of condensate with purified gas;
- ensuring high reliability and safety of operation;
- small dimensions and low metal consumption, which makes it possible to install in limited conditions;
- low hydraulic resistance and high efficiency of gas cleaning (not less than 99%).

In order to ensure compliance with the requirements for quality indicators of gas taken from UGS facilities depending on the season and its unhindered transportation to consumers, the main technological scheme of the integrated gas drying unit was selected; ways to increase of the effectiveness and efficiency of the devices were proposed, UGS gas lines and the operation of another the necessary technological equipment and a booster gas compressor station operated in UGS, a method for choosing the optimal mode of its operation based on the results of the operation of the units is proposed, ways to increase the volume of active gas pumped into the storage facility are shown, the principles of creating underground gas storage facilities are analyzed, proposals and recommendations are developed to solve problems of improvement functioning of storages and increase of their efficiency.

The study of the technological mode of operation of the CS in UGS facilities showed that, depending on the overhaul period, the performance of the units is reduced by 10-20%, and the efficiency by 5-10%. To improve the efficiency of technological, technical and economic indicators of compressors used in the process of pumping gas into UGS facilities, it is advisable to take the following measures:

- in order to provide the normal process of gas injection into UGS facilities, the creation of optimal working pressure in the system;
- supplying the required amount of gas to the compressor to increase the volume of active gas pumped into the storage;
- prevention of technological losses in the closed storage system of UGS and reduction of fuel gas consumption, etc.

In order to develop and select a new reagent, studies out to determine the physicochemical and technological parameters of various samples of reagents taken from local chemical enterprises were carried, an effective absorbent with a complex composition based on PPG and isopropyl alcohol (IS) was developed.

The surface area of the Garadagh UGS is 1,530 ha, and the initial predicted gas volume is 1.7 billion m3. The results of the study show that the geological structure of the field allows increasing the volume of gas injection into the reservoir up to 5 billion m3. However, the current gas storage capacity is 1.5 bcm.

The minimum pressure of the gas pumped in the Garadagh UGS, according to the design indicators, should be at least 8.0 MPa. However, during the operation of the field, the gas pressure fluctuated within the 6.0-7.2 MPa. In 2016, the volume of gas injection into the Garadagh UGS amounted to 1.5 billion m3, and the reservoir pressure was increased to 8.6 MPa.

In addition, the improvement of the technology of equipment used for taking of gas should be carried out in the following areas:

- the dew point of the gas preparing for transportation according to our climatic conditions should be minus 5-10°C;
- increase the efficiency of gas-liquid mixture separation;
- an integrated automation system should be implemented in the gas storage facility;

- operation of gas storage facilities should be controlled by an automated control system.

The application of this proposal in the Kalmazskoye UGS facility in the control system and primary gas treatment during seasonal withdrawal will allow achieving the following indicators:

- after drying the gas taken from the underground storage, the DP temperature of gas on humidity will meet all the requirements of the industry standard;
- gas losses due to the formation of hydrates in the system will be excluded;
- liquid phase will be prevented from entering the main gas pipeline;
- the productivity of the transport network will increase, and the technological regime will stabilize;
- pollution at the bottom of the well and in the reservoir will be prevented, therefore, the active volume of gas injected into UGS facilities will increase;
- the cost of transporting gas to the consumer will be significantly reduced, the use of a complex absorbent to prepare gas for transport will eliminate the supply of imported chemicals.

In order to improve the efficiency of the quality indicators of the transported gas in the Garadagh UGS facility: it is proposed to initially build and apply to work gas separation and drying units of a block-complex type using liquid absorbers (glycols).

As a result of the commissioning of the complex gas drying unit at the Garadagh UGS facility, the following results will be achieved:

- gas losses due to hydrate formation in the process system will be completely eliminated;
- the DP temperature of the gas for water vapor, taken from the storage and prepared for transportation, will comply with the standard (minus 15-20°C);
- the ingress of the liquid phase into the main gas pipelines will be prevented and, as a result, the gas pipelines will operate efficiently in full compliance with the technological regime;
- the cost of the gas transportation system will be reduced;

- indicators of the quality of gas intended for consumers and export to foreign countries will comply with international standards;

- the use of an absorbent developed on the basis of local chemicals as an absorbent and an inhibitor of hydrate formation in a gas dehydration unit under construction at the UGS facility will reduce the cost of transported gas;

- liquid hydrocarbons will be additionally separated from the gas taken from the storage.

Studies have shown that an increase in gas volumes can be achieved without additional wells, by restoring the stock of idle wells.

To restore the technological regime of these wells, it is necessary to carry out the following measures:

- to carry out geophysical surveys;
- lift up of tubes;
- wash the filter and treat the bottom of the well with acid;
- master the well and use it to the gas injection process.

Regarding this, the well stock is divided into three categories:

- operating - 17 wells;
- temporarily not working - 9 wells,
- non-operating wells - 11 wells.

To determine the total amount of gas injected into wells, it is necessary to pre-calculate the volume of gas injected into each well.

Calculations were performed in six variants at wellhead pressure - 8.7; 9.5; 10.5; 12.5; 15.0; 18.0 MPa according to the following formulas:

$$P_{qd}^2 - P_l^2 = aQ_q + bQ_q^2;$$

$$Q_q = \frac{-a \pm \sqrt{a^2 + 4b(P_{qd}^2 - P_l^2)}}{2b};$$

$$P_{qd} = P_{qa} e^s; s = 0.03415 = \frac{\bar{p}L}{Z_{or}T_{or}};$$

where P_{qd}, P_{qa}, P_l - bottomhole, wellhead and reservoir pressure, MPa; a, b - filtration resistance coefficients; Q_g - gas consumption, m3/day; ρ - is the relative density of the gas; L - well depth, m; Zor - gas compression ratio when determining P_{qa} at the wellhead using T_{or}, T_{or} = 273+T_{or}

$$T_{or} = \frac{(T_{qd} - T_{qa})}{l} \frac{T_{qd}}{T_{qa}}$$

- average temperature of the wellhead and wellbore zones.

After the implementation of the proposed measures, the data obtained as a result of calculating the volume of gas injected into the wells) make it possible to accurately calculate the volume of gas injected into inactive wells in the Garadagh UGS.

The results of studying the current state of the technology of the "Low-temperature separation" plant, used in the process of preparing gas for transport from the Garadagh gas station, during the periods of seasonal withdrawal in recent years, showed that many technical means have shortcomings, technological parameters are not correctly selected. Basically, these are the following disadvantages:

- there is no device for trapping sand and other mechanical impurities coming from the storage with a gas flow. As a result, the efficiency of the separators is reduced, valves, nozzles and other equipment fail prematurely, and other complications arise in the system.
- gas enters the plant, into the 1st and 2nd separators operating in series at a lower pressure (5.5-7.5) MPa, which does not allow obtaining a low temperature in the process system for separating the liquid phase from the gas phase;
- the removal of the liquid phase from the separators is carried out mechanically, which does not allow to regulate the technological mode of operation of the separators and, as a result, increases the likelihood of large volumes of the liquid mixture entering the main gas pipeline;
- in the technology of the low-temperature separation device, there are no “separation devices” for separating and stabilizing liquid phases from separators. As a result, the mixture of water and condensate released from the gas is mechanically collected from the separators directly in the tanks.
- “dust collectors” must be installed to trap dust, sand and other mechanical mixtures that previously came with the gas flow, meeting modern requirements, taking into account the daily productivity of the installation;

- to increase the efficiency of separation of the liquid phase in the separators of the 2nd and 3rd stages and prevent it from entering the main gas pipelines, it is required to install 2 "separator units" in accordance with the daily amount of liquid separated from the gas;

- apply throttling of the gas entering the unit at the inlet to the 2nd and 3rd separators;

- injection of glycol into the gas flow at the inlet to the "2nd and 3rd stage" separators to prevent hydrate formation in the process system;

- implementing of the corresponding unit for regeneration of the saturated with water vapor glycol solution used in the technology.

The gas taken from the wells enters the gas distribution point (GDP) at a pressure of 12-13 MPa and a temperature of 27-29°C. After adjusting the pressure in GDP, the gas must enter the 1st stage filter-separator under the appropriate pressure and temperature.

In this regard, it is advisable to make the following changes to the technological scheme of the installation operating in the Garadagh UGS (Fig. 18):

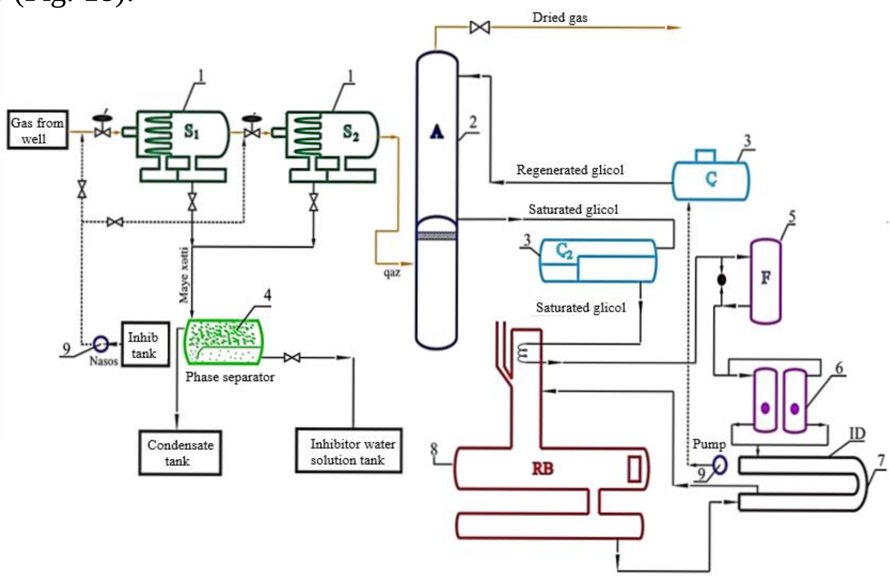

Fig.18. Technological scheme of gas preparation

- minimization of gas pressure when regulating gas pressure at the gas distribution point;

- selection of the absorption-technological regime in the process of seasonal gas withdrawal at the NTS unit, after completion of work to improve the process of preparing gases for transport.

Thus, as a result of the output of the complex installation, built and put into operation of the Garadagh UGS, to the optimal technological mode of operation:

- the liquid phase will be prevented from entering the main gas pipelines, the gas pipelines will operate in a rhythmic mode and with a stable performance;

- quality indicators of gas supplied to consumers will meet the requirements;

- the amount of hydrocarbons in the composition of gas withdrawn from storage in accordance with the technology and the cost of the gas transmission system will be reduced;

- the introduction of the technology will prevent contamination of the reservoir and the bottomhole zone of the well during the injection of gas into the reservoir and will create conditions for increasing the volume of active gas injected into the reservoir.

In order to develop new high-performance technological processes and relevant instructions for the rational use of absorbents to eliminate technical and technological complications in gas dehydration plants at gas condensate fields, were study of the operating modes of the booster compressor station and of the integrated gas treatment unit at the OGPD named after N. Narimanov.

It has been defined that the technology and consumption of absorbents and inhibitors introduced into the gas flow in the process system change due to changes in the thermodynamic parameters of gases depending on the duration of operation of gas condensate fields.

The mode of operation of gas collection and transport units located in the offshore zone of OGPD (Fig.19) (where 1 - is a compressor station; 2 - is a separator; 3 - is an absorber; 4 - is a glycol regeneration unit; 5 - is a mechanical filter; 6 - is a carbon filter; 7 -

tank for fresh glycol; 8 - tank for saturated glycol; 9 - pump; 10,11 - heat exchangers).

The quality indicators of gas compressed at the compressor station No. 2 of the OGPD and supplied to the main were studied. The results of the study of the technological mode of operation of individual devices of gas treatment plants for transport showed that the quality indicators of gas supplied to the pumping system from the outlet of the BCS do not meet the requirements, the formation of hydrate compounds in the gas transportation system is observed.

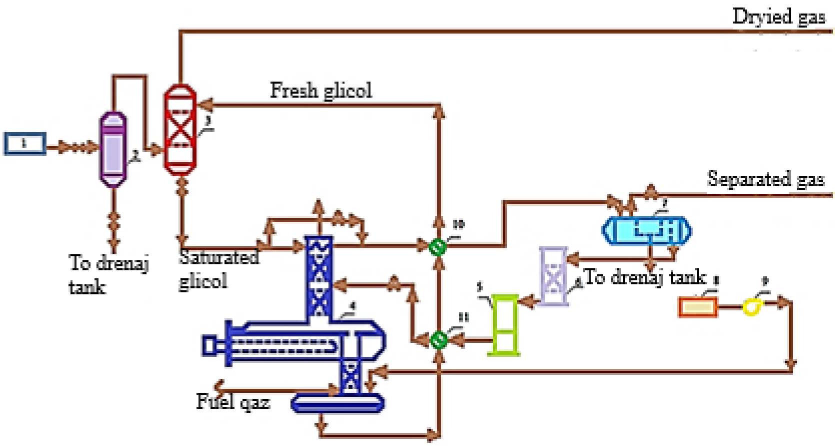

Fig. 19. Unit collection and preparation of gas to transportation

Due to the absence of a regeneration unit for the water solution of the inhibitor introduced into the gas stream, its complete loss and environmental pollution occur.

Regarding this, it was considered expedient to improve the technological process for the use of a new absorbent, it was proposed to build and put into operation a new gas dehydration unit to achieve the required quality level of gas supplied to the transport system from the out of BCS.

CONCLUSIONS

1. Based on the results of numerous laboratory studies, widely application the new absorbent proposed, which allows to return the glycol used in the complete removal of water vapors in the gas drying process to the system and to reuse it, in the preparation of gases for transportation in oil field conditions.

2. As a result of experimental studies, it was determined that the new nanocomposite inhibitor reduces the temperature of hydrate formation by 15-20% and metal corrosion by 2-3 times compared to methanol.

3. A non-toxic and ecologically clean multifunctional composition against hydrate formation and corrosion of the inner surface of metal pipes was developed and applied based on bed clays of the Absheron peninsula.

4. The determination error of chromatographic measurement of polypropylene glycol in gas is 3.1% to 18.2% for the mole fraction range of 0.001% to 0.05%, that does not exceed the measurement uncertainty of existing gas chromatography methods of determination quantity of components in natural gas or in the other gaseous environment.

5. The combined effect of a fixed magnetic field and an inhibitor on the freezing and hydrate formation temperatures of formation water by using an improved magnetic activator device was studied. As a result, it was determined that the temperature of formation water freezing and hydrate formation changes from 269ºK to 258ºK during joint action.

6. The effect of the new multifunctional composition developed on the basis of sodium sulfonate and dimethylethanolamine on the corrosion rate in aggressive environments with carbon dioxide, hydrogen sulfide and sulfate-reducing bacteria separately and together was studied, and effective results were obtained by reducing the corrosion rate to a minimum at the optimal consumption rate.

7. As a result of the study of the effect of the inhibitor contained in bitumen-polymer-based, modified mastics and the method of metal surface treatment on the resistance of the insulation coating to separation, it was determined that the application of ammonium class

and ammonium salt inhibitors in the main mastic, the resistance to separation of modified mastics increased by more than 11%. , increases up to 22% when the metal surface is treated with sandblasting, and at a certain concentration the retardation efficiency of SRE propagation was 93.8% and 97.7% .

8. By improving the internal elements of the separators and installing two-stage separator devices in the technology, as well as by creating a foam system based on various reagents and supplying it to the gas line, the efficient transportation of low and high-pressure gases received from the deep-sea foundations of the "Gunashli" field to the CS was achieved.

9. Based on the analysis of the experimental results, it was determined that with the presence of a new adsorbent containing polypropylene glycol oligomers, it is possible to effectively carry out the process of preparing natural gas for transportation by drying it according to industrial standards.

10. A new insulating coating has been developed for corrosion protection of the external surfaces of the equipment used in the gas gathering and preparation process at the Gunashli field platform, and it has been determined to have high protective properties during testing in laboratory conditions.

11. Based on numerous analyzes conducted, it was recommended to consider the loss of the reagent in contact with the gas, dissolution in liquid hydrocarbons, mechanical loss in the gas flow, and losses in separate technological lines for the annual calculation of the optimal consumption of the reagent, that injects into the gas flow during gas preparation for transportation.

12. To increase the active volume of gas injected into the Galmaz and Garadagh UGS and to improve the quality of the extracted gas, based on the analysis of the existing technologies of gas preparation for transport, the thermodynamic parameters of all wells and field equipment, the optimal thermodynamic and the technological operating mode of the equipment during gas taking from UGS was selected.

13. Based on the analysis of the results of the conducted research and test work, a new improved cyclone separator with economic efficiency was proposed.

14. The application of new technical proposals developed because of the analysis and research of the current condition, technological and thermodynamic parameters of the Garadagh UGS wells and field equipment allows to accurately calculate the volume of gas injected into non-working wells at the Garadagh UGS and to reliable predict the repair and restoration works to be carried out in the wells.

The main content of the dissertation has been reflected in the following works:

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Personal contribution of the applicant:

Works [1-3, 6, 7, 9, 11-13, 15, 18-20, 23-27, 33-35, 39, 44, 48, 54] - performed independently.

Works [4, 5, 8, 14, 19] - statement of the problem, data collecting, analysis of results and analytical review, selecting of analogues, prototypes.

Works [10, 16-17, 21] - data collecting, analysis, verification of test results, solution of technical tasks.

Works [22, 28, 29] - data collecting, analysis and processing of results.

Works [30, 40, 41] - conducting analytical review and reports, setting the problem.

Work [31] - data collecting, analytical review.

Work [32] - problem statement, data collecting, analysis.

Work [41, 43, 49] - data collection, report, and analysis contucting.

Works [36, 38, 45, 46] - statement of the problem, data collection, analytical review, selecting of the optimal technological mode of operation.

Works [47, 50-52] - statement of the problem, collecting of data and results, reporting and analytical review.

Works [53, 55, 56] – raise the issue, conducting analytical analyzes and analyzing the results.

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