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ENERGY EFFİCİENCY,RECOURCE SAVİNG METHODS AND TECHNOLOGİES OF HYDROCARBONS TRANSPORTATİON AND STORAGE

Speciality: **3354.01 - «**Construction and exploitation of oil and gas pipelines, bases and storages**»**

Field of science: Technical sciences

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ABSTRACT

of the dissertation for the degree of Doctor of Science

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General features of dissertation

The relevance of the theme and the degree of development. Commissioning of high performance fields in the Caspian Sea since the signing of the "Contract of the Century" has helped Azerbaijan develop more rapidly by demonstrating the increasing energy potential. At the opening ceremony of the XXII International Caspian Oil and Gas 2015 exhibition, the "Contract of the Century" was the contract of the 20th century, the President of the Republic of Azerbaijan, Mr. Ilham Aliyev successfully continuing the domestic and foreign policy of the Great Leader. Today we are already implementing the contract of the 21st century. "The Southern Gas Corridor is a 21st Century Contract, and the treaty signed in 1994, its subsequent success made it possible today" this following statement is a visual proof of Azerbaijan's new oil strategy is being implemented at a higher level.

Measures implemented in the late 1990s, commissioning of Baku-Tbilisi-Ceyhan and Baku-Tbilisi-Erzurum oil pipelines in the early 2000s; The implementation of projects for the development of Shah Deniz gas, Azeri-Chırag oil, Umid gas and condensate fields has made Azerbaijan a reliable partner in international energy projects.In 2012, Turkey and Azerbaijan signed a TANAP pipeline contract, the Trans Adriatic Pipeline was selected as the main export route to Europe and the South Gas Corridor was launched. The Shah Deniz-2 project has been launched. The gas from Shah Deniz-2 is transported to Georgia and Turkey. Azerbaijan, Georgia, Turkey, Greece, Bulgaria, Albania and Italy are members of the Southern Gas Corridor, while a number of Balkan countries have also signed a Memorandum of Understanding. With the timely implementation of the TAP project, Azerbaijani gas will be transported to Europe. If we take into account, the approved gas reserves of Azerbaijan (2.6 trillion m^3 according to the latest information) are not the final goal (in many fields, evaluation studies are continuing, in some fields, intelligence studies are carried out), then resources are expected to increase further. Therefore, the diversification of routes, the reliability of the hydrocarbon resources transportation and storage complex is one of the main conditions for ensuring energy security.

Accidents occurring in the storage and transportation system resulting from the complexities arising from their physico-chemical and rheological properties during transportation and storage of hydrocarbons, along with loss of valuable raw materials ,also affect the ecological state of environment. The elimination of the consequences of accidents and environmental damage, and restoration of the normal functioning of the transportation system will require additional financial resources. Thus, both hydrocarbon losses and environmental pollution occur , and the cost increases due to additional financial resources. On the other hand, the imbalance in the amount of products transported as a result of problems with the control and measurement system due to losses results in breach of contractual obligations in the "producer" "consumer" relationships.

The analysis shows that in many cases , the difficulties and complications that occur during the gathering ,processing and storage of hydrocarbons are due to their multicomponent and multiphased structure as well as their stucture. During transportation of multiphase hydrocarbon mixtures in pipelines (gas separation from oil, condensate (liquid) drop from gas, formation of the 3rd solid phase - paraffin, hydrate sediments due to structural changes) occur phase transformations and anomalous rehydration water and oil water emulsion processes. The emerging heterogeneous gas liquid mixtures have a very significant impact on the operation of hydrocarbon gathering, transportation and storage systems, in addition to non-additively differentiation from the primary components due to their rheological and physical and chemical properties.Thus, there is an increased likelihood of an increase in energy costs as well as accidents. All of this, as mentioned above, is of great practical importance and relevance as it is closely linked to hydrocarbon losses and environmental issues.

The purpose of the research. Development of energy efficient, resource saving methods and technologies to improve the efficiency of technological processes during the gathering, transport and storage of hydrocarbons.

The main objectives of the research are:

- Analysis of ways to calculate and reduce the losses during the transportation and storage of hydrocarbons, including the losses from phase transformation;
- Analysis of subsea gas transportation technology;
- Application of synergistic composite systems against hydration and corrosion in gas pipelines;
- Assessment of hydrocarbon leaks from vertical pipes of subsea pipelines;
- Development of a flow apparatus class for extracting liquid from gas pipelines;
- Investigation of hydrodynamic corrosion problems in multiphase gas pipelines;
- Determination of the degree of water cutting of hydrocarbon mixture;
- Development of improved method of hydraulic calculation of gas pipelines for gas-condensate mixtures;
- Cluster analysis of gas pipeline operation indicators;
- Diagnostics of changes in gas pipeline operation modes based on artificial neuron technologies;
- Development of methods of diagnostics of internal condition of gas pipelines;
- Diagnostics of structural changes in the transport of gas mixtures;
- Development of the method of diagnostics of the hydraulic characteristics of multiphase pipelines;
- Development of the method of regulation of pressure pulse in multiphase flows;
- Analysis of gas transport and storage system operation based on an electrical anology.

Research methods. The solutions of problems presented in the dissertation were made by using theoretical and practical methods, real-time data processing, mathematical-statistical, standard laboratory equipment, computer and software tools in the gathering, transport and storage of hydrocarbons.

Scientific novelties of the research:

- Development of the method of determining the gas pipeline operation indicators and internal conditions for gas pipelines according to the composition of the gas;
- Development of a method for controlling the quality of the thermal protection layer of gas pipelines based on cluster analysis;
- Development of innovative technologies for efficient gathering and transportation of gas condensate mixtures;
- Development of hydrodynamic regulation of corrosion-erosion processes in multiphase gathering-transport pipelines;
- Development of control methods of gas pipelines based on artificial neuron technologies;
- Development of methods of diagnostics of stable and unstable zones in the hydraulic characteristics of multiphase pipes.

Key provisions to be protected:

- Methods of diagnostics of internal condition of gas pipelines;
- Innovative technology for transportation of gas-condensate mixtures;
- Method of hydrodynamic control of corrosion-erosion processes in multiphase pipelines;
- Methods of diagnostics of unstable flow rate characteristics in multiphase flows.

Theoretical and practical significance of the research. The dissertation is of practical importance for developing control and diagnostics and troubleshooting methods based on operating data in order to reduce the loss of hydrocarbon during transportation and storage of gases, to increase the reliability and efficiency of the transportation system. The methods proposed in the work can be used extensively in the design and operation of assembling and technological and main gas pipelines by research and design institutes and industrial enterprises. The developed methods will allow to determine the change of gas pipeline internal status and gas leakage regardless of the mode of flow and promptly eliminate any complications.

Approbation and utilization of research outcomes in dissertation. The main provisions of the dissertation were reported and discussed: At the meetings of the Department of "Oil and Gas Transportation and Storage" at ASOIU; International scientific-practical conference "Caspian oil and gas-2016" (Baku, 2016); Conference "Actual problems of the development of offshore oil and gas fields", dedicated to the 100th anniversary of Israfil Guliyev (Baku, 2017) V International Scientific and Technical Conference "Geology and Hydrocarbon Potential of the Balkans-Chernomorskaya Region" (Varna, Bulgaria, 2017); Russian Scientific and Technical Conference "Problems of Geological, Developement and Exploitation of Fields and Transportation of hard-to-recover hydrocarbon reserves" (Ukhta, Russia, 2017); International scientific-practical conference "Problems and prospects of development of oil and gas deposits" (Almetevsk, Russia, 2017) at the International Conference "Rassokhinskoe chtenie"(Ukhta, Russia, 2018); Academician A.Kh. At the International Conference "Modern Problems of Innovative echnologies in oil and gas production applied mathematics", dedicated to the 90th anniversary of Mirzazhanzadeh (Baku, 2018); At the IX International Scientific and Technical Conference "Reliability and Safety of main Pipeline Transportation" (Novopolotsk, Belarus, 2018); Scientific Conference "Nagiyev's Readings", dedicated to the 110th anniversary of the academician M. Nagiyev (Baku, 2018); International Scientific and Practical Conference "State and Prospects of exploration of mature deposits", dedicated to the 5th anniversary of KazNIPmunaygas (Aktau, Kazakhstan, 2019); At the International Conference "Rassokhinskoe chtenie" (Uhta, Russia, 2019); 10th International

Conference on Theory and Application of Soft Computing, Computing with Words and Perceptions (Prague, Czech Republic, 2019);

The new methods and technologies that were noted in the dissertation were applied in the Gas Export Department of State Oil Company Azerbaijan Republic (SOCAR) and "Umid Babek Operating Company" and relevant acts and references were obtained.

Publication of the dissertation. 53 scientific works on dissertation, including 2 monographs, 1 patent, 1 methodical manual, 54 articles and 1 thesis were published.

The structure and scope of the dissertation. The dissertation consists of an introduction, five chapters, conclusion, references used in 215 titles and a total of 368270 characters, including 59 figures, 29 tables and appendices.

The content of the dissertation

The introduction is based on the relevance of the work, the purpose and the key issues that have been addressed, its scientific novelty, practical significance and the defended provisions are justified, and the content of the dissertation is briefly presented. The current state of scientific research on the issues raised in the dissertation is deeply analyzed.For this purpose scientific research work carried out by prominent academicians A.Kh.Mirzajande, M.T. Abbasov, H.B.Yusifzade,well-known scientists A.B.Suleymanov, E.E.Ramazanova, R.S.Gurbanov, R.M.Sattarov, G.G.Ismayilov, T.Sh.Salavatov, A.R.Sadikhzade, Z.Y.Abbasov, V.D.Aslanov, G.I.Jalalov, A.M.Guliyev, R.A.Aliyev B.A.Suleymanov, F.S.Ismayilov, T.M.Mammadov, T.A.Samadov, G.M.Panahov, S.R.Rasulov ,N.B.Agaev and others, as well as foreign scientists N.M.Baykov, A.P. Babenko, K.S.Basniyev, T.M.Bekirov, E.B.Bukhalter, P.P.Borodavkin, A.I.Grichenko, O.V.Klapchuk, A.I.Gujov, Y.P.Karatayev, G.S.Lutoshkin, V.A.Mamayev, M.V.Lurye, A.L.Novikov, B.V.Pustovit, N.A.Svarovskaya, A.M.Shammazov, M.M.Khasanov, P.N.Bakhtizin, V.T.Sitenkov, D.Chisholm and others' works were used.

The first chapter of the dissertation covers the analysis of ways to assess and reduce the loss of hydrocarbon (including due to leaks and phase transformations) during the gathering, transportation and storage of oil and gas.

Sources of technological losses of oil and gas are indicated, classification of losses by sources and objects is given,and it was noted that the losses were due to the lack of modern equipment and technology used in the processes of gathering, processing and storage of gas. Due to the unsatisfactory operation of these devices and equipment, a large amount of liquid phase (hydrocarbon condensate and water) remains in the processed gas and is transferred to the transportation system along with the gas. As a result of thermobaric effects of the environment during transport,with the changes in the thermodynamic parametrs of the gas and the process of condensation of hydrocarbon condensate and water vapor into a liquid, ie phase transformation ,as a result of which changes the density of the gas and the composition of the component. This, in turn, creates an imbalance between the amount of gas delivered and received. The amount of gas losses in transportation systems due to phase transformation varies depending on the seasons.

On the other hand, under certain thermobaric conditions, retrograde events may also occur, such as "reverse condensation" and "reverse vaporization". Vaporization can occur when the pressure increases, and condensation can occur when the pressure decreases. As the composition of the products produced during depletion of the fields is continuously changed, the maximum condensation pressure set at the beginning of the development may not be sufficient for the further period. At the same time, the lower temperature of the gas enriches it with water vapor and heavy hydrocarbons. Taking into account that the main condition for condensation of liquid vapor in the gas depends on the degree of saturation of the gas with steam, the change of pressure and temperature during transportation is important.

Since the phase transformation due to pressure and temperature changes during transportation were observed with hydrocarbon losses, for assessing these losses, gas “losses” were assessed on the basis of physical and chemical analysis of gas samples taken from high and low pressure gas pipelines. It has been found that gas “losses” and the amount of sediment are greater at higher pressures. It has been determined that gas “losses” and the amount of sediment are greater at high pressure values (Figure 1).

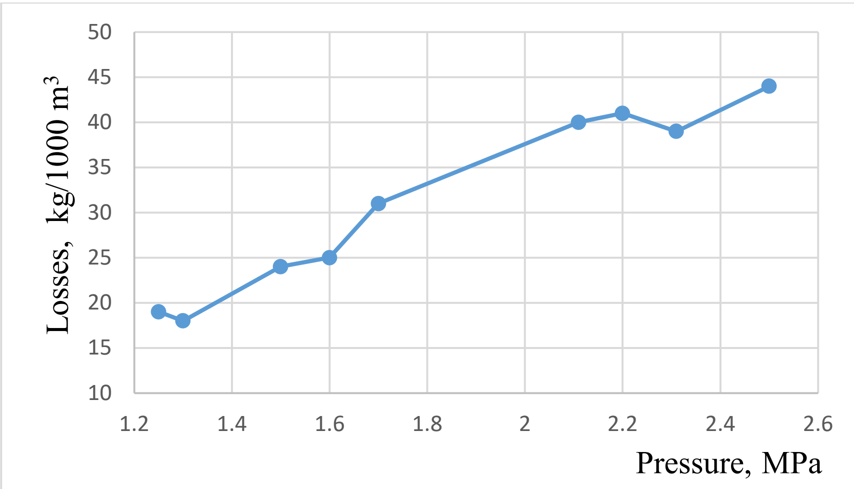


Figure 1. Dependence of gas losses on Pressure

Based on the results of experiments and calculations, it was determined that gas loss occurs due to condensation of hydrocarbons in the pipeline as the pressure declines along the route during gas transportation, and these losses are greater at the beginning of the pipeline, at high pressure. The deposition of mechanical particles in the gas also occurs almost in accordance with the deposition of the liquid phase.

Timely detection and elimination of leaks during the operation of subsea oil and gas pipelines have specific features. Operating experience has shown that the most common accidents are at the junction of vertical pipes and the linear part of the pipeline. First of all, the cases (times) of the liquid flowing from the hole formed at the junction at the wellhead ($H_{w.h.}$) and the depth of the sea (H_d) under the difference of constant pressures and variable (decreasing) pressures were evaluated. In both cases, calculations were made based on the following mathematical expressions to determine the discharge times (t and t_1) vertical pipe, respectively, and it was determined that the hydrocarbon losses for pressurized flow in case of small leaks increase by about 2 times compared to free flows with increasing wellhead pressure at constant sea depth. It has a maximum value of 0 at depth of the sea.

$$t = \frac{2D^2}{d^2\mu \cdot \sqrt{2g}}\left(\sqrt{H_{wh}} - \sqrt{H_d}\right) \qquad (1)$$

$$t_1 = \frac{V}{Q_{leak.}} = \frac{D^2}{d^2} \cdot \frac{1}{\mu\sqrt{2g}} \cdot \left(\frac{H_{wh} - H_d}{\sqrt{H_{wh}}}\right) \qquad (2)$$

Here: μ - consumption factor; d-is the diameter of the leakage; D-is the diameter of the vertical pipe.

In order to reduce hydrocarbon losses during gas gathering, transportation and storage, first of all, it is important to develop and apply new, innovative methods and technologies, as well as to develop a normative document-field standard regulating natural gas quality indicators. It was noted that it is important to bring the quality of transported gas in both gas and condensate fields and underground gas storage facilities in line with the requirements of the field standard, as well as to organize work on the normalization of gas technological losses.

The second chapter presents the results of research on the development of efficient methods and technologies for the gathering and transportation of gases in the sea conditions.

As it is known, the development of hydrocarbon deposits in the Azerbaijani sector of the Caspian Sea is carried out mainly through offshore wells and subsea pipelines transporting multiphase well products. As a part of subsea oil and gas pipelines constructed in connection with the developement of offshore fields in vertical pipes there are forms of movement from veritcal top down and bottom top.

Liquid particles in oil and gas (water, condensate) accumulate in the depressions of the pipeline on the one hand, reduce the cross sectional area, reduce the capacity of the pipeline induction, and on the other hand cause corrosion of metal pipes and equipment. Most of the serious problems are closely related to the change of thermodynamic conditions, as well as the multiphase of flows during the gathering and transportation of well products. Intensive cooling, throttling, phasing of the product transported in the marine environment, as well as various structural forms of movement, depending on the direction of flow, significantly affect the efficiency of the pipeline. However, in many cases, for objective reasons, well products are transported from one foundation to another or to the shore under subsea collection lines under wellhead pressure without undergoing a preparation phase. In this case, the main difficulty and energy (pressure) losses occur in the flows corresponding to the shape of the liquid gas mixture (oil gas water, gas condensate, etc.) divided into layers (phases), mainly in the horizontal and shield parts of the route relief and this results in increased fluid accumulation and pressure loss in these areas.

The location of offshore fields away from the mainland, high environmental humidity, limited area on stationary foundations, difficulties in the installation of equipment and pipelines are characteristic features of offshore gas transportation systems. The uninterrupted and safe supply of produced gas to the main gas pipelines and then to consumers depends on the correct choice of gas processing and transportation technologies. This chapter of the dissertation also provides a comparative analysis of the technologies applied in this field of oil and gas production in the international arena and in our country in order to eliminate the problems and difficulties encountered during the gathering and processing of gases. It is not possible to solve all the issues required to gather and prepare gas in the fields in accordance with the requirements of existing regulations, as well as to determine the actual ratio of liquid and gas phases, as the principles of oil preparation are adopted when selecting the technology of well production at the initial stage of field development. The reasons for this situation are as follows:

- non construction of fields on a complex project;
- expansion of gas gathering and processing systems with the commissioning of new fields;
- lack of technical and technological capabilities to measure well products on individual wells;
- joint implementation of gas condensate well gathering and processing in most cases.

Section 2 of the second chapter contains materials related to the development and application of a synergistic composite system for the protection of mining gas pipelines from hydrate formation and corrosion. A complex composite inhibitor designed to combat both hydrate formation and disintegration erosion by the same operation was applied during the gathering of gas for transformation at the department of OGP named after H.Z. Tagiyev .The results of research on transmission lines have shown that the new composition inhibitor is not only an effective gas dryer, but also allows to limit erosion disintegration of metal pipes. Thus, as a result of the application of a composite inhibitor based on local products, can be carried out the process of drying the gas from water vapor and cleaning it from harmful components.

Due to the presence of a liquid phase in the transported gas, as well as phase transformations that occur with changes in pressure and temperature, lead to a number of technological complications in the pipeline. In this case, the capacity of gas pipelines is reduced and fertile conditions are created for the formation of hydrates in the pipeline. This leads to internal corrosion of the pipelines, malfunction of control and measuring devices and significant hydrocarbon losses.

Researches show that the precipitation of the liquid in the gas occurs mainly due to gas-dynamic reasons. Thus, in this case, the liquid entering the separator is subjected to a rotational motion, and as it moves away from the inlet, a radial fluid flow is formed and then enters the transport lines together with the separated gas.

The composition of the liquid entering the pipeline during the transportation of gas can, in a sense, characterize how it is formed. Thus, if the composition of the liquid in the separator is the same as the composition of the liquid collected in the pipe, then the fall of the liquid into the gas line can be explained by its mechanical expulsion from the separator. If the composition of the fluid in the pipeline consists only of light fractions and condensing water, then the flow of fluid into the line must be explained by another reason, ie thermodynamic reasons. However, it should be noted that fluid leakage into the pipeline may be due to one or both of these reasons.

The occurrence of a retrograde event during the transport and separation of gas under high pressure (P>6 MPa) can also be attributed to the second thermodynamic cause of the accumulation of the liquid phase in the pipeline. The retrograde feature is characteristic of multi-component hydrocarbon mixtures in gas reservoirs, gas pipelines and reservoir systems at high pressures.

It is possible to ensure the efficient operation of gas collection and transportation systems by continuously removing liquids from the pipelines without interfering with the operation of transportation systems with the help of pipe type design for the extraction of liquids from gas pipelines. This also reduces hydrocarbon losses. In addition, the cost of the proposed unit is significantly lower than the cost of existing gas preparation devices with the same capacity.

It is important to create sufficient gas reserves in underground gas storage facilities to ensure uninterrupted and stable operation of transport systems. In the underground gas storage, the gas storage mode corresponding to the maximum value of the reservoir pressure is achieved by means of compressors. Therefore, increasing the efficiency of the gas storage process depends on the construction of new compressor stations and the efficient use of existing compressor stations.

One of the main indicators of the efficiency of gas injection and gas extraction processes in underground gas storage facilities is the appropriate and correct selection of the initial parameters of the system in real conditions.

Due to the season, gas supply to both industry and utilities is uneven, which is mainly due to climate change in different seasons. In the context of seasonal inequality in the distribution of natural gas in the fuel and energy complex, increasing the efficiency of gas injection and extraction processes depends more on ensuring the stability of active gas volumes in gas storage facilities.

As noted, in addition to the creation of new stations, the efficient use of existing compressor stations is of great practical importance in modern times, when the demand for natural gas, which is a strategic fuel, has grown significantly. However, the difficulty of measuring the productivity of each gas compressor (GMC) operating separately at compressor stations makes it difficult to control the operation of individual GMCs and the compressor station as a whole.

In addition, the closure (coordination) of the entrances to the compressors, as well as the compressor station as a whole, has a significant impact on their productivity. The associated gas supplied to the compressor station inlet is distributed in series with a single collector.Analysis of the pressure data shows that the leading GMCs in the suction lines of the GMCs receive additional pressure from their consumption characteristics, and the pressure exerted by the GMCs located at the end of this line is not sufficient for their normal operation.Accordingly, if the previous GMC is already working with overload, the latter cannot work at full capacity. Such conditions adversely affect the operation of the compressor station as a whole.

An electrical analogy was used in the study to quantify the effect of sequential and parallel gas supply schemes on the compressor station on the efficiency of each injection unit and the compressor station in general. For this purpose, the following energy equation was used for the steady flow of gas:

$$P_1^2 - P_2^2 = K\frac{L}{D^5}Q_{g.st.}^2 \quad (3)$$

Here:

$$K = \left(\frac{4P_{st.}}{\pi T_{st.}}\right)^2 \cdot \frac{M}{R}\,\lambda_{av.}\,T_{av.}\,Z_{av.} \quad (4)$$

Pst. and *Tst,* pressure and temperature under standard conditions, respectively; *M* is the molecular mass of the gas; *L and D* length and diameter of the pipeline; *Qg.st.*. gas consumption under standard conditions.

According to Kirchhoff's laws 1 and 2, the following identifications are applied to model (3):

- Pressure (P) by voltage (U):
- Square of gas consumption (Q^2) with energy power(J);
- hydraulic resistance of the gas line ($K\frac{L}{D^5}$) with the electrical resistance of the (R);
- The square of the pressure difference ($P_1^2 - P_2^2$)between the inputs and outputs of the GMCs with electiric energy

On the basis of the electrical analogy, the supply of gas to the new, ie parallel scheme, was investigated and the cost of consumption was calculated. The results of the calculations show that the productivity of the GMCs is approximately the same. The effect of the gas supply scheme on the efficiency of the compressors is shown in Figure 2.

Thus, the operation of the compressor station was analyzed on the basis of electrical analogy, taking into account the gas supply scheme, the efficiency of each pumping unit entering the compressor station was determined.It was found that the supply of gas to the inlet of the compressors according to the proposed parallel scheme allows both equal distribution of gas on the GMCs and increases their efficiency. This also has a significant impact on the productivity of gas filler aggregate.

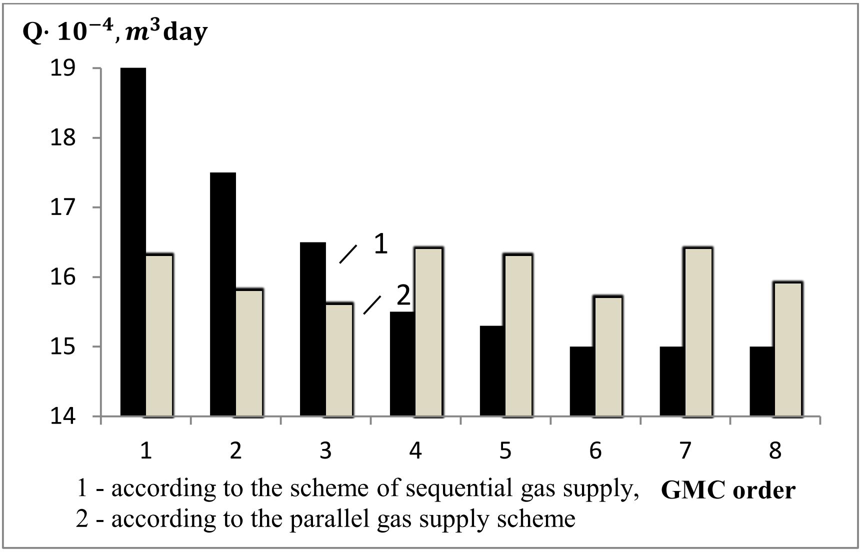


Figure 2. Impact of gas supply on GMC productivity

The third chapter deals with the development of innovative methods for diagnosing and eliminating technological difficulties and complications in the process of transportation and storage of hydrocarbons. The main operational difficulties in crude oil accumulation and transportation systems (paraffin and salt deposition, leakage, mechanical mixing and air accumulation, cavitation, deterioration of rheological properties of oils due to irrigation and mixing factors) were analyzed and evaluated.

Recent years researches show that the factor of water cut of oils also creates significant difficulties in the collection and transportation system and increases energy costs. Due to the deterioration of the rheological properties of water cut of oils in the autumn and winter months, when the temperature is low, transportation may even stop. The collection and transportation of high-viscosity, abnormal oil emulsions are associated with additional costs.

In order to study the effect of the degree of water cut of oils on the component composition of the soluble gas under static conditions, the change in the component composition of the dissolved gas at different pressures in water-liquid hydrocarbon systems with different volume ratios was studied. Based on the analysis of the results of laboratory tests by the method of expert assessment, it was determined that there is an effect of the degree of water cut on the composition of the gas, and this effect occurs with regularity. This, in turn, allows you to diagnose the degree of water cut of oil according to the dynamics of changes in the composition of the gas.

The study examines the effect of changes in the volume ratios of water and oil on the composition of the gas component through experimental tests. The experiments were carried out by filling a container with a volume of liquid (10^{-4}м^3) with a volume of $2 \cdot 10^{-3}$ m^3, as well as at different stages that characterize the volume ratios of water and oil. The dodecane ($C_{12}H_{26}$) was chosen as the oil model. In this case, 4 experiments were performed in which the ratio of water volume to oil volume was changed and the water cut rate β_{water} = 0; 30; 50; 70% was obtained.In all tests, the starting pressure of the system was 12,8 MPa.

The tests used natural gas with the following composition as the gas phase: (% mol) : C_1 *– 95,57;* C_2 *– 2,75;* C_3 *– 0,75;* C_{i4} *– 0,13;* C_{n4} *– 0,22;* C_{i5} *– 0,09;* C_{n5} *– 0,08;* C_6 *– 0,07;* C_7 *– 0,02* and CO_2 *– 0,32.* The mixture, prepared to ensure the equilibrium state of the gas-water-oil system in the container, was stored for one day at a "gas cap" pressure equal to the initial pressure. As the pressure dropped, a gas sample was taken at the outlet of the container at its values of 12,0; 10,5; 9,0; 7,5; 6,0 MPa. The analysis of the gas samples taken showed that the change in the oil water cut leads to a significant change in the amount of individual components of the extracted gas.

A diagnostic method based on changing the component composition of the dissolved gas has been developed to diagnose the degree of water cut of gaseous oils. Based on the analysis of the results obtained during laboratory tests on changes in the composition of the gas by the method of expert assessment, it was determined that the effect of the degree of water cut on the composition of the gas occurs with regularity. It was determined that the classification function developed on the basis of the component composition of the gas phase increases with increasing amount of water phase.(table 1)

Table 1

Changing of ranks depending on water cut and pressure

Water cut, %	Pressure, MPa				
	12,0	10,5	9,0	7,5	6,0
	Rank (R)				
0	17	17	17	17	16
30	19	20	18	19	22
50	24	24	22	22	27
70	25	25	26	26	29

As it is a field of transportation and marketing, the main problem of the gas industry is not the deficit of gas reserves and production, but mainly the shortcomings in the transportation of natural gas to consumers. For the efficient operation of the transportation system, the gases must be dried in the field through a preparatory stage in accordince with quality, technical conditions, and cleaned of heavy hydrocarbons and aggressive components. The technology of preparation of gases for transportation must also ensure the use of hydrocarbon condensate, which is a valuable raw material, as a commodity product and the monophasic transportation of gas. The analysis shows that the main reason for the decrease in the capacity of the pipelines induction, technological difficulties during operation and the resulting increase in energy costs is the multiphase of the gases to be transported, in other words, the imperfection of their preparation processes. Suffice it to say that the induction capacity of the pipeline can be reduced by more than 15% due to condensate and water condensation from the gas inside the pipeline. The requirements for the quality of transported gas were applied in the gas industry of the former Soviet Union in the 1960s and have been gradually improved. These standards are based on the formation of hydrate along the pipeline, taking into account the maximum value of the initial and final pressure in the gas pipeline. In addition, the determination of the drying depth of the gas is closely related not only to the temperature regime along the pipeline, but also to the initial pressure, length, diameter, speed, hydraulic losses, and most importantly, the throttling of the gas.

Extraction, accumulation, preparation and transportation of hydrocarbon gases is based on the movement of multiphase mixtures of natural and associated gases, produced water and mechanical particles, which includes the processes related to lifting the product from the deposit to the surface, directing it to the separation points , cleaning and transportation within the field. Mining problems related to multi phase gases can include the failure of individual facilities, process pipelines, loss of valuable raw materials, environmental pollution and the use of additional financial resources to eliminate the consequences of accidents during their accumulation, preparation and transportation.

Various sediments accumulate on the inner surface of gas pipelines operating in complex conditions (pressure and temperature changes, corrosion, vibration, etc.) depending on the relief and worsen the performance of the transport system.

Occurrence of blockages of gas pipelines during operation is usually due to the following reasons:

- freezing of the collected water in the pipeline;
- deposition of condensate as a result of phase transformation during transportation;

- formation of hydrate deposits.

Due to the multiphase nature of the transported product, in other words, the presence of gas and liquid particles in the mixture regularly causes fluid blockages and pressure pulses on the inner surface of the pipeline. These features necessitate the development of new diagnostic methods and technologies to increase the efficiency of technological processes based on the analysis of actual operational data in order to eliminate technological complexities and difficulties, taking into account the different characteristics of gas gathering, preparation and transportation processes. Based on the analysis of operational data, it was determined that in addition to regular monitoring of transport parameters, scientifically substantiated analysis of gas quality indicators and component composition dynamics along the length of the gas pipeline (including inlet and outlet) allows for better quality control of the pipeline.Evidence of this is the discovery of the difference between the components of the gas samples taken at the beginning and end of the liquid phase collapse of gas pipelines. Thus, the presence of a liquid phase in the transported gas, as well as phase transformations due to changes in flow pressure and temperature, lead to technological complications in the pipeline. As a result, the productivity of the pipeline is significantly reduced, conditions for hydrate formation and internal corrosion occur in the pipes, the operation of control and measuring devices is disrupted and significant hydrocarbon losses occur. In this study, gas dynamics and thermodynamic causes were investigated as the causes of the liquid phase falling on the gas transmission lines As it is known, unequal consumption of natural gas makes it necessary to store it. Thus, the demand for natural gas decreases in summer and the "excess" gas is pumped into storage and supplied to consumers in winter.

As it is known, unequal consumption of natural gas makes it necessary to store it. Thus, the demand for natural gas decreases in summer and the "excess" gas is pumped into storage and supplied to consumers in winter. In the world practice, underground gas storages

(UGS) are widely used for gas storage. Due to the high growth of gas production in our country, the issues of increasing the efficiency of transportation systems, storage and operation of gas in underground storage facilities (UGS) are of great importance. It is known that gas storage facilities are of great importance for the uninterrupted supply of gas to the population and industrial enterprises. Currently, underground gas storages such as Garadagh and Kalmaz operate in our country. It is known that technological difficulties and gas losses occur in the operating gas pipelines due to the injection and removal of various amounts of gas into the storage. The pressure associated with the injection and removal of gas into the reservoir varies between the maximum and minimum values. Such changes (depression and repression) create tension in the downhole zone and allow it to collapse intensively. Therefore, during the extraction of gas from underground storages, sand is intensively removed from the wells. The analysis shows that the extraction of gas from the Garadagh and Kalmaz under ground gas storage is accompanied by the release of sand, which is further increased by increasing water cut and decreasing reservoir pressure. Despite the existence of a large number of technical means (filters) and technological processes against the manifestations of sand, their widespread application has not been possible. It is recommended to use newly constructed GAQS 94 type well filters to prevent sand from entering the borehole from the reservoir. The use of this type of filter allows to prevent the collapse of the formation structure around the bottom of the well, to thoroughly filter the gas from the formation to the bottom of the well by creating a layer of gravel in the space behind the production line. These filters can be installed at the bottom of the well without hitting the back of the filter, as well as with gravel. If colmatation occurs in the gravel layer, the yield of the well is reduced, and it is possible to wash the gravel layer by injecting condensate and solvent through the pipes, as well as to clean it without siltation.

The technological condition of the gas pipelines was investigated based on the operational data. It is well known that in the 70s and 80s of the last century, academician A.Kh Mirzajanzadeh and his students developed methods for controlling and diagnosing technological processes in oil and gas production (formation mode, field type, water cut of wells etc.).

Timely and accurate assessment of the technological condition of gas pipelines for reliable and safe operation is also very beneficial in terms of reducing hydrocarbon losses. The analysis showed that in addition to controlling the transport parameters, it is possible to increase the effectiveness of quality and operational control over the operation of the gas pipeline on the basis of constant monitoring of gas quality indicators and composition. In other words, how the composition and properties of the gas change along the pipeline can be used as a source of information. It has been established that the composition of the transported gas can be a tool for predicting the formation of water and liquid hydrocarbons in the pipeline. The discovery of a significant difference between the components of the gas at the beginning and end of the gas pipeline confirms the above said. Parameters such as C_{5+}, humidity, amount of mechanical mixture, dryness of the gas – C_1/C_{2+} , dew point and even the need to use it as an indicator have been identified.

One of the most common operational difficulties in the transportation of natural gas, as well as associated oil gases, is the separation of the liquid phase in the pipelines, such as water and condensate, regardless of whether they have completed the preparatory phase. It should be noted that a new cycle of accumulation can occur after the removal of the liquid phase. Thus, in some cases, fluid circulation occurs in the shielded parts of the pipes. As the gas lifts it up, it separates again as soon as the equilibrium is disturbed, and thus the liquid settles again. The oncoming gas again carries the liquid or part of it along the stream or lifts it up. This recycling process increases the energy costs of transporting gas. Therefore, the transportation of gases and their various mixtures requires a proper assessment of the internal condition of the pipelines and the prevention of additional energy costs.

Taking into account the structural changes during the transportation of gases, including their various mixtures, the development of new innovative methods to monitor the operation of the pipeline based on changes in the composition of the gas component to diagnose the technological condition of the pipeline was considered.

It became clear from the analysis that the component composition of both natural and associated oil gases (variant I) and mixtures of two separate natural gases (variant II) in two variants the change in component composition over time was different (Figures 3 and 4). Among the variable parameters, the rank classification was carried out on the most characteristic parameters, such as C_1, C_3, C_5, CO_2, N_2 and ρ_q. For this purpose, the ranks of the intervals (R_i) on a 5 point scale were noted. For both variants, the rankings for the intervals of parameters C_1, C_3, C_5, CO_2, N_2 and ρ_q were summarized at different points and the total rank values ($R = \Sigma R_i$) for each day of the study were calculated and analyzed (Figures 5 and 6).

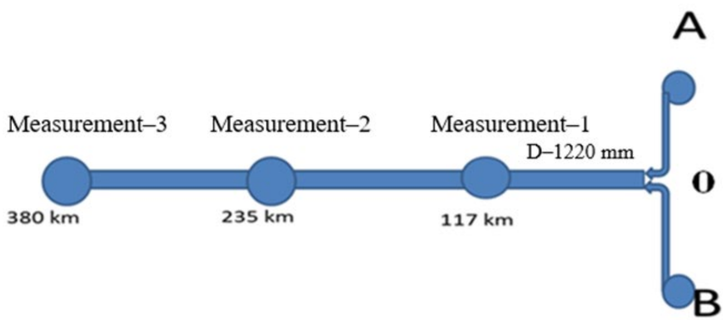


Figure 3. Stations where the component composition of the gas is determined in variant I

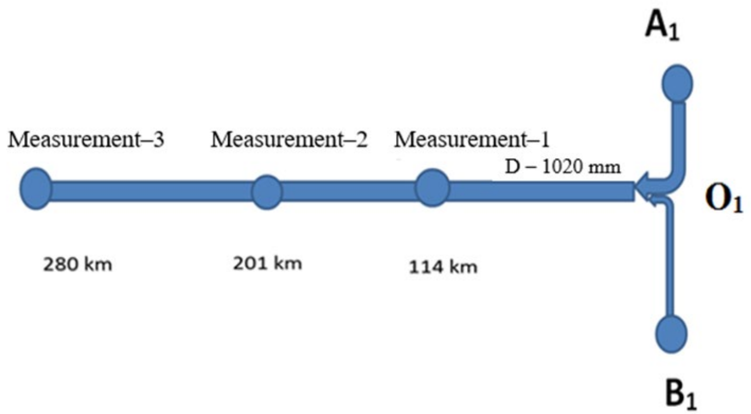


Figure 4. Stations where the component composition of the gas is determined in variant II

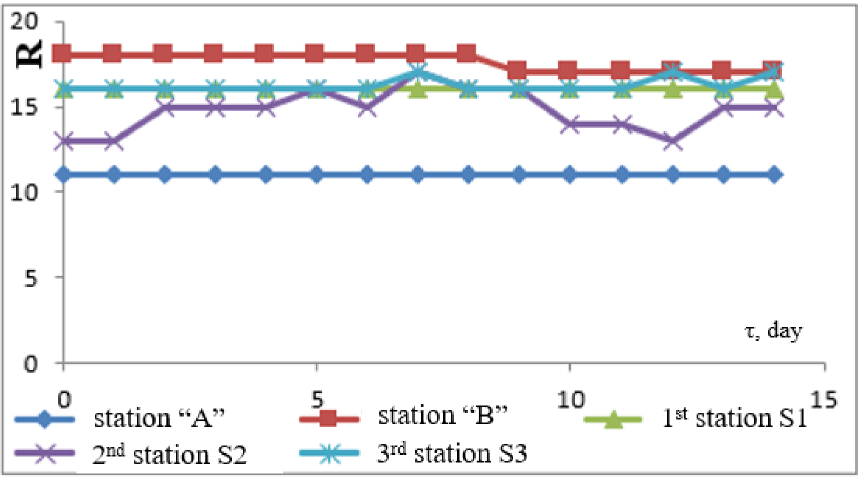


Figure 5. Dynamics change of ranks by days (variant I)

It should be noted that non additive changes due to the mixing of individual gases, the formation of a liquid phase in the pipeline, can be explained by retrograde phenomena such as reverse vaporization and reverse condensation. Thus, in the considered cases, the increase in its value in the dynamics of the rank indirectly confirms the reverse vaporization, and the decrease, on the contrary, indirectly confirms the cases of reverse condensation and accumulation of the liquid phase.

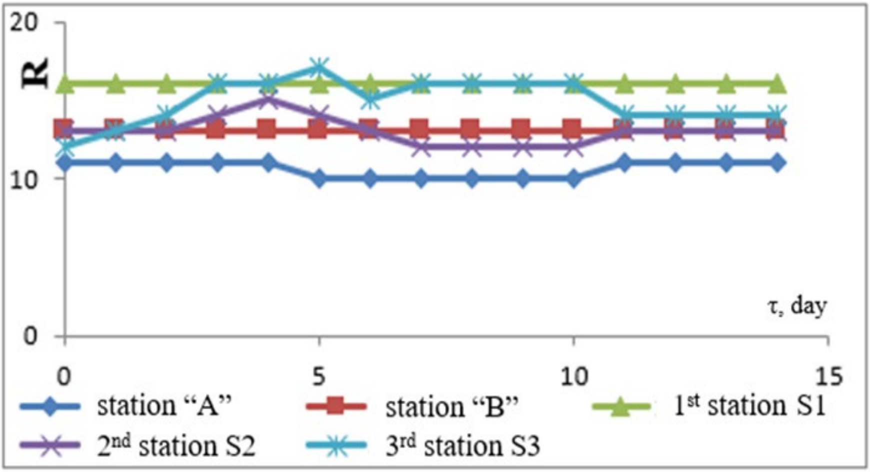


Figure 6. Dynamics change of ranks by days (variant II)

Based on research on the mixing and transportation of various gases, it can be said that, as in the case of oils, the effect of their composition and proportions is great during the mixing of gases. Since the compositions of natural and associated oil gases are very different from each other (variant I), the additive rule for their mixtures does not justify itself. Thus, it was determined that the technological (internal) condition of gas pipelines can be indirectly diagnosed according to the component composition of the transported gases. Based on the analysis of mining data on the component composition of natural and associated gases, it was determined that after mixing the gases, their composition and quality indicators change significantly. Therefore, the component composition of the gases can be used as a diagnostic criterion for structural change in the mixture.

In the example of the Kalamkas field, the possibility of diagnosing the gas according to its component composition after mixing was tested indirectly by changes in the humidity and other parameters of natural and associated gases.

In addition to the component composition, some quality indicators of gases (density, humidity, dew point for water and amount of mechanical particles) were also studied. As expected, the composition and quality of natural and associated gases differ significantly. For example, the amount of methane (in % by mass) and mechanical impurities, density, humidity and dew point are on average 92,1%; 0,57 mq/l; 0,694 kq/m3; 0,2230 mq/l and -10 0C for natural gas; and 81,0%; 0,08 mq/l; 0,755 kq/m3; 4,80 mq/l and 35 0C for associated gas, respectively. Actual indicators after mixing of natural and associated gases show that with the mixing of gases, the above parameters get the following values, respectively: 88,69, 0,64 mq/l; 0,713 kq/m3; 0,354 mq/l and -120 C. Taking into account the actual mixing ratios of natural and associated gases (80: 20 %), the parameters characterizing the composition and quality of their mixture were calculated in the ratio of (30:70), (50:50), (70:30), (80: 20%) according to the rule of additivity. A comparison of the additive values of the parameters of a mixture of natural and associated gases (80:20%) with the actual values of their gas mixture (80:20%) parameters shows that the most subject to change are heavy fractions (C5+), moisture and mechanical impurities, as well as dew point. This indirectly indicates the separation of the liquid phase (water and heavy fractions).

Thus, the study of structural changes in the gas mixture during the storage and transportation of natural and associated gases, as well as their mixtures in the field, shows that the component composition of hydrocarbons can be used as a diagnostic indicator of the formation of liquid phase in the mixture.

Analysis of the operation of gas pipelines shows that daily fluctuations in ambient temperature have a significant impact on their operation. The effect of gas temperature changes on the operation of the pipeline is explained by the fact that the coefficient of hydraulic resistance of the gas flow is related to the Reynolds number, which in turn varies in proportion to the density and viscosity of the gas. Since the latter are functions of pressure and temperature, daily changes in the hydraulic resistance of the gas pipeline and, consequently, changes in their operating modes are not excluded. However, the direct calculation of Re and λ is difficult. For example, taking gas samples at different times of the day, examining their composition on a chromatograph, etc.

By covering the surface of the pipelines with a heat protective layer, it is possible to minimize daily temperature fluctuations. Changes in the mode of operation of gas pipelines without thermal protection as a result of temperature fluctuations in the environment also lead to changes in the structural forms of flow.

Cluster analysis was conducted based on the performance indicators of the mentioned gas pipeline operating modes. Based on the cluster analysis, observational data on changes in temperature, pressure and consumption of gas transported through a number of gas pipelines in Azerbaijan over time were processed and it was shown that daily temperature fluctuations can affect the operation of the pipeline. This effect is manifested by the processing of the vectors "temperature pressure", "temperature consumption", "pressure consumption" and "temperature pressure consumption". Calculations show that there are two modes of operation of gas pipelines, called "day" and "night".

Thus, the possibility of diagnosing structural changes in gas pipelines based on cluster analysis was revealed and the temperature pressure consumption vector clustering by temperature was shown (Figure 7).

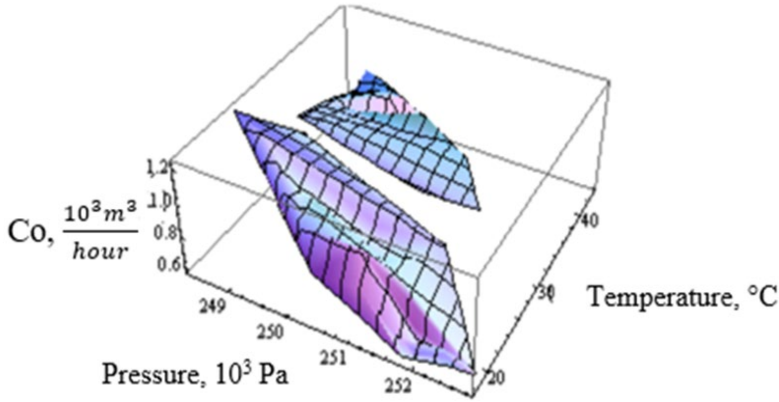


Figure 7. Clustering of "temperature pressure consumption" vector for Azadkend Bilasuvar 2 gas pipeline

The fourth chapter is dedicated to the development of methods to increase the operational efficiency of multiphase oil and gas pipelines, and the issues of the development of efficient transportation technology for the transportation of gas condensate mixtures were considered. Since gas plays a crucial role in the transportation of gas condensate mixture, the calculation of the pipeline is carried out mainly for the gas pipeline. In this case, the factor of separation of condensate from the gas phase must be taken into account. Depending on the condensing pressure and temperature, condensate separation (drop) from the gas can occur in the formation, bottom hole, wellhead and gathering-transportation lines. The hydraulic properties of the gas pipeline will also change depending on the dispersion of the condensate in the gas phase, ie its distribution with the gas as the second liquid phase. That's why depending on the flow forms in the form of emulsions and separate phases, it is possible to select the optimal energy and resource efficient transport option for the gas condensate mixture. That is, the correct determination of the structural form of the mixture flow is one of the main conditions for the selection of the scheme and methods of calculation of pipelines. As the volumetric quality is β> 0.7, the hydraulic calculation of the pipeline is based on the following expression for the gas pipeline:

$$Q_g = A\sqrt{\frac{(P_b^2 - P_e^2)\cdot D^5}{Z\,T_{or}\,\lambda\,L\,\Delta}} \quad (5)$$

$$A = 0,0385\,\frac{m^2\cdot s\cdot K^{0,5}}{kg}$$

Here: Z – is the gas compressibility factor, Δ-is the relative density, and L is the length of the gas pipeline.

The calculation of the Reynolds number (Re) and the coefficient of hydraulic resistance (λ) in the gas condensate mixture is carried out on the basis of known formulas of hydraulics.

In order to determine the structural forms of the flow regime and the flow for the gas condensate mixture at a given diameter of the pipeline, the specific gravity difference of the phases $g(\rho_k - \rho_g)$ and maximum value of the pressure gradient is found and compared. If $(dP/dr)_{max} > g(\rho_k - \rho_g)$ the flow form is accepted as emulsified (dispersed), $(dP/dr)_{max} < g(\rho_k - \rho_g)$ it is considered to be stratified (ie, separate phases).

$$(dP/dr)_{max} = 6,158\cdot \rho_{mix}\cdot \vartheta_{mix}^2/D \quad (6)$$

For different values of the initial data, the pressure loss in the gas pipeline, the transport distance or the amount of gas transported depending on the diameter of the pipeline were calculated. It was found that the accumulation and transport distance of mono and multiphase gases varies depending on the diameter of the pipeline (Figures 8 and 9).

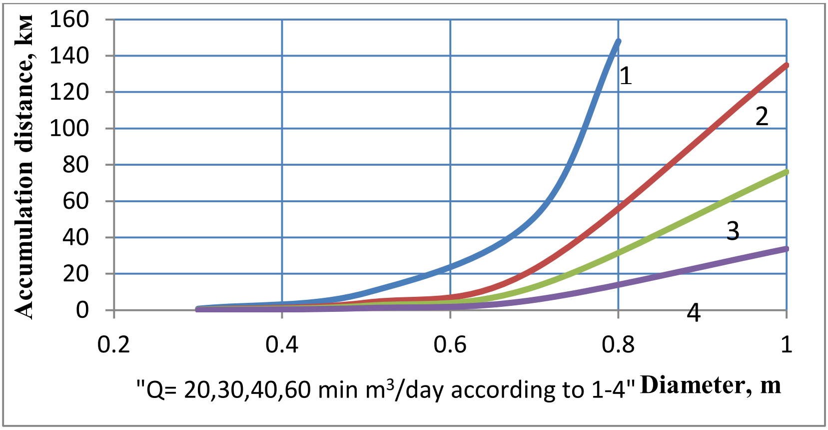


Figure 8. Diameter dependence of the accumulation distance for a mono- phase gas pipeline

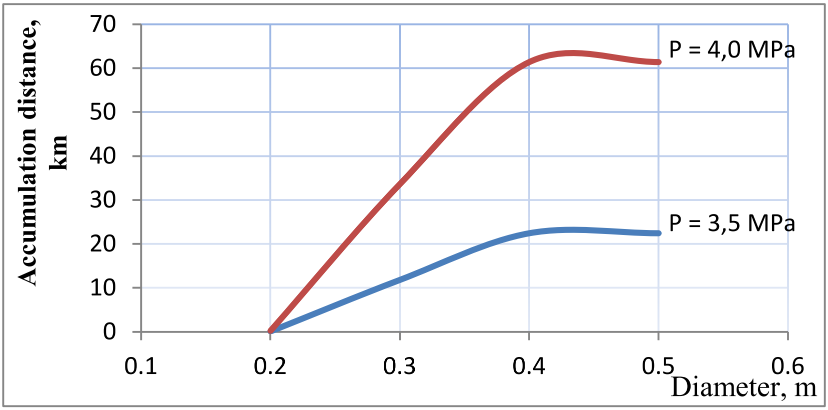


Figure 9. Dependence *L =f (D)* at different values of initial pressure

An improved methodology for hydraulic calculation of the gas pipeline during transportation of gas condensate mixtures has been developed and tested at the Umid gas condensate field. Based on the results of hydraulic calculations, it was determined that the transport distance of the gas condensate mixture has limited values depending on the volumetric rate of gas and condensate and the initial pressure. Therefore, the interaction of phases during the transportation of gas condensate mixtures through pipelines must be taken into account and the maximum transport distance must be selected.

During the transportation of gas condensate mixture from gas condensate fields through pipelines, 2-phase gas and condensate can move in separate layers as if they were moving on top of each other. However, as condensate falls from the gas, the cross section of the pipe begins to shrink, which in turn causes blockages and pressure pulsations in these flows. These pulsations (pulses) increase the probability of accidents by increasing the tension in the pipeline. To prevent such cases, there is such an optimal transport distance of the gas condensate mixture that at the end of this distance there is a need for a second separation due to the high probability of accidents. In this case, it is also important to choose the optimal diameter for the transport line.

The results of recent research show that one of the main reasons for the premature failure of mining storage and transportation lines is the multi phase, multi component and various structural flow systems of pipelines. Thus, water containing hydrocarbons, mechanical mixtures are divided into phases during transportation, as they come into contact with the inner surface of the pipes, accelerating the corrosion process and destroying steel pipes by wear. Due to the presence of mechanical particles, erosion processes occur, which further accelerates the disintegration of pipes. In all cases, the deposition of water, mechanical mixings, asphaltene, resin and paraffin compounds from the oil can accelerate the corrosion erosion process, as well as cause various blockages in pipelines, oil tanks and other equipment.

The dependence of the frictional force generated in the pipelines on the size of the mechanical particles for different speeds of multiphase flow has been determined. The analysis showed that the filtering of $d>0,5$ mm particles at the beginning of the pipeline, which cause more erosion of the gathering lines, allows to significantly reduce the corrosion rate. Thus, a wide range of measures has been developed to limit the corrosion-erosion problems that lead to accidents, loss of raw materials and additional financial costs in the multi phase storage and transportation system of hydrocarbon mixtures.

The hydraulic properties of multiphase flows should be taken into account to prevent local erosion-corrosion spills in the pipelines during the gathering and transportation of well products, and first of all, water and mechanical mixtures should not be separated from oil emulsions during transportation. One of the ways to protect oil and gas pipelines from collapse is to select a hydrodynamic regime so that the mixture does not move in a stratified manner, ie in separate phases. In order to prevent contamination of gathering and transportation systems in mines with mechanical mixtures, their protection from erosion and corrosion and environmental protection, mechanical mixtures can be disposed of by accumulating in the drainage tanks with the installation of hydrocyclones with sand chambers at the entrances of technological equipment and pipelines.

Fields experience also confirms that steel pipelines are more resistant to corrosion at high mix mixture velocities. Based on the facts, it can be said that the correlation between the rate of corrosion and the modes of movement in the pipelines of the mixture is very strong.

Active spills are more likely to occur at the beginning of the shield sections of the gas pipeline route. The greater erosion of these parts is due to the accumulation of the liquid phase (water, condensate), solid mechanical particles in these parts, and their up and down movement of the mixture along the flow. In general, the statistics of the collapse of the oil and gas storage network and the individual pipelines included in this network show that the volume of oil spills and repair and insulation works in the environment is significantly higher.

The most important factor is how the hydrodynamic regime changes for such flows. Other major causes of erosive (cracked) corrosion in pipelines include general corrosion activity and failure to purify transported gases.

There is no complete explanation for the formation of cracks of a certain length in the less active corrosion environment, namely at the bottom of the pipelines. In general, the problems of dynamic corrosion have not been extensively studied, and the local corrosion spills observed in the lower parts of existing mining process pipes often seem mysterious.

Taking into account the hydrodynamic factor in multiphase flows, the effect of the composition of mechanical mixtures on transported gases on corrosion-erosion processes in field technological gas pipelines was studied.

The frictional force of the erosion effect for a multi phase gas flow is calculated as follows:

$$N = F\,\upsilon = 5{,}144(\rho_{m.p.} - \rho_g)\,\varphi u\,(2 - d/D)d^4/D \qquad (7)$$

Here: $\rho_{m.p.}$ and ρ_g density of mechanical particles and gas; d and φ -diameter of the mechanical particle and the coefficient of friction of the metal; u is the average velocity of the gas flow.

Considering that the mechanical mixtures coming from the layers consist mainly of sands, and the average size of the individual fractions and their relative distribution according to their effect on the pipes, the conditional assumptions were made as shown in the table . The strength of the erosion effect of mechanical particles on the pipeline was calculated based on the following preliminary data by expression (7):

D=200mm; $\rho_{m.p.}$=1500 kg/m^3; ρ_g= 3 kg/m^3; u=5; 10; 15; 20 m/s

The results of the calculations are given in the table. As can be seen from the table, the share of almost 100% of the friction capacity is mainly the share of fractions-mechanical particles with size d> 0,5mm. Interestingly, the vast majority of the erosion effect

(95%) is caused by the largest diameter (1-2 mm) fractions. Another important result is that, although the fractions of 0,1-0,3 mm make up more than half (56%) of the total volume of mechanical mixtures, their share in the total friction capacity is negligible. Thus, the rate of corrosion-erosion increases in proportion to the friction capacity of mechanical particles on the inner surface of the gas pipeline, and this increase depends on their size rather than the amount of mechanical particles.

As can be seen, in order to protect the gas pipeline from the effects of solid mechanical particles (erosion), it is important that these particles break off from the bottom wall of the pipe and fall into the flow core and move there. To do this, the static pressure gradient (*dP/dr*) in the flow must be greater than the difference between the specific gravities of the mechanical particle and the gas.

$$dP/dr > (\rho_{m.p.} - \rho_g)\, g \tag{8}$$

It can be assumed that at α = 0,995, the thickness of the remaining layer on the lower surface of the pipeline will be 0,005D. The remaining mechanical particles will move with the gas flow. Thus, the motionless layer at the bottom will not cause to erode the pipe wall.

Taking into account the above said, the value of the flow rate for erosion-corrosion of the pipeline can be determined on the basis of the following expression:

$$\upsilon = A\sqrt{\left(1 - \frac{\rho_g}{\rho_{m.p.}}\right) \cdot D} \tag{9}$$

Here: A = 7,86, is coefficient $\frac{\sqrt{m}}{s}$.

Table 2

Dependence of friction capacity generated by mechanical particles on particle size at different flow velocities in mining gas storage lines

Average diameter of mechanical particles, mm	Part fraction in volume	Friction capacity (at different flow velocities),N, 10^{-11}Vt							
		5,0 m/sec.		10,0 m/sec.		15,0 m/sec.		20,0 m/sec.	
		capacity	Share ratio	capacity	Share ratio	capacity	Share ratio	capacity	Share ratio
2,00	0,01	294100,00	0,72	588141,00	0,72	882120,00	0,72	1176280,00	0,72
1,50	0,02	93160,00	0,23	186325,00	0,23	279488,00	0,23	372651,00	0,23
1,00	0,03	18430,00	0,05	36851,20	0,05	55276,80	0,05	73702,40	0,05
0,50	0,05	1153,00	0,00	2306,09	0,00	3459,13	0,00	4612,17	0,00
0,30	0,25	149,50	0,00	299,01	0,00	448,52	0,00	598,04	0,00
0,20	0,16	29,54	0,00	59,08	0,00	88,62	0,00	118,16	0,00
0,10	0,15	1,85	0,00	3,69	0,00	5,54	0,00	7,39	0,00
0,08	0,05	0,76	0,00	1,51	0,00	2,26	0,00	3,03	0,00
0,06	0,03	0,24	0,00	0,48	0,00	0,72	0,00	0,96	0,00
0,04	0,06	0,05	0,00	0,09	0,00	0,14	0,00	0,19	0,00
0,02	0,08	0,00	0,00	0,01	0,00	0,01	0,00	0,01	0,00
0,01	0,11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
			1,00		1,00		1,00		1,00

As can be seen from the last expression, the velocity of the particles transported by the gas flow will vary depending on the phase density ratio and the diameter of the pipe. Based on the obtained expression, it was determined at what flow velocities of mechanical particles at a value of α = 0.995 for gas pipelines of different diameters. Figure 10 shows the graph of the calculated values of the velocity of mechanical particles transported by the gas flow in the gas pipelines depending on the diameter of the pipeline.

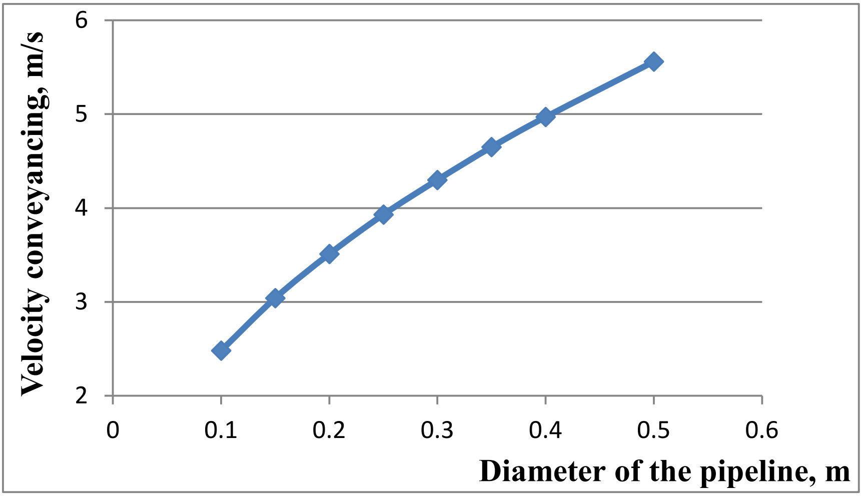


Figure 10. Dependence of the speed of transport of mechanical particles in the gas pipeline by the gas flow on the diameter of the pipeline

As can be seen from Figure 10, as the diameter of the pipeline increases, the value of the velocity required to transport mechanical particles larger than 1.0 mm in the gas flow also increases.

As a result of the research, the hydraulic (consumption) characteristics of the pipeline for mono and multiphase flows were studied, and the variation of the transport distance depending on the diameter of the pipeline and the speed of transport of mechanical particles in the flow for technological gas pipelines of different diameters were determined.In this work, concrete options have been proposed to reduce the rate of corrosion-erosion processes in multiphase infield pipelines where exist mechanical mixtures.

The presence of a large number of gas condensate fields in the Caspian Sea means that there are broad prospects for the use of condensate at the solvent part during the transportation of high viscosity oil through pipelines. In this regard, it is important to consider the water cut factor to assess the effect of the flow on the productivity and hydraulic resistance coefficient of the pipelines transporting the oil condensate mixture at different hydraulic regimes and temperatures. The presence of dispersed water in the oil condensate mixture not only increases the volume of the mixture, but also significantly increases its viscosity, which leads to increased transportation costs. Therefore, for multiphase oil condensate water mixtures, the dependencies for which water cut is not clearly included are not sufficient for engineering calculations. Taking into account that in mining conditions, the determination of water cut unlike to density is associated with a number of difficulties for such systems, the study proposed an empirical expression for the three dimensional dependence of oil condensate water mixtures on the mass fraction of condensate and mixture density at different water cut percentages shown to be suitable for engineering calculations.

In modern time in order to increase oil and gas production from the onshore fields of Azerbaijan, especially in the Caspian Sea, it is necessary to ensure the efficient operation of the oil and gas storage system, to further improve it in order to reduce capital investment and current costs. In this case, the simplest technology that ensures long term safe operation of pipelines and does not require high starting pressure can be considered the technology of joint transportation of gas liquid mixture in the well.

At present, reliable equipment that allows the application of multiphase technologies in devices that combine regulated multi phase pumps in oil fields around the world, including Russia, are being operating successfully. Tests have shown that their use allows the well (or group of wells) to operate continuously and maintain the pressure at the wellhead. The analysis shows that the application of multiphase technologies in offshore fields in Azerbaijan, which are in the final stages of development, can be effective as a promising way to transport well products from separate stationary platforms to the gathering transit platform or to the coast without initial separation. At the same time, the capacity of the oil storage reservoir will increase due to the creation of the required pressure in the pipelines operating between the stationary platforms. The application of this technology, which ensures the closure of the "Well-pump-pipeline" system, can also be considered a prospect for the final stage of field development, as it allows to solve another important problem environmental issues.

The fifth chapter encloses the improvement of control methods and the development of new ones to control the operating modes of gas transportation systems.

At present, the issue of solving the problem of gas imbalance in all technological processes of production, transportation and use of natural gas with the application of energy saving technologies and improving the control and measurement system is in the center of attention.

The imperfection of the control and measurement system and the inaccuracy of commercial junctions complicate the efficient use of transported gas and lead to financial losses due to imbalances in the system of supplier consumer relations in determining its volume. The imbalances in the control measuring junctions included in the supplier consumer system of the transported natural gas were investigated and were shown the ways to reduce them.

It was noted the existing methods for diagnosing a number of complications in the system of production, storage and transportation of hydrocarbons in many cases, especially in the system of subsea oil and gas pipelines with complex operating conditions, and the need for new technologies. There were considered the issues of changing regime parameters and diagnosing hydrocarbon leaks in oil and gas pipelines with the application of artificial neuron technology, which has been tested successfully in practice. Large companies engaged in the production and transportation of hydrocarbon products in the world have equipment based on special technologies for the diagnosis of leaks. On the other hand, the use of this equipment in long producing oil and oil products pipelines is accompanied by great difficulties. Therefore, the diagnostic methods proposed in the study were solved as engineering issues, and the coordinates of the leakage location were determined according to the changes in the composition, pressure and flow of the mixture, and was proposed an innovative method to reduce accidents. If there are any changes in the regime parameters of the oil and gas pipeline, it is possible to accurately detect this change on the basis of artificial neuron technology. It should be noted that the application of such information technology is very useful as an effective diagnostic method for detecting hydrocarbon leaks (including latent leaks) from pipelines, both onshore and offshore, as they do not require additional funding for special research.

Control and optimization of technological processes in oil, gas production, storage, transportation and storage systems, as well as diagnosis of a number of complications are performed by various mathematical methods and tools. However, these methods are applied only to any part of the system (separator, flow line of well, pipeline connecting two objects, etc.) or process. The application of known methods to the whole system is very difficult and in most cases impossible. In particular, the application of these methods is not possible due to changes in the operating modes of the oil and gas pipeline system for a number of reasons. With the help of artificial neural networks, one of the advanced elements of modern information technology, it is not difficult to recognize individual images, perform optimization operations and solve many management problems. According to a simple model of an artificial neuron, based on input signals (parameters), weight ratios and output parameters signals, the network consists of a summation, conversion (transmission) function and feedback functions. Currently, the existing software package has a wide range of capabilities for artificial neural networks for application in various fields of technology, and there is special software for this.

Based on the above principles, the application of artificial neural networks in the direction of early diagnosis of various accidents in the natural gas transportation and distribution network and control of regime parameters was considered. Observation indicators specific to that process were used to select and adapt an acceptable model that reflected the real process. The main criterion for selecting the best model is the condition that the mean square error is minimal.

The following mathematical model was used as the main transmission function when constructing an artificial neural network for a gas pipeline system:

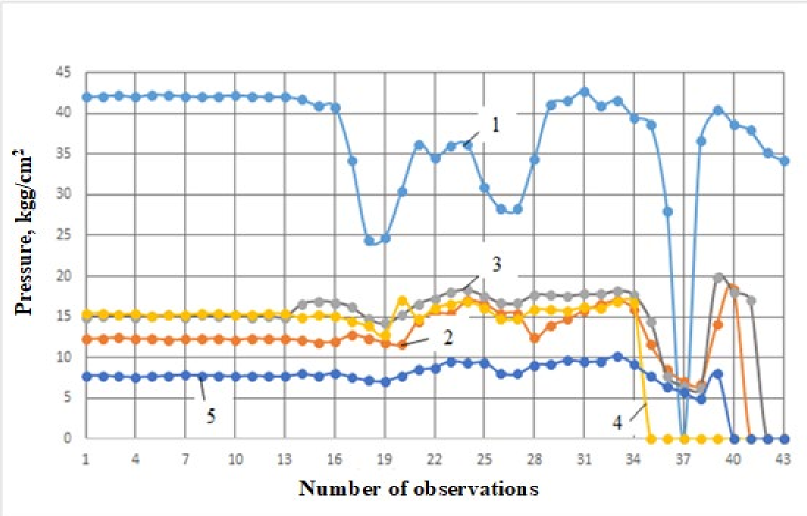
$$P_b^2 = P_e^2 + \frac{1}{K^2} \cdot \frac{z\, T_{aver} \lambda L \Delta}{D^5} \cdot Q^2 \quad (10)$$

$$K = \frac{\pi}{4} \cdot \frac{T_{st}}{P_{st}} \cdot \sqrt{R_a} \quad (11)$$

Here: P_b *və* P_e - pressures at the beginning and end of the gas pipeline, respectively, Pa; z - gas compression ratio; Δ - relative density of gas; T_{aver} – average temperature of the gas, *K*; T_{st} və P_{st} respectively, the temperature ($T_{st} = 273\, K$) and pressure ($P_{st} \approx 10^5\, Pa$) of the gas under standard conditions; R_a gas constant for air ($R_a = 287\, m^2/s^2K$); λ is the coefficient of hydraulic resistance.

(10) The pressure at the end of the pipe can be calculated according to the initial pressure given by the expression or, conversely, the starting pressure based on the final pressure. Provided that the gas consumption is known.

Gas transportation in the gas distribution network was investigated at different points and the observation indicator was used for 43 days. The dependence showing the dynamics of pressure change at the points is given in Figure 11.



1-5 in points 1 and 5, respectively
Figure 11. Pressure distribution across stations

The figure shows that there were no significant changes in the operation of the gas pipeline system between observations 1 and 15 (that is, during the 13th day) due to the stability of gas transportation and consumption. However, starting from the 13th observation, significant changes were noted in the gas pipeline network and the supply of gas from the 1st point was stopped, albeit for a short time. The pressure at the entry point varies widely. During the 37th observation, it was revealed that even the gas pipeline was stopped. This indicates that the gas supply for the pipeline is unequal. That is, unequal gas losses are allowed not only due to the season, but also during the month. Such changes are reflected in the regime parameters of all points of the given gas pipeline network. However, as can be seen from Figure 11, although these changes are seen clearly in point I, they are not seen in other points.

Figure 12 shows the dynamics of changes in the analogs of the output of pressure signals at these points for the developed artificial neural network.

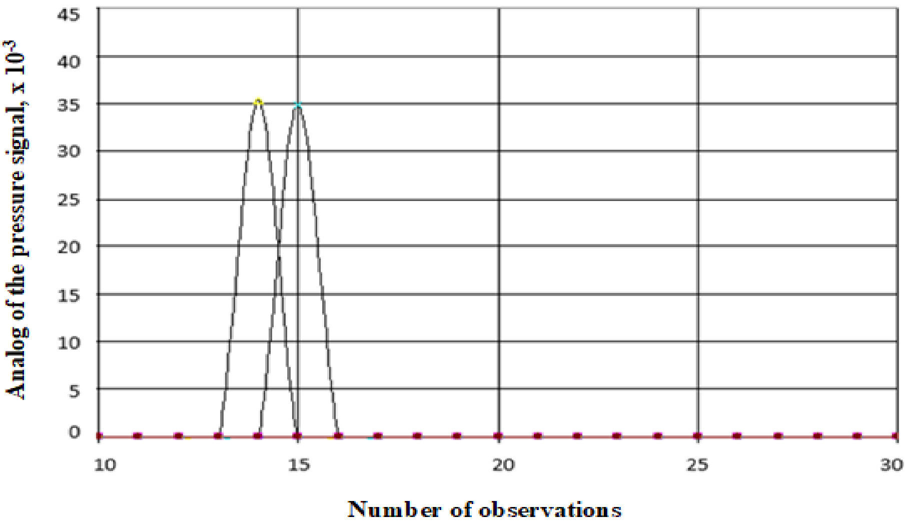


Figure 12. Distribution of pressure signal analog at the output of an artificial neural network

As can be seen from the figure, until the 13th observation, the analogs of the pressure signals at the output of the artificial neural network were close to unity for all GDPs. After pressure changes in the system, the ratio of signal analogues to their initial average values was up to 35,000 times. The multiplication of this ratio in the artificial neural network (by increasing the number of layers of neurons) makes it possible to detect changes in the operating modes of gas pipelines for one reason or another.

Thus, if there are any changes in the regime of gas pipelines, it is possible to reliably and quickly detect this change with the use of an artificial neural network. Conducting and evaluating research based on proposed neural technologies is cost-effective and can now be considered cost-effective in detecting gas leaks of various origins from gas pipelines. Based on the application of neural technologies, it is possible to control the operation of gas pipelines, as well as to consider the presence of phase transitions within the pipelines and the occurrence of hydrocarbon losses due to these transformations.

Multiphase flows are found in a number of areas of the oil industry oil and gas wells, oil transportation lines and storage tanks, refineries and petrochemical plants. Predicting the productivity and economic efficiency of both fields and pipelines requires accurate modeling of the hydrodynamics of these processes. However, the development of a reliable model for the correct modeling of processes is quite complex. For this reason, it is understandable to give preference to laboratory experiments.

During the transportation of multi phase mixtures, phase transitions often occur, which leads to blockages in the system, a number of negative consequences and additional costs for their elimination. Complications occur due to the imbalance of the phase at different pressure values and sharp changes in the viscosity of the oil. Studies show that a system with gas bubbles or very small hydrocarbon vapors distributed over the entire volume of the liquid is characterized by unbalanced phase characteristics. By changing any major thermodynamic parameter, the system changes. If this change causes a phase transition, then first the micro embryos of the new phase are formed, and then they gradually increase in accordance with the basic parameters. Free gas is separated from the liquid, and depending on the thermodynamic conditions, there happens a structural change in the gas liquid flow.

As can be seen, the phase behavior of the oil and gas mixture creates an unbalanced thermodynamic two-phase flow in the pipelines, and in this case, the liquid and vapor phases in the same cross section of the pipe have different characteristics.These factors lead to significant changes in thermodynamic and hydrodynamic characteristics, increased pressure fluctuations and the onset of unstable processes, which in turn can lead to various complications with additional costs for the transportation of gas liquid mixtures through pipelines.Hydraulic calculation of production wells' gathering and transportation pipelines for offshore oil and gas fields does not meet modern engineering practices. Transportation of multi phase mixtures in a stratified mode, which creates the pressure and flow pulses felt in the gas pipeline, requires a number of non-productive energy costs. The presence of harmful pulses in some cases leads to disruption of the transport system as a whole and accidents in the pipelines. Therefore, in order to ensure the efficient operation of the pipeline system affected by pulsed flow, there is a need to reduce pressure pulses and control methods to minimize hydraulic resistance. Although there are some mechanical methods of eliminating pulsation in gas pipelines, these mechanical dampeners cannot be considered acceptable for multiphase flows, as the structural diversity and rheophysical properties of the latter do not allow to achieve the desired results.

The pulsation characteristics (ΔP) of the gas liquid mixture (variation of the pressure difference in time) were studied both with and without rotation. Experiments have shown that the rotation of the flow allows a significant reduction in pressure pulses compared to the non rotating flow. This is due to the fact that the gas liquid mixture cannot be separated from the gas as a result of its rotation as it enters to the device. On the other hand, the mixing of gas compounds and bubbles with the liquid by the rotation of the flow leads to the collapse of local structures of the gas liquid system with unbalanced rheological properties.

As a result of the research, the following condition for the existence of a stable characteristic for multiphase flow was determined:

$$\frac{0{,}54\left(\frac{l_1}{l_2}-1\right)}{\frac{\rho^{'}}{\rho^{''}}-1} < \Psi X_{o.} < \frac{7{,}46\left(\frac{l}{l_1}-1\right)}{\frac{\rho^{'}}{\rho^{''}}-1} \qquad (12)$$

Here: $\rho^{'}$ and $\rho^{''}$ *is a* density of liquid and gas; Ψ – is a coefficient indicating the two-phase flow; $X_{o.}$-mass fraction of gas at the outlet of the pipe; l_1 and l_2 are the lengths of mono- phase (liquid) and two-phase zones.

Based on the above, have been identified criteria for multiphase flow management and pressure loss optimization in pipelines. Thus, according to the latter expression (10), calculations were made for the determination of stable and unstable zones in the flow characteristics of multiphase current depending on the change of l/l_1 və $\rho^{'}/\rho^{''}$ simplexes and boundary conditions were determined (Figure 12).

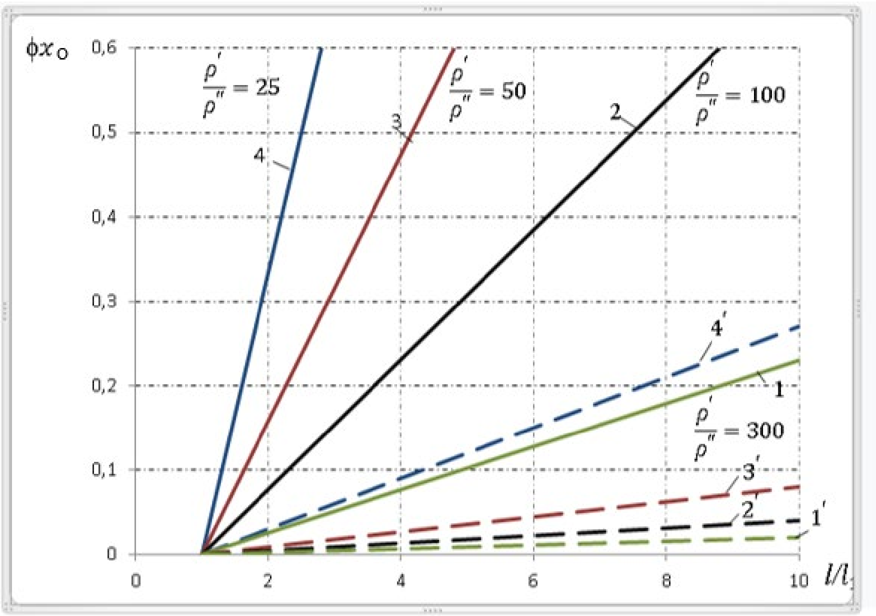


Figure 12. Boundary conditions for stable flow characteristics (lines 1, 2, 3 and 4 show the upper limits, and lines 1 ', 2', 3 'and 4' show the lower limits)

As can be seen from Figure 12, the unstable flow profile in the system can be observed under any conditions with large or insignificant mass fractions of gas. In this case, the unstable flow characteristics caused by the change in pressure along the length of the pipeline can be avoided by adjusting the flow rate, ie by selecting the parameters (Q) and (l_1/l_2).

Based on the above, criteria can be identified for the management of multiphase flow in pipelines and the optimization of pressure losses. The results of theoretical and experimental research can be applied in real oil and gas pipelines.

Thus, as a result of research, the possibility of creating a controlled method of reducing pressure pulses in multiphase flows has been confirmed. The works which have done during the research suggests that the rotation of the flow can be used as an effective way to eliminate the pressure pulses in gas liquid flows.

Taking into account all the above mentioned, it can be said that the innovative,in the dissertation energy efficient, resource saving methods and technologies developed for the diagnosis and elimination of complications in the transportation and storage of hydrocarbons in Azerbaijan shows that it is a successful project both economically and environmentally.

CONCLUSIONS AND RECOMMENDATIONS

1. The causes of complexities and operational difficulties in the gathering and transportation of hydrocarbons and ways to overcome them were analyzed.
2. Methods for estimating gas losses due to phase transitions and hydrocarbon leaks from subsea pipelines have been proposed.
3. In order to increase the efficiency of gathering and transportation of gases in offshore conditions:
- A composite system with hydrated and corrosion resistant, patented synergetic properties was applied in gas lines;
- Tubular design for liquid extraction from gas pipelines was proposed and patented.
4. The possibility of diagnosing the degree of water cut of oils according to the component composition of the gas is shown.
5. An express method has been developed to diagnose the technological condition of gas pipelines due to changes in the composition of transported gas.
6. An express method has been proposed for the diagnosis of structural changes in the mixture of transported natural and associated gases.
7. To increase the operational efficiency of multi phase pipelines:
- An innovative transportation technology based on hydraulic calculation of gas pipelines transporting gas condensate mixtures has been proposed;
- Selection of optimal diameter and maximum transportation distance of pipeline for transportation of gas condensate mixtures has been substantiated;
- A method of hydrodynamic regulation of corrosion-erosion processes in field oil and gas pipelines has been developed.
8. New advanced technology has been proposed in gas control and measurement systems.

9. It is shown that it is expedient to carry out operative control of changes in operating modes in gas transportation systems on the basis of artificial neuron technology.
10. Cluster analysis of gas pipeline performance was conducted and based on the cases of clustering, it was found that the insulation in the system is weak or not.
11. The possibility of using multiphase current rotation as an effective method of reducing pulsation and eliminating unstable zones in flow characteristics has been shown. Thus, the hydraulic characteristics of the system are improved due to the collapse of local gas liquid structures with unbalanced rheological properties due to the difficulty of gas separation during the rotation of the flow and the disintegration of the separated gas bubbles with the liquid.
12. The flow characteristics of multi phase pipelines show that unstable zones can occur at both small and large values of gas capacity, as well as the possibility of preventing the formation of these zones by selecting the flow parameters.
13. A new innovative method based on electrical analogy has been developed to ensure the rational loading and control of compressor units.

List of published literature on the topic of the dissertation

1. **Iskandarov E.KH., Sh.H. Aliyev** Research of technology transportation of natural and associated gases in gas fields of OGP department named after H.Z. Tagiyev // Scientific works of "NGGP and K" Research Institute, Baku, 2014, Volume XV, p. 219 232.
2. **Fariz F. Ahmed, E.KH. Iskandarov, Sh.H. Aliyev, L.Q. Hacikarimova** Exploitation of underground gas storage facilities to prevent the Collapse of bottom hole during the development of a new filter design// "Azerbaijan Airlines" CJSC National

Aviation Academy Scientific Proceedings, Baku, 2015, Volume 17, №2, p.39 44.
3. **H.Gurbanov,E.Iskandarov,A.Karimova** Phase transformations in gas transport lines and research of gas drying process // AzTU Scientific works, p. 1, №3, Baku, 2016, p.24 29.
4. E**.A. Zeynalov, E.Kh. Iskandarov, B.G. Ismayilov** About estimates of minor oil leaks due to damage to risers of subsea oil and gas pipelines // Scientific and Technical Journal Equipment and Technologies for the Oil and Gas Complex, Moscow, August 2016, No. 4, p. 4-57.
5. **Ismayilov G.G., Iskandarov E.Kh., Ismayilova F.B., Seyfullayev G.H.** Determination of the optimal accumulation distance for gas-condensate mixtures// "KHAZAR-OILGASFIELD-2016"Scientific-practical conference, collection of articles, Baku, December 22-23, 2016, p. 253-261.
6. **Ismayilova F.B, Iskandarov E.Kh., Musayev S.F.** Development of a diagnostic method for the analysis of the "gathering- transportation" system on the basis of electrical analogy // Proceedings of the Scientific Practical Conference "CaspianOilGas 2016", Baku, 2016, p. 266-274.
7. **İsmayilov G. G. Nurullayev V.H., İskenderov E. KH.** The Role of Saturated Vapor Pressure of Cavitations in the process of oil supply // «Bulletin of Environment, Pharmacology and Life Sciences, 2016, Vol 5, (6) May, p.15-24.
8. **İsmayilov G.G. Nurullaev V.H, Musaev S.F, İskenderov E.KH, Ismayilova F.B.** The Prediction Of Water Cutting And Dencity Of Oilwatercondensat Mixes // «International Journal Of Engineering Sciences & Research Technology, 2016, 5 (8) August, 768-775.
9. **G.G. Ismailov, R.A. Ismailov, E.KH. Iskenderov,V. H.** Nurullayev Diagnosing of Structural Modes of Gas Flow inThe

Pipeline Systems // «Bulletin of Environment, Pharmacology and Life Sciences, 2016, Vol 5, (10) September, p. 28-34.

10. **G.G.Ismailov,E.KH.Iskandarov,IsmayilovaF.B,Q.KH.Seyfullayev** Analysis of funktioning of offshore piplines of storage and transport of gas-condensate mixtures // Bulletin of environment, Pharmacology and Life Sciences, 2016, November, p. 28-34.
11. **Iskandarov E.KH., Ismayilova F.B.** On the efficiency of accumulation of hydrocarbons from offshore gas condensate fields // Proceedings of the conference on "Actual problems of development of offshore oil and gas fields" dedicated to the 100th anniversary of I.Guliyev, Baku, 2017, p. 6-12
12. **G.G. İsmailov, E.H. İskenderov, V. H. Nurullayev** Methods For An Assessment of Emergency Leaks Taking Into Account Hydraulic Characteristics of Oil Pipelines // «Bulletin of Environment, Pharmacology and Life Sciences, 2017, Vol 6, (6) May, p. 28-36.
13. **Iskenderov E.Kh., Ismayilov B.G.** About evaluation of the changes regime parameters in the gas pipeline according to neural technology // Baku,Theoretical and applied mechanics 2017, № 1-2, p.134-139.
14. **Iskandarov E.Kh., Ismayilov G.G., Izbasarov E.I.** Analysis of structural changes in a mixture of transported natural and associated gases // Scientific Information Collection "Transport and Storage of Petroleum Products and Hydrocarbon Raw Materials", Moskva, 2017, No. 3, p. 43 47.
15. **Iskandarov E.Kh**. Optimal technologies for gathering and transportation of multiphase well products in offshore fields // Baku, News of the Azerbaijan Academy of Engineering, 2017, volume 9 №3, p.92 100.
16. **Iskandarov E.Kh., Ismayilov G.G., Ismayilova F.B.** Investigation of the effect of the degree of oil water cut on the composition of the gas phase // Baku, ANAS, International "Eco

energetics" Academy, "ECOENERGETICS" Scientific-technical journal, 2017, No. 3, p. 76-83.

17. **Ismayilov G.G, Alakbarov Y.Z, Seyfullayev G.H, Iskandarov E.Kh** Causes of technological difficulties in main gas pipelines and ways to eliminate them // Azerbaijan Oil Industry, Baku, 2017, №6, p. 37-42.
18. **İskanderov E.Kh.** Efficiency Of Offshore Gaspipelines / E.Kh. Iskanderov, "Science & Applied Engineering Quarterly", London, Published in the UK," 2017, p.20-22.
19. **Ismayilov G.G., Iskandarov E.Kh., Seyfullayev G.H., Ismayilova F.B.** Diagnosis of oil and gas leakages from pipelines on the basis of artificial neuron technologies // Transactions of Azerbaijan Institutes of Technology, Baku: 2017, volume 19, №4 (108), p. 29-39.
20. **Iskandarov E.Kh, Gurbanov M.M, Sadigov R.E, Alakbarova G.A** Corrosion protection of casing pipes with mechanical strength composites // Theoretical and applied mechanics, scientific and technical journal, Baku, 2017, №3 4, p.21-25
21. **Miralamov H.F., Iskandarov E.Kh.** Improvement Of Gas Measuring And Control Systems Using Energy Efficient Technology // // News of the Azerbaijan Academy of Engineering, Baku, 2017, Volume 9, № 4, p. 50-54.
22. **Ismayilov G.G, Ismayilova F.B, Iskandarov E.Kh, Adigozalova M.B** Multiphase technologies in oil and gas production, Baku, Science Publishing House, 2017, p.248 p. --
23. **İsmayilov G.G., Seyfullayev G.H., Alakbarov Y.Z., Iskandarov E.Kh., İsmayilov R.A., İsmayilova F.B., Huseynov A.J., Mirzayev V.Kh.** Methodical guidance on diagnostics of technological condition of gas pipelines, Baku, Science Publishing House, 2017, 38p.

24. **Iskandarov E.Kh., Gurbanov M.M., Sadiqov R.E.** Theoretical and practical basics of corrosion protection of oil field equipment // Azerbaijan Oil Industry, Baku, 2017,Volume10, p. 41-46.
25. **Iskandarov E.Kh., İsmayilov G.G., F.B. Ismayilova** Problems Of Hydrodynamic Corrosion In Multiphase Gas Pipelines And The Ways To Solve Them // scientific and Pedagogical news of Odlar Yurdu University, Baku, 2017, volume 47, s. 60-66.
26. **İskandarov E.Kh., Gurbanov M.M., Sadigov R.E.** Corrosion protection of oilfield manifold pipelines// Proceedings of the V international scientific and technical conference“Geology and Hydrocarbon potential of The Black sea Region”, Varna, 18 - 22 september, 2017, p.247-252.
27. **İskandarov E.Kh., Gurbanov M.M., Sadigov R.E.** Corrosion-resistant composite basalt-plastic casing pipes of oil wells // Proceedings of the V international scientific and technical conference“Geology and Hydrocarbon potential of The Black sea Region”, Varna, 18 - 22 september, 2017, p.253-256.
28. **Iskandarov E.Kh.** Prediction of water cut of pumped oil-water-condensate mixtures // Proceedings of the All Russian Scientific and Technical Conference "Problems of Geology, Development and Operation of Fields and the Transport of Hard to Recoverable Hydrocarbon Reserves", Ukhta, November 02 03, 2017, Ural State Technical University, p. 202-204.
29. **Ismayilov G.G., Iskandarov E.Kh.** The effect of pressure on the flow rate of gaseous liquids in field collection pipelines // Proceedings of the International Scientific and Practical Conference "Achievements, Problems and Prospects of Development of the Oil and Gas Industry", Almetyevsk: October 25-28, 2017, Volume I, p.447-452.
30. **Iskenderov E.Kh.** Some issues of increasing the efficiency of the operation of pipelines for transporting gas condensate mixtures // Proceedings of the International Scientific and

Practical Conference "Achievements, Problems and Prospects of Development of the Oil and Gas Industry", Almetyevsk, October 25-28, 2017, Volume I, p.443-447.

31. **Ismayilov G.G., Y.Z. Alakbarov, E.Kh. Iskandarov, Ismayilova F.B.** Gathering, preparation and transportation of gases in extreme conditions, Baku, Science Publishing House, 2018, 506 p.
32. **Ismayilov G.G., Iskandarov E.Kh., Nasif Valid Mukhamed** About one specific problem of mixing field oils // Materials of the international conference "Rassokhin Readings", Ural State Technical University, Ukhta, February 1-2, 2018, p. 284-288.
33. **G.G.Ismayilov, E.Kh.Iskandarov, F.B.Ismayilova** Problems Of Corrosion In Multi-Phase Pipelines Of Gathering And Transportation // Azerbaijan National Academy of Sciences Proceedings The Science of Earth , Baku, 2018, Volume 1, p. 31-37.
34. **E.K.Iskandarov, F.B.Ismayilova** Diagnostics Of The Degree Of Irrigation Of Partially Purified Oils By Gas Composition // Transactions of Azerbaijan Institutes of Technology, Bakı: 2018, Volume 20, №2 (112), p. 19-24.
35. **E.Kh.Iskenderov** Diagnostics of structural change in transported natural and associated gas // Baku, Herald of the azerbaijan Engineering Academy, 2018, volume 10, №3, p. 75-79.
36. **E.Kh.Iskenderov.**Some Problems Of Improvement Of Ecological Parameters Of Oil Pipelines // "Modern problems of innovative echnologies in oil and gas production applied mathematics" proceedings of the international conference dediscadet to the 90th anniversary of Academician Azad Khalil oglu Mirzajanzade, Baku, December 13-14, 2018, pp.437-439.
37. **İsmayilov G.G, İskenderov E. H.** The efficiency of functioning multiphase gas pipelines // "Modern problems of innovative echnologies in oil and gaz roduction applied mathematics" proceedings of the international conference dediscadet to the 90th

anniversary of Academician Azad Khalil oglu Mirzajanzade, Baku, December 13-14, 2018, pp. 444-446.

38. **Miralamov G.F., Iskandarov E.Kh., Seifullaev G.Kh.** Diagnosing the internal state of gas pipelines // Abstracts of the IX International Scientific and Technical Conference “Reliability and Safety of the Main Pipeline Transport”, Novopolotsk, December 18–20, 2018, p. 53-54.
39. **Ismayilov G.G., Iskandarov E.Kh., Seyfullayev G.H., Najif V.M.** Hydraulic calculation of gas condensate pipeline // Scientific works of “NQGP and K” Research Institute, Baku, 2018, Volume XVIII, p. 276-281.
40. **Ismailov G.G. , Iskandarov E.K. , Zeynalova G.A., Khalilov F.T.** Technological Difficulties In Field Pipelines And Ways To Eliminate Them // Scientific works of “NQGP and K” Research Institute Baku, 2018, Volume XVIII , P. 281-287.
41. Iskandarov E.Kh., Ismayilova F.B., Babirov H.M. The prospects of application of multiphase technologies in offshore fields // Scientific works of “NQGP and K” Research Institute, Baku, 2018, Volume XVIII, p. 292-298.
42. **Ismayilov G.G, Iskandarov E.Kh, Gurbanov M.M, Sadigov R.E** Technology of application of basalt plastic polymers in corrosion protection of reservoirs, tanks and other capacities where oil products are stored // Proceedings of “Nagiyev readings” Scientific Conference dedicated to the 110th anniversary of Academician M. Nagiyev, Institute of Catalysis and Inorganic Chemistry of ANAS, Baku, 2018, p. 56.
43. **Ismayilov G.G., Ismayilova F.B., Iskenderov E.Kh.** The efficiency of the operation of multiphase gas pipelines taking into account the dynamics of the development of gas condensate deposits // MATERIALS of the International Scientific and Practical Conference "STATE AND PROSPECTS FOR OPERATION OF MATURE DEPOSITS", Aktau, May 16 17,

2019, "KazMunaiGas Research Institute of Production and Drilling Technologies" “KazMuniGas” “KazMuniGas” ”, volume 2, p. 75-82.

44. **Miralamov G.F., Ismayilov G.G., Iskandarov E.Kh.,** Seyfullaev G.Kh. Cluster analysis of the functioning of gas pipelines // Materials of International scientific practical conference “State and prospects of exploitation of mature fields” to the 5th anniversary of KazNIPI munaigas, Aktau, May 16 17, 2019, Scientific Research Institute of Production and Drilling Technologies KazMunayGaz KazNIPImunaigas ", 2 volume, p.127-135.
45. **Gafar G. Ismayilov, Vugar M. Fataliyev, Elman Kh. İskandarov** Investigating the impact of dissolved natural gas on the flow characteristics of multicomponent fluid in pipelines // Open Phys., 2019;17, p.206 -213.
46. **Miralamov G. F., Ismayilov G. G., Iskandarov E. Kh., Izbasarov E. I.** Gas composition is a diagnostic sign for structural changes in gas flows // Materials of the international conference “Rassokhin Readings”, Ukhta, Ural State Technical University, February 7-8, 2019, p. 101
47. **E.Kh. Iskandarov** Selection of optimal diameter of Multyfase Underwater Gas Pipelines // Baku, Transactions of Azerbaijan Institutes of Technology, 2019, volume 21, №3 (119), p. 35-41
48. **Ramazanova E.E, Ismayilov G.G, Alakbarov Y.Z, Iskandarov E.Kh, Ismayilova F/B, Khalilov R.Z** Patent, utility model (Azerbaijan) Pipe type device for gas preparation // F 2019 0004, 2019
49. **Iskandarov E.Kh.** Diagnosing structural changes in gas flows // Moscow, EURASIAN UNION OF SCIENTISTS (EUS) Scientific Journal on a monthly basis, 2019, No. 7 (64), part 6, p.47- 51.
50. **G.G. İsmayilov, E.H. İskenderov** Compressor Stations Analysis on the Electrical Analogy Basis // SOCAR Proceedings, Baku, 2019, № 3, p. 081-087.

51. **İsmayilov G. G., İskenderov E. H., İsmayılova F.B.** Diagnostic Operation of Gas Pipelines Based On Artificial Neuron Technologies // 10th International Conference on Theory and Application of Soft Computing, Computing with Words and Perceptions - ICSCCW 2019, Prague-Czech Republic, 27-28 August, 2019, p.787-791.
52. **İsmayilov G. G., İskenderov E. H., İsmayılova F.B.** Diagnosis of functioning of gas pipelines by cluster analysis method // 10th International Conference on Theory and Application of Soft Computing, Computing with Words and Perceptions - ICSCCW 2019, Prague-Czech Republic, 27-28 August, 2019, p. 557-564.
53. **Ismayilov G.G., Iskandarov E.Kh., Ismayilova F.B.** Controlled methods of decreasing pressure pulsations in multiphase pipelines // Engineering Physics Journal, Minsk, 2020, No. 1, p. 222- 228.

Researcher's contribution to published works:

Works number [15, 18, 28, 30, 35-36, 47, 49] independently;

In works number [1-4, 6, 21, 38, 44, 46] problem statement, conducting experimental researches development of technologies and methods and analysis of results ;

In works number [11, 13-14, 16, 20, 24-25, 27, 34, 41] theoretical and practical formulation of problems, systematization and processing of results, substantiation of diagnostic methods ;

In works number[5, 7-10, 12, 17, 19, 22-23, 26, 29, 31-33, 37, 39-40, 42-43, 45, 48, 50-53] operation in technological and main gas pipelines analysis of difficulties, systematization and mathematical processing of operational and experimental data, analysis of results, development of control diagnostic methods.

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