**ANNOTATION**

dissertation submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D070800 - "Oil and Gas Business"

**Imansakipova Nurgul**

# Decrease in effects of hydraulic loadings on a profile of the route of oil pipelines

More than 50% in the world, and in Kazakhstan, in the absence of a marine component in the territory, over 80% of oil is transported through trunk pipelines, a feature of which is a long length. The main pipeline is a combination of successively alternating, heterogeneous technological elements, functionally integrated into a single system to ensure the necessary conditions for transportation.

Since the density and speed of the transported oil in the pipeline are significant, the flow of liquid with a moving mass, determined by the diameter and length of the pipeline, of the order of tens of thousands of tons, has colossal inertia. Therefore, technological operations, such as starting and stopping the operation of the pipeline, turning on and off the pumping station, full or partial closing of the valve, rupture of the pipeline, etc., authorized and emergency situations can lead to hydraulic loads in the form of a sudden increase in pressure in the pipeline, measured in tens of atmospheres and manifested in the form of water hammer.

The pressure impulse arising from hydraulic shocks propagates at high speed in the form of a pressure wave (the speed of the shock wave is higher than the speed of sound in the medium) from the place where the liquid stops up and downstream. An abrupt increase in pressure can damage the equipment, rupture the pipe and lead to an emergency with severe environmental consequences for the environment. Along with internal reasons associated with technical changes in the operating mode of the transport system, affecting the manifestation of hydraulic loads and their intensity, a decrease in the pipeline's throughput, such external factors as the relief of the area along which the oil pipeline is laid and the ambient temperature play an important role.

With the change in the ambient temperature on the inner walls of the pipeline, especially when pumping heavy oil deposited a significant amount of wax. The inflection point of the pipeline located at higher elevations or depressions having air-gas accumulations.

Most of Kazakhstan's main oil pipelines are laid in a heterogeneity of the relief areas. In this regard, the study of the process of formation of gas-air accumulations and their influence on the efficiency of transportation is of particular scientific and practical interest.

The classical theory of unsteady flow of fluid is not acceptable to the calculation of transients in the main oil pipelines. This is explained by the fact that the classical theory contains one, although not often formulated, restriction on the

absence of phase transitions in a liquid. This assumes that under no circumstances does the liquid pass into the vapor-gas phase, even when the pressure is reduced to the pressure of saturated vapor. Meanwhile, with the propagation of rarefaction waves and relief inhomogeneity of the route in the pipeline, this condition is violated in many sections of the pipeline and, first of all, at the tops of its profile.

There are no explanations for the experimentally revealed facts, such as the removal of a gas-air accumulation entirely, and not layer-by-layer, the existence of high-frequency and low-frequency pressure pulsations determined by gas accumulations is ambiguous, the reasons and conditions for the formation and stability of gas-air accumulations are interpreted.

Thus, the analysis of the state of knowledge of the processes of formation of gas-air accumulations and their influence on hydraulic loads in the oil pipeline shows the need for new approaches to solve the problems caused by these phenomena.

According to numerous domestic and foreign works devoted to the unsteady flow of a real fluid in pipelines, mathematical modeling is practically the main way to study unsteady processes.

At the same time, the known mathematical models are limited in their capabilities, since they do not fully reflect all the factors influencing the fluid flow regime under these conditions, which does not allow investigating various aspects of the behavior of such complex interconnected systems. In this regard, the work proposes an innovative mathematical model.

Ensuring operational safety and stability of the main oil pipeline is the main task of all existing transport systems. One of the most successful and effective ways of solving the problem is methods based on the analysis and assessment of risk factors and their level for making management decisions to prevent the manifestation of crisis situations based on their forecast. Basically, all known methods are focused on analyzing the level of risk both at the design stage and during operation. At the same time, they do not allow assessing the risks of a number of unaccounted for or difficult to predict factors that complicate the operation of oil pipeline systems and appear during the operation of the main oil pipeline under conditions of increased hydraulic loads.

Currently, to protect the technological equipment of main oil pipelines from high pressure waves, there are various systems, methods and devices: surge tanks, which are widely used in low pressure pipeline systems to protect against hydraulic loads; an air cap that allows you to smooth out waves of different pressures by converting high-frequency pressure fluctuations into low-frequency ones with a reduced amplitude; automatic control system that smooths pressure waves by throttling the flow by means of control valves, etc. Despite a number of advantages in dealing with hydraulic loads, they have a number of significant disadvantages that appear when smoothing out pressure waves of high intensity and duration, which require elimination to improve the efficiency of oil transportation. Thus, the analysis of the current state of the problem allows us to draw the following

conclusion about the relevance and need for scientific research aimed at reducing the effects of hydraulic loads in the main oil pipeline along the profile of the route, which are of great scientific and practical significance.

**Basis and initial data for the development of the theme**

The basis for the development of the dissertation topic is the lack of universal methods for reducing hydraulic loads and scientific foundations for creating a physical model of formation, stability of gas-air accumulations, changes in the density of the transported liquid in a relief pipeline.

The operational data of the main oil pipeline of the Caspian Pipeline Consortium (CPC) were chosen as the initial ones for the development of the research topic.

**Justification of the need for this research work on the topic**

Ensuring the stability of work, industrial and environmental safety of the operation of the main oil pipeline based on the reduction of hydraulic loads of technogenic origin. This predetermines the need for research work on the topic of the dissertation and the solution of the tasks.

**Information about the planned scientific and technical level of development**

The high scientific and technical level and practical significance are determined by the high efficiency of development to reduce hydraulic loads in the main oil pipeline along the profile of the route and make informed management decisions to prevent risk situations or minimize their consequences. This was the result of solving the assigned tasks on the basis of an interdisciplinary approach using modern scientific advances in the field of fluid and gas mechanics, physical chemistry and molecular physics.

**Patent research**

Patent research in the work was carried out on the basis of an analysis of existing systems, methods and devices for protecting the equipment of an oil pumping station from high pressure waves. The main systems considered are: surge tanks, which are widely used in low pressure pipeline systems to protect against hydraulic loads; an air cap that allows you to smooth out waves of different pressures by converting high-frequency pressure fluctuations into low-frequency ones with a reduced amplitude; an automatic control system that smooths pressure waves by throttling the flow by means of control valves, etc.

**Conclusions on patent research**

Despite a number of advantages covered by patent studies of systems, methods and devices for protecting technological equipment of main oil pipelines from high pressure waves, they have a number of significant disadvantages associated with the technological modes of oil transportation. The most effective and economically viable system for reducing hydraulic loads is pressure wave mitigation systems. Three systems protected by patents were selected as analogs. The proposed system for smoothing pressure waves on counter streams has shown patentability and a patent application has been filed for it.

**Information on metrological support of dissertations**

Laboratory research in the work was carried out on the basis of the Department of Transportation and Storage of Oil and Gas, St. Petersburg Mining University. The results of laboratory research at the stand "Study of the phenomenon of water hammer" are confirmed by the use of modern measuring equipment, which has an accuracy class of 0.25-0.5. The devices undergo annual metrological verification.

**Relevance of the topic**

The operation of the main oil pipeline is accompanied by various operational problems, which boil down to manifestations of hydraulic loads and a decrease in throughput. An abrupt increase in pressure can damage the equipment, rupture the pipe and lead to an emergency with severe environmental consequences for the environment. Therefore, the solution to the problem of reducing the effects of hydraulic loads along the profile of the pipeline route is relevant and of great practical importance.

**The novelty of the dissertation topic.** For the first time, a physical model of the influence of surface and boundary effects of liquid-gas-solid contact on the process of formation and stability of gas-air accumulations has been created. An effective system for smoothing pressure waves in the main oil pipeline was developed, on which an application for a patent of the Republic of Kazakhstan was filed.

**Goals and objectives of research, their place in the implementation of the dissertation as a whole**

The aim of the work is to ensure the stability of the operation of the main oil pipeline in the event of hydraulic loads based on the forecast of risk situations and the adoption of preventive measures to prevent them.

To achieve this goal, the following tasks were identified:

- the creation of a mathematical model of unsteady fluid flow in a manifestation of hydraulic loads of great intensity;
- create a physical model of the effect of surface and boundary effects contact of the liquid-gas-solid on the formation and stability of gas-clusters at the vertices of the relief oil;
- experimental verification of the results of theoretical calculations
- development of an effective system for smoothing pressure waves in the main oil pipeline;
- development of a methodology for expert assessment and ranking of sections of the main oil pipeline by the level of difficult to predict risk factors.

**The objects of research** are the main oil pipeline of the Caspian Pipeline Consortium (CPC).

**The subject of research** is the hydraulic loads of varying intensity in the main oil pipeline.

**Positions submitted for defense**

- mathematical model of unsteady fluid flow under conditions of high-intensity hydraulic loads;

- physical model of the influence of surface and boundary effects of liquid-gas-solid contact on the formation and stability of gas-air accumulations in the tops of a relief oil pipeline;

- effective system for smoothing pressure waves in the main oil pipeline;

- a methodology for expert assessment and ranking of sections of the main oil pipeline by the level of difficult-to-predict risk factors.

**The theoretical and practical significance of the work.**

The theoretical significance of the work lies in an innovative, original approach to modeling unsteady fluid flow in a relief oil pipeline, and solving the problem of the formation and stability of gas-air accumulations.

The practical significance of the results lies in the creation of a methodology for assessing risk factors and their level, ranking oil pipeline sections according to the state of problematicity to predict possible manifestations of crisis situations and take preventive measures to prevent them; development of a device for smoothing pressure waves and having great prospects in ensuring the stability of the operation of the main oil pipeline on the basis of reducing hydraulic loads.

**Testing results of the thesis.**

The main results of the dissertation work were reported at the International Scientific Conference "High Technologies and Innovations in Science" (St. Petersburg, 2018), the International Conference Satpayev Readings "Innovative technologies - the key to successfully solving fundamental and applied problems in the ore and oil and gas sectors of the economy RK "(Almaty, 2019), the International Scientific Conference" Science. Research. Practice "(St. Petersburg, 2019), IV International Scientific and Practical Conference" WTO Membership: Prospects for Scientific Research and the International Technology Market "(Vancouver, 2019).

**Publications.**

The main results of the study are presented in 11 publications, including in journals included in the Scopus database - 2 articles, in publications from the list approved by the Committee for the Control of Education and Science of the Republic of Kazakhstan - 4 articles, a patent of the Republic of Kazakhstan, equivalent to articles from the list approved by the Committee for Control in Education and Science of the Republic of Kazakhstan - 1, abstracts of the report at international conferences - 4.

**The structure and scope of the thesis.**

The dissertation work consists of an introduction, 4 sections, a conclusion, a list of references from 104 titles. The work is presented on 111 pages, includes 40 figures and 15 tables.

**Thesis summary**

The introduction gives an assessment of the current state of the scientific and technical problem of reducing the effects of hydraulic loads along the profile of the pipeline route and substantiates the relevance of the topic of the dissertation work.

**The first section** provides an analysis of research work aimed at reducing hydraulic loads. Based on the analysis results, the goal of the work was set and the tasks for its achievement were determined.

Analysis of the current state of the problem of reducing the effects of hydraulic loads in the main oil pipeline shows:

1. The classical theory of unsteady fluid flow in pipelines and mathematical models based on its conclusions have a limited scope and, in most cases, turn out to be unacceptable for calculating transient processes in relief main oil pipelines and need to be improved;

2. A large number of studies of technological processes and modes of main, field pipelines are devoted to the issue of the influence of gas accumulations on the throughput of a pipeline. At the same time, many questions directly related to the processes and properties of the formation of stable gas-air accumulations remain open. There are no explanations for the experimentally revealed facts, such as the removal of a gas-air accumulation entirely, and not layer-by-layer, the existence of multi-frequency pressure pulsations determined by gas accumulations in the section, the reasons and conditions for the formation of gas-air accumulations are interpreted ambiguously.

3. Despite the large number of known technologies, methods and technical devices for smoothing pressure waves, the development of new and improvement of existing ones is of great scientific and practical interest.

4. The main oil pipeline, which has a large length, is a complex system of serially connected technological elements, each of which performs a certain transformation of parameters and, therefore, requires special approaches in assessing risk factors and their level to ensure its industrial and environmental safety.

**Statement of thesis problems.**

To ensure the reliability, stability and safety of operation of main oil pipelines based on the reduction of hydraulic loads, taking into account the results of the analysis of the state of the problem, the following tasks were set in the work:

- creation of a mathematical model of unsteady fluid flow under conditions of high-intensity hydraulic loads.
- creation of a physical model of the influence of surface and boundary effects of liquid-gas-solid contact on the formation process and stability of gas-air accumulations at the tops of a relief oil pipeline;
- experimental verification of the results of theoretical calculations and mathematical modeling;
- development of an effective system for smoothing pressure waves in the main oil pipeline;

- development of a methodology for expert assessment and ranking of sections of the main oil pipeline by the level of difficult-to-predict risk factors.

**The second section** presents theoretical studies of unsteady liquid flow and formation processes, the stability of gas-air accumulations in a relief oil pipeline.

1. The dependence of the stability of gas-air accumulations on the angle of inclination of the oil pipeline and the speed of the flow from the conditions of equilibrium of all forces was determined (Figure 1):

$$\overrightarrow{F_C} + \overrightarrow{F_{\text{тр}}} = \overrightarrow{R_{II}} \tag{1}$$

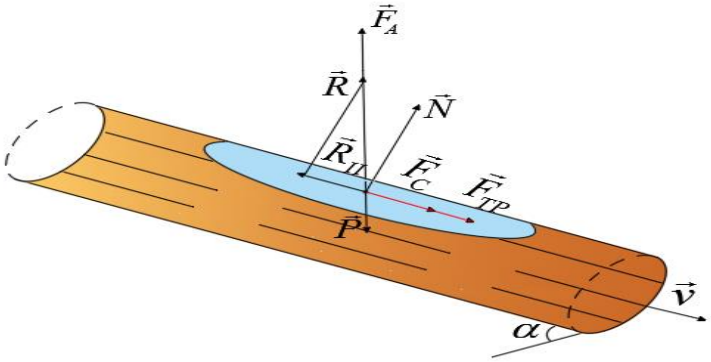


Figure 1 - Fragment of an oil pipeline with a gas-air accumulation

$\vec{v}$ – the speed of the oil flow, $\alpha$ – oil pipeline tilt angle. $\overrightarrow{F_A}$ , $\vec{P}$, $\vec{R}$, $\overrightarrow{R_{||}}$, $\overrightarrow{F_c}$ , $\vec{N}$, $\overrightarrow{F_{\text{тр}}}$ forces acting on the air cluster, respectively, Archimedes force, weight, resultant force, projection of the resultant force on the pipeline axis, Stokes force, normal pressure, friction force.

From equation 1, the minimum angle of inclination of the oil pipeline at which the gas accumulation is in a state of equilibrium, $\alpha_{min}$ will be determined by the condition:

$$\sin\alpha_{\min} = \frac{2K\sigma_{жг}\sin\theta + CS\eta_{ж}\upsilon}{S\rho_{ж}g}, \tag{2}$$

Accordingly, the minimum flow rate $v_{min}$ , at which the gas-air accumulation will be held on the pipe wall:

$$\upsilon_{\min} = \frac{2K\sigma_{жг}\sin\theta - S\rho_{ж}g\sin\alpha}{CS\eta_{ж}}, \tag{3}$$

where $K$ is the coefficient of friction, $\sigma_{t.l.}$- liquid-gas surface tension coefficient; $\theta$- contact angle, $\eta_j$- viscosity, $\rho_j$ – density, $\upsilon$ - the velocity of the fluid flow

2. Factors and processes influencing the mode of oil transportation in a relief oil pipeline in conditions of high intensity hydraulic loads are determined

3. A new mathematical model of unsteady fluid flow in a relief oil pipeline has been developed, under conditions of the manifestation of hydraulic loads in the form of high-intensity pressure waves, which has shown its effectiveness.

4. It has been established that the density of the transported liquid in the relief pipeline decreases due to the barometric effect.

5. A physical model of the influence of surface and boundary effects of liquid-gas-solid contact on the process of formation and stability of gas-air accumulations at the tops of a relief oil pipeline has been developed

The third section presents experimental studies of unsteady fluid flow and the development of technical solutions to reduce hydraulic loads.

1. Developed and implemented a problem-oriented technological scheme of a laboratory installation for experimental studies of the dependence of the velocity and amplitude of a shock wave in a relief pipeline on the velocity, temperature and gas saturation of the flowing liquid (Figure 2) ;

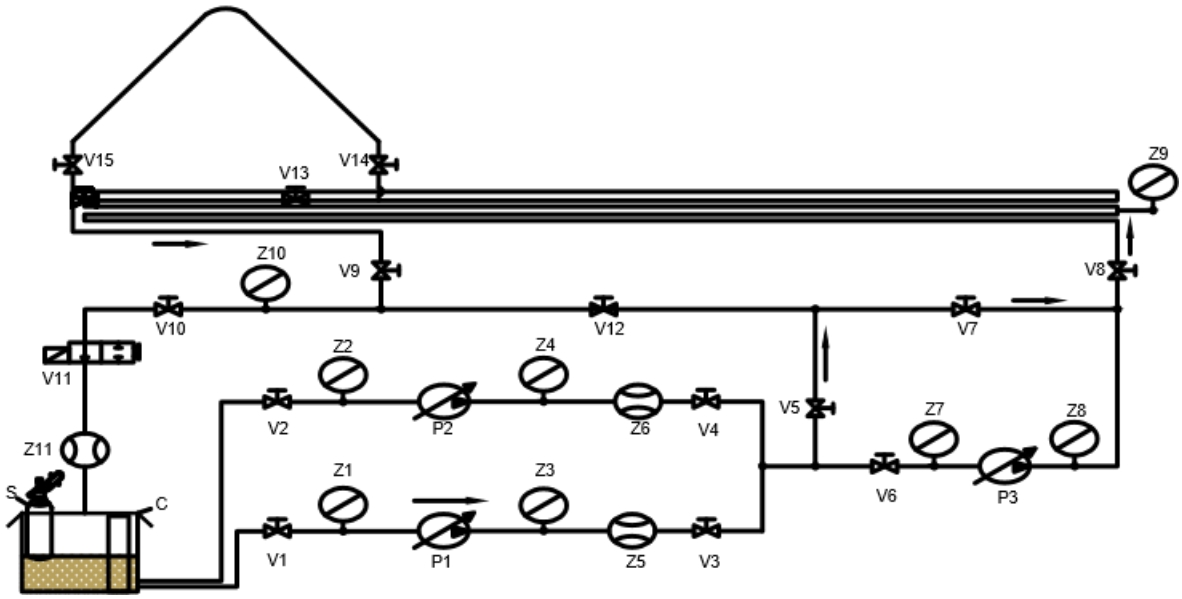


Figure 2 - Basic hydraulic diagram of the laboratory bench with the changes introduced

P1-P3 - dynamic variable pumps; V1-V10, V12-V15 – shut-off valves with manual control; V11- valve with electric control; Z1-Z4, Z7-Z10 – analog pressure sensors; Z5, Z6, Z11- analog flow sensors, s- siphon, c- cap.

2. The results obtained and the comparative analysis showed that the calculations of the proposed mathematical model for the conditions of the manifestation of high-intensity hydraulic loads, built on the basis of the regularities of the formation and stability of gas-air accumulations at the tops of a relief oil

pipeline, changes in oil density due to the barometric effect coincide with experimental data and theoretical conclusions.

3. A system has been developed for smoothing pressure waves on counter streams, which performs all the necessary functions to control and manage the transportation mode in order to prevent the manifestation of a risky situation or minimize their consequences.

4. The system provides regulation of the amplitude of pressure waves by the amount, speed and direction of the inlet-outlet fluid by the relief valves according to a predetermined algorithm, which allows the system to operate in several modes of smoothing, including the self-regulation mode and prevents the passage of an increased pressure wave into the working area of the pump station.

**In the fourth section**, the issues of ensuring industrial and environmental safety of the operation of main oil pipelines are considered and an assessment of economic efficiency is given.

A technique has been developed for expert qualitative and quantitative risk analysis of difficult-to-predict manifestations of emergencies during the operation of oil trunk pipelines. The task of identifying risky sections of the pipeline was solved on the basis of a retrospective causal analysis of the occurrence, development of risk situations and accidents that occurred in the world practice of using main oil pipelines, and independent expert opinions of specialists in the design, operation of oil pipelines, and the fight to prevent emergencies.

Figure 3 shows a diagram of an expert assessment of the level of risk factors by sections of the pipeline.

In accordance with the principles laid down in the methodology, risk factors were ranked by sections of main oil pipelines according to the qualitative and quantitative level of contribution to the total risk by dividing into high, medium and low levels using 50%, 75% boundary quartiles, determined on the basis of statistical analysis of the distribution of points for "risk density".

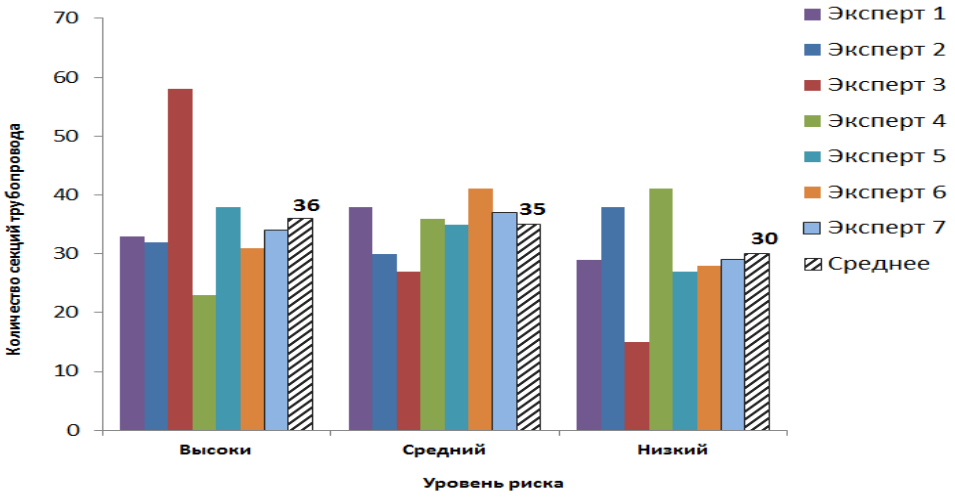

Figure 3- The result of an expert assessment of the level of risk factors for pipeline sections

The method, based on the example of CPC, makes it possible to halve the cost of organizing and conducting technical control.

The expected economic effect is a consequence of the development of methods and means for increasing the reliability and long-term forecasting of crisis situations associated with the manifestation of high-intensity hydraulic loads (water hammer) and ensuring the timely adoption of measures to prevent them. The magnitude of the economic effect is determined by the saving of colossal material costs for the elimination of the consequences of man-made disasters in the event of their prevention.

**Brief conclusions based on the results of dissertation research.**

The main pipeline is a combination of successively alternating, heterogeneous technological elements, functionally integrated into a single system to ensure the necessary conditions for transportation.

An uncontrollable deviation of the technological parameter of any element from the specified one can lead to the manifestation of hydraulic loads in the form of a sudden increase in pressure, which can damage the equipment, rupture the pipe and lead to an emergency with severe environmental consequences for the environment. Therefore, the solution to the problem of reducing the effects of hydraulic loads is urgent and of great practical importance. In the dissertation work, scientifically based methods and means were developed to reduce the effects of hydraulic loads.

This made it possible to obtain the following main results, reflecting the scientific novelty and practical significance of the work.

The main factors and processes influencing the mode of oil transportation in relief oil pipelines in conditions of high-intensity hydraulic loads are determined, the consideration of which made it possible to create a highly effective mathematical model of unsteady fluid flow. In the model, for the first time, a decrease in the density of the transported liquid in a relief pipeline based on the barometric effect was established.

The characteristic features of the formation and stability of gas-air accumulations at the tops of a relief oil pipeline are revealed. It has been established that the main factors influencing the formation and stability of gas-air accumulations are surface and boundary effects of liquid-gas-solid contact. A physical model of the influence of surface and boundary effects of liquid - gas - solid contact on the formation process and stability of gas-air accumulations has been developed. The dependence of the stability of gas-air accumulations on the angle of inclination of the oil pipeline and the flow rate is determined.

The mathematical model makes it possible to determine possible ways of influencing the process of formation of hydraulic loads and rational ways to reduce

them, to create optimal and effective systems for protecting PS equipment from pressure waves.

The efficiency of the developed system for smoothing pressure waves on counter flows has been theoretically substantiated and experimentally proved. The system performs all the necessary functions to control and manage the transportation mode in order to prevent the manifestation of risky situations or minimize their consequences. The system provides regulation of the amplitude of pressure waves by the amount, velocity and direction of the inlet-outlet fluid by the relief valves according to a given algorithm, which allows the system to operate in several modes of smoothing, including the self-regulation mode.

To study the influence of the relief of the pipeline, gas saturation, temperature and velocity of the transported liquid on the amplitude and velocity of the shock wave propagation, to compare the experimental data with the results of mathematical modeling and theoretical conclusions, a problem-oriented technological scheme of the laboratory installation was developed and implemented.

The obtained results and comparative analysis showed that the calculations of the proposed mathematical model for the conditions of the manifestation of high-intensity hydraulic loads, built on the basis of the regularities of the formation and stability of gas-air accumulations at the tops of a relief oil pipeline, changes in oil density, due to the barometric effect, coincide with experimental data and theoretical conclusions.

A method of qualitative and quantitative expert assessment of risk factors and their levels in the design, construction and operation of the main oil pipeline has been developed. To increase the reliability of assessing the level of the risk factor determined by the spatio-temporal changes in the stress-strain state of the massif in which the oil pipeline is laid, the results of zonal zoning are used. The methodology allows for risk analysis of difficultly predicted manifestations of emergencies and to rank sections of the pipeline according to three risk levels: high, medium and low.

**Assessment of completeness of problem solving.**

All tasks set in the work are fully solved:

- created a mathematical model of unsteady fluid flow under conditions of high intensity hydraulic loads;
- a physical model of the influence of surface and boundary effects of liquid-gas-solid contact on the process of formation and stability of gas-air accumulations at the tops of a relief oil pipeline has been created;
- experimental verification of theoretical conclusions and results of mathematical modeling
- an effective system for smoothing pressure waves in the main oil pipeline has been developed;
- developed a methodology for expert assessment and ranking of sections of the main oil pipeline by the level of difficult to predict risk factors.

**Recommendations and baseline data for specific use of results.**

The results obtained can be used in various transport pipeline systems for pumping liquids.

The methodology of expert assessment and ranking of sections of the main oil pipeline by the level of difficult-to-predict risk factors was used when ranking sections of the main oil pipeline CPC.

**Assessment of the economic efficiency of technology.**

The method based on risk analysis allows predicting possible manifestations of crisis situations of natural and man-made origin. Thus, the methodology for the qualitative and quantitative assessment of risk factors and their levels, the pressure wave smoothing system developed in the work, allow preventing the emergence and development of crisis situations, increasing the level of industrial and environmental safety of the operation of the main oil pipeline. This predetermines the saving of colossal material costs for the elimination of possible man-made disasters and the solution of the associated environmental consequences.

**Assessment of the scientific level of the work performed in comparison with the best achievements in this field.**

The complexity of the tasks and the development of innovative methods and tools predetermined an interdisciplinary approach to their solution using the methods of molecular physics and physical chemistry with the expansion of the applicant's competence. This, together with the significance of the results obtained, allow us to conclude that the dissertational work corresponds to the modern scientific and technical level, which is confirmed by publications in the corresponding works of the author and the discussion of the results at international conferences at various levels, obtaining a patent of the Republic of Kazakhstan.

**List of published works on the topic of the dissertation:**


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3. Imansakıpova N.B., Irgıbaev T.I. Analız faktorov, vlıaıýıh na gıdravlıcheskıe nagrýzkı nefteprovodov // Vestnık KazNITÝ, Almaty, 2018, №2 (126) - S. 242-247, ISSN 1680-9211
4. Kıdırbaev B.I., Kakımjanov E.H., Imansakıpova N.B., Kosnıkov V.A. Spetsıalızırovannaıa geoınformatsıonnaıa sıstema ýpravlenıia tehnogennymı

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7. Baıgýrın J.D., Spıtsyn A.A., Imansakıpova B.B., Kojaev J.T., Imansakıpova N.B Patent na ızobretenıe №33566 «Sposob razrabotkı poleznyh ıskopaemyh v oslablennyh zonah mestorojdenıı» // KazNITÝ, g.Almaty

8. Samıgýllın G.H., Imansakıpova N.B. Modelırovanıe voln davlenıia prı voznıknovenıı gıdroýdara v nefteprovode // Mejdýnarodnaıa konferentsıia «Vysokıe tehnologıı ı ınnovatsıı v naýke», Sentıabr 2018, Sankt-Peterbýrg, S.77-82, ISBN 978-5-6041437-4-2

9. Imansakıpova N.B., Irgıbaev T.I., Bakesheva A.T. Vlıianıe protsessov obrazovanıia gazovozdýshnyh skoplenıı na effektıvnost raboty nefteprovoda // Mejdýnarodnaıa naýchnaıa konferentsıia «Innovatsıonnye tehnologıı –klıých k ýspeshnomý reshenııý fýndamentalnyh ı prıkladnyh zadach v rýdnom ı neftegazovom sektorah ekonomıkı RK», Almaty, 2019, KazNITÝ, S. 427-430, ISBN 978-601-323-145-7

10. Samıgýllın G.H., Savelev D.V., Imansakıpova N.B. Otsenka eksplýatatsıonnyh rıskov magıstralnyh nefteprovodov // Mejdýnarodnaıa naýchnaıa konferentsıia «Naýka, ıssledovanıia, praktıka», Aprel 2019, Sankt-Peterbýrg, S.123-126, ISBN 978-5-9500836-9-3

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