REPUBLIC OF AZERBAIJAN

On the rights of the manuscript

ABSTRACT

of the dissertation for the degree of Doctor of Philosophy
(Doctor of Science)

DEVELOPMENT OF GEOECOLOGICAL MEASUREMENT METHODS IN THE CONSTRUCTION AND OPERATION OF UNDERGROUND PIPELINES

Speciality: 3337.01 – information-measuring and management systems (Technological measurement)

Field of science: Technical sciences

Applicant: **Habib Mirgalib Nasirov**

Sumgayit - 2022

The work was performed At the Institute of Ecology of the National Aerospace Agency

Scientific supervisor: doctor of technical sciences, professor
Tofig İbrahim Suleymanov

Official opponent: doctor of technical sciences, professor
Aminaga Bahman Sadigov

doctor of technical sciences, professor
Javanshir Firudin Mammadov

doctor of technical sciences, professor
Bayram Ganimat Ibrahimov

Dissertation council FD 2.25 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at Sumgayit State University

Chairman of the Dissertation council: doctor of Technical Sciences, professor
Aqil Hamid Huseynov

____

Scientific secretary of the Dissertation council: doctor of Philosophy in Technology, Accocciate professor
Turqay Klim Huseynov

____

Chairman of the Scientific seminar: doctor of technical sciences, professor
Ali Hasan Nagiyev

____

INDRODUCTION

The topic relevance and elaboration degree. Nowadays, many industries, including the fuel and energy complex have a great importance in providing and developing the economic stability of our country. Increasing the economic efficiency of this area is achieved not only by improving the quality of exploitation of existing resources, the commissioning of new fields, but also by the industrial and environmental safety and reliability of existing infrastructure. That is why, there is a need to monitor, assess, forecast and optimize for the condition of gas – oil transportation pipelines.

Modern monitoring systems of underground gas – oil pipelines take into account to perform the following functions:

-technical diagnostics of the pipeline;

-plan–elevation of condition of pipline and monitorinparameters which is characterizing the elevation and hydrogeological conditions.

The main issues which is solved by using monitoring systems are following.

- Detection of violations of the technical condition of the pipeline;
- Carrying out regular monitoring of pipeline areas laid in zones of complex geological conditions;
- Assessment of the impact of active processes in the subsoil on the stress-strain state of the pipeline
- Identification of corrosion hazard zones of high seismically active zones, floods and salinization areas;
- To perform diagnostic researches, etc.

However, because of the existing pipeline monitoring systems operate only during pipeline operation and are based primarily on contact-type primary gauges, they are not considered suitable for initial pipeline design, site monitoring and selection of optimal routes based on monitoring results.

Thus, the creation of universal monitoring systems based on not only contact-type primary measuring transducers, but also aerial surveillance, remote sensing technology, laser scanners, which can perform both pipeline design and control functions during operation, and provide their production and environmental safety on a new basis is proposed as a topical issue.

Object and subject of the research: Main pipelines, results of geoecological measurements in the land areas where the pipelines pass, analytical statements of the dependence of corrosion losses on the specific parameters of the soil, as well as spectral indices of the assessment of the soil condition parameters were taken as the research object of the dissertation work.

The subject of the research consists of the methods of conducting diagnostics and geoecological measurements of pipelines, the detection of integral indicators of the detection of leaks in pipes, the development of the methods of determining the volume of spectral measurements for monitoring and the optimal drawing route of pipes.

The purpose and objectives of the research. The main purpose of the dissertation is to develop the scientific and methodological basis for the creation of a universal monitoring system for geoecological measurements, control and evaluation of the pipeline and the area where it passes through during the design and operation of main gas – oil pipelines.

To achieve this goal, the following tasks were set and solved within this thesis paper:

1. The improvement of the geo-ecological measurements in the territories of gas – oil terminals and pipelines of Azerbaijan and development of lidar-thermal measurement methods for periodic monitoring of the pipeline.
2. The development of a time period model for corrosion monitoring of underground pipelines which depend on the physical properties of the soil and determination of the optimal temperature regime to minimize corrosion losses.
3. Solving the problem of optimizing of the founding out the relationship between the degree of corrosion of the pipeline and the specific resistance of the soil, temperature and electrical conductivity.
4. Use of an integrated model of the semivariogram, which allows to measure corrosion in the elevation zones of the pipeline, classification of soil corrosion aggression on the basis of measured values of specific resistance.

5. The improvement of new spectral index consisting of a combination of Landsat ETM + satellite measurements and a method for determining the required number of spectrometric measurements in the monitoring of oil-covered lands.

6. Using of a diagnostic method that allows to determine the location of leaks in underground gas pipelines based on the new measurement signal.

7. Determination of the analytical expression of the thickness and diameter of the pipe wall, which is considered resistant to impact, depending on the tensile stress and the solution of the problem of optimizing the minimum value of the compressive stress.

8. The using of an integrated indicator of the exposure of the pipeline to landslides and the peak value of soil acceleration along the entire route and a method for determining the optimal laying route.

Research methods. Elements of atmospheric and soil physics, metal corrosion theory, remote spectral probing, spectral properties of gases, methods reflecting physical and chemical laws of seismology were used to solve the problems of the dissertation. The theoretical implementation of these methods was carried out according to the main provisions of mathematical analysis, integral and differential calculation methods, the theory of variational optimization.

The main provisions submitted for defense.

1. Method of geoecological measurements in the areas where pipelines and gas – oil terminals are located and a model for determining the optimal time period of corrosion monitoring.

2. The lidar-thermal sounding method of the control of underground main pipelines is the optimal expression of the relationship between the flight height and the initial ground voltage, which provides the reduction of the measurement error.

3. Analytical expression of the corrosion losses in the pipeline which depends on the specific parameters of the soil and furthermore, the regularity of changes in the specific resistance of the soil, which provides the minimization of these losses.

4. Optimal integrated model of the semivariogram, which allows to measure the variability of the specific resistance of the soil

in the elevation zones, and the procedure for classifying soils for corrosion aggression.

5. Graphical-analytical method for determining the volume of necessary spectral measurements which is required for monitoring oil-covered lands, and a new spectral index for assessing the condition of different soil types.

6. Determining of the location of leaks from underground gas pipelines which is based on the method of the new signature.

7. Integral indicator of the exposure of the pipeline to the peak value of soil acceleration in the seismically active zone and on slopes with different steepness, and the method of determining the optimal laying route.

8. Analytical expression of the relationship between the outer diameter of the pipe and the wall thickness, which provides the minimum value of the compressive stress as a result of possible mechanical effects.

Scientific novelty of the researches.

1. For the first time, the methods for improving geoecological measurements, relevant control procedures, corrosion monitoring period, taking into account the functional characteristics of gas – oil terminals and pipelines in Azerbaijan, have been proposed.

2. The method of lidar-thermal remote sensing, the optimal relationship between the flight height of the sensor carriers and the initial ground voltage has been determined to reduce errors in determining the position and geometric coordinates of the underground pipeline.

3. A new expression was obtained to determine the dependence of the underground pipeline corrosion losses on regime parameters such as temperature, pH, soil resistance, and the condition of inversion of soil temperature was found to be necessary to minimize corrosion losses over time.

4. To determine the degree of integrated soil corrosion, a new indicator which consists of integral of the product of the specific resistance which is related to the soil multiply with the length of the pipeline was proposed, and a constraint condition was established to ensure the smooth operation of the pipeline.

5. A new mathematical expression for the condition that corrosion can reach a maximum is obtained on the basis of a linear model of the decrease in electrical conductivity with increasing soil temperature.

6. For the initial time, an averaged integrated model of a semivariogram has been proposed to measure the specific resistance of the soil during the construction of a pipeline in high-altitude areas, and the possibility of demonstration this model as a mathematical polynomial has been informed.

7. A new method based on the inverse relationship between the concentration of methane and oxygen and the optimal function of the distance between the measurement points has been proposed in order to determine the location of gas leaks from the pipeline.

8. A new approach based on the inverse relationship between the steepness of the slopes and the peak value of the accelerations in the selection of the pipeline route has been proposed, and an optimal design methodology has been used, taking into account possible mechanical effects.

Theoretical and practical significance of the research.

1. Lidar-thermal remote sensing method with optimal selection of on-board measurement system mode parameters allows to increase the accuracy of determining the coordinates of underground pipelines, which is especially important for periodic monitoring over large areas.

2. Analytical expression of values which is related to corrosion losses of the pipeline, integrated soil corrosion index, pipeline model characterizing the degree of corrosion in different zones, mathematical dependencies between different factors affecting the intensity of corrosion. can be used successfully in the development of foundations.

3. Optimal averaged integrated semivariogram synthesized on the basis of the Gaussian model allows to determine the specific resistance of soils in high-altitude areas, which is not only important in the research of soil corrosion in difficult terrain, off-road conditions, but also cost-effective in terms of economy.

4. The proposed new spectral index for assessing the condition parameters of land plots, graphical-analytical method for determining the volume of spectral measurements will allow developing more

accurate indication models for the classification of soil types and oil-contaminated areas degraded by anthropogenic factors and natural processes.

5. Ensuring the inverse relationship between the steepness of the slopes and the peak value of the accelerations in landslide zones, the optimal functional relationship between the diameter of the pipe and the wall thickness, and furthermore, taking into account possible mechanical effects for the design methodology which is used for decreasing of the risk exposure in breaking and dissection contribute to ideal and perform with cost-effective way which have a special practical significance in the presentation.

Approbation and implementation. The main results of the dissertation were reported and discussed at the meeting of United Scientific – Technical Council of NASA and the following international conferences:

1. XII International scientific-practical conference "Actual problems of ecology and labor protection", Russia, Kursk, May 20, 2020.
2. Information systems and technologies: achievements and perspectives. International Scientific Conference. Sumgait State University, July 9-10, 2020.
3. Proceedings of the International Conference. International Journal of Advanced Studies in Computer Engineering. St. Louis, Missouri, USA, April 2022, №1.

The main results of the thesis have been recommended by the experts who is used in the assessment of the condition of the pipeline route in the Oil Pipeline Department of the State Oil Company of Azerbaijan Republic, in the corrosion monitoring of terminal areas (act of application dated October 1, 2021 is attached to the thesis paper).

Name of the organization of the thesis paper performance. The dissertation was carried out at the Institute of Ecology of the National Aerospace Agency of the Ministry of Defense Industry of Azerbaijan Republic.

The total volume of the thesis paper, taking into account the volumes of individual structural sections. The dissertation was written in accordance with the requirements set by the Higher

Attestation Commission under the President of the Republic of Azerbaijan.The introduction consists of 17140 characters, I chapter of 38800 characters, II chapter of 32000 characters, III chapter of 33286 characters, IV chapter of 41966 characters. The total volume of the dissertation is 163192 characters.

MAIN RESULTS OF THE DISSERTATION WORK

The introduction substantiates the relevance of the topic, forms the goals and main objectives of the study, outlines the novelty, practical value and implementation of the results obtained.

The first chapter of the dissertation is devoted to the issues of optimal organization of geo-ecological measurements in the monitoring system used in the construction and operation of underground gas – oil pipelines. First of all, the main functions of the complex geological process monitoring system in the construction of main pipelines developed jointly by the Russian Transoil Society and the Bauman Higher Technical School were studied, the type of the measurements has been analyzed and some shortcomings in the methodological approaches have been improved. After that devices of geo-ecological measurements, control methods and procedures which are essential to be carried out during the operation of the Dubandi and Sangachal terminals and the pipelines they serve in the territory of Azerbaijan has been determined. Soil corrosion potential, hydrological processes, natural-destructive events have been researched as the main factors in the geo-ecological monitoring of the pipelines, and for this purpose the laser and infrared measurement methods of remote sensing used in world practice have been explained.

Taking into account the what are mentioned above, to calculate the depth of corrosion which has been got as a result of previous experimental studies[1]

$$P_0 = 0{,}5 k_0 \cdot t^{0{,}373} \qquad (1)$$

dependence has been investigated

where P_0 – the ratio of the maximum corrosion depth to the average value of the maximum corrosion depths under certain conditions characterizing the condition of the soil, k_0 – the experimental value of a quantity that depends on the physical properties of the soil, t – is when the maximum corrosion depth is recorded. At the mentioned dependency, due to the characteristics of the geographical areas are not taken into account, a model has been proposed to determine the optimal time period for corrosion monitoring. Because of this, that is assumed that the general heterogeneity of the soil in the area where the pipeline is laid as the main factor. For this, the area in question is divided into n number of $_i\ (i = \overline{1,n})$ fields, and it is assumed that $k = \{k_i\}$ it is a regular set, so $k_i = k_{i-1} + \Delta k;\ \Delta k = const;\ k_0 = 0$ the condition is satisfied. In this case, the average value of the maximum corrosion depth is defined as follows.

$$P_{or} = \frac{1}{n}\sum_{i=1}^{n} k_i \cdot t^n \qquad (2)$$

Since the lifespan of the individual parts of the pipeline is not the same, the problem of finding $t = f(k)$ the optimal function that provides the minimum value of P_{or} was considered. To do this, the expression in the continuous variant (2) within the constraint condition

$$P_{or.k} = \frac{1}{k_{\max}} \cdot \int_0^{k_{\max}} f(k)^n\, dk \qquad (3)$$

[1] Soil corrosivity analysis. http://www.corrosionsurvey.co.kr/viewer/pdf/n_02.pdf

presented as and F purpose of optimization is designed functionally:

$$F = \frac{1}{k_{\max}} \cdot \int_0^{k_{\max}} f(k)^n\, dk - \lambda\left[\int_0^{k_{\max}} f(k) dk - C\right]$$

where λ is lagrange multipiler. Thus, the function f (k), which maximizes the function F, is found by the method of variation optimization as follows:

$$f(k) = \sqrt[(1-k)]{k} \cdot C_1; \qquad C_1 = \sqrt[(1-k)]{\frac{n}{k_{\max} \cdot \lambda_0}} \tag{4}$$

Thus, it has been determined that the period of periodic monitoring should be smaller than the period determined by expression (4) and the corrosion depth should not be allowed to reach its maximum.

Then, in that chapter, the issue of optimizing the periodic monitoring of oil penetration into the soil from the pipeline as a result of the accident has been considered. First of all, the maximum depth of penetration of oil products in different types of soils, the amount of evaporation, the storage capacity of the soil, etc. the average depth of oil penetration into the studied, water-saturated soil has been determined as follows.

$$D_{or}{}^2 = \ln t \cdot \left[a_1 a_3 T^2 + T\left(-a_2 \cdot 15 \cdot a_4 + a_2 \cdot a_3 + a_1 a_4\right) + a_1 a_3 - a_2 a_3 15\right] \tag{5}$$

where a_1, a_2, a_3, a4 are the volume of actively spilled oil, being the technological constant characterized by the ambient temperature, the area of the oil pond on the ground, the viscosity of the liquid, the storage capacity of the soil, t is the time period. It is also shown that this condition is satisfied in order for the expression (5) to receive a minimum value depending on the ambient temperature T as follows:

$$T_{opt} = \frac{a_2 a_3 + a_1 a_4 - 15 a_2 a_4}{a_2 a_4} \tag{6}$$

Furthermore, the potential accuracy of lidar and thermal control of the route through the underground pipelines has been considered. Similarly, the rise in soil level under the influence of stress was estimated by the Fredlund and Paxorco formula:

$$S_h = \frac{C_s}{1 + e_0} \cdot h \cdot \log\left(\frac{P_f}{P_0}\right). \tag{7}$$

where S_h is rising surface level, m; h is the thickness of the soil on the pipeline; C_S is initial value of soil swelling coefficient; P is the current voltage of the ground. In this regard, such an issue which is related to optimal $P_0 = \varphi(h)$ dependence has been to propose so that

$S_{h.or} = \frac{1}{h_{\max}} \int_0^{h_{\max}} \left(\frac{C_s}{1+e_0} \right) \cdot h \cdot \log \left(\frac{P_f}{P_0} \right) dh$ the average integral value reaches a minimum.

The zone through which the pipeline passes is accepted $\int_0^{h_{\max}} \varphi(h) dh = C;\ C = const$; because it is geotechnically homogeneous. By using conditions of Euler – Lagrange equation

$$F = \frac{1}{h_{\max}} \int_0^{h_{\max}} \left(\frac{C_s}{1+e_0} \right) \cdot h \cdot \log \left[\frac{P_f}{\varphi(h)} \right] dh + \lambda \left[\int_0^{h_{\max}} \varphi(h) dh - C \right]$$

the optimization problem is solved and the value $\varphi(h) = \frac{2Ch}{h_{\max}^2}$ that minimizes F is obtained. That is why, it is shown that in a geotechnically homogeneous environment, the depth of the pipe should be proportional to P_0, and it is really possible to reduce the errors caused by hydro mechanical processes.

The analysis of the optimal placement depth of the pipe in a homogeneous environment shows that the sufficient condition for satisfying the possible necessary condition of the optimality of the above solution is true for each of the points ht1 and ht2. But for the $P_{02} = \psi(h)$ function, this condition is satisfied only at the point ht2. Thus, it can be considered that the proposed solution is a condition for the minimum integral value of the swelling of the soil layer above the underground pipeline.

The second chapter of the thesis paper the issue of measuring soil corrosion in the monitoring system of main underground gas – oil pipelines is considered. Based on Wenner's "four-pin" method used in the world, the concentration of moisture and salt ions in the formation of soil corrosion potential is presented as the main indicators of soil specific resistance.

Taking these into account, the calculations proposed by other authors[2] were based on the following expression of the dependence of soil electrical conductivity (σ) on its water content (θ), electrical conductivity of dry soil (σ_s) and mud content (σ_w).

$$\sigma = \left(a\theta^2 + b\theta\right)\sigma_w + \sigma_s\,; \qquad a, b = const \qquad (8)$$

For this purpose, the known $pH = 5{,}403 - 0{,}152\sigma\left(\text{мS}/\text{м}\right)$ relationship between soil pH and electrical conductivity at a depth of 0.45 m was taken into account and a methodology for determining the main parameters for corrosion protection of the pipeline was proposed:

1. Calculation of electrical conductivity (8) by giving different values (σ) of soil volume to water composition (θ).

2. By taking into account (8) dependency expression,

$$pH = 5{,}403 - 0{,}152\cdot 10^3\left[\left(a\theta^2 + b\theta\right)\sigma_w + \sigma_s\right]$$

the calculation of value of formula.

3. As a result of corrosion, by taking into account the dependence of weight loss of metal (W) from duration of action (t) and also from pH, the expression is calculated as follows($A = const;\ d_1,\ d_2,\ a,\ b = const$).

$$W = \left[A - \left(d_1 + d_2\left[5{,}403 - 0{,}152\cdot 10^3\left[(a\theta^2 + b\theta)\sigma_w + \sigma_s\right]\right]\right)\right]\cdot t \qquad (9)$$

4. By taking into account $\theta, \sigma_w, \sigma_s$ indicators, if the function of $\theta = \theta(t)$ exists then calculation of the extremum of a function.

[2] Grandjean G. From geophysical parameters to soil characteristics / G.Grandjean, I.Cousin, M.Seger [et. al.] // Report № BRGM/FP&-DIGISOIL-D2.1. p. 52.

$$F = \int_{t_{\min}}^{t_{\max}} \left[W\left(A, d_1, d_2, a, b, t, \sigma_w, \sigma_s, \theta(t)\right)\right]dt$$

5. The determination of expression (8) as $W = \left[A_0 + k_4\theta^2 + k_5\theta\right]\cdot t$ within the constraint condition $F_1 = \int_{t_{\min}}^{t_{\max}} \theta(t)dt = C;\quad C = const$.

where the parameters A0 = A · K1; K4 = K2 · σ_W; K5 = K3 · σ_W; K1, K2, K3 are quantities determined by linear combinations of d_1, d_2 and σ_S.

Thus, it is shown that tmax - tmin, which characterizes the average value of corrosion losses over time

$$F = \frac{1}{t_{\max} - t_{\min}} \int_{t_{\min}}^{t_{\max}} \left(A_0 + k_4 \theta^2(t)\right) t\, dt + \lambda \left[\int_{t_{\min}}^{t_{\max}} \theta(t) dt - C \right]$$

The purpose of the function

$$\theta = \frac{C}{t \cdot (t_{\max} - t_{\min}) \cdot \ln\left({t_{\max}}/{t_{\min}} \right)} + \frac{k_5}{2k_4 \cdot t \cdot \ln\left({t_{\max}}/{t_{\min}} \right)} - \frac{k_5}{2k_4 \cdot t_m}$$

takes a minimum value within the condition mentioned above, so corrosion losses are minimized when there is a feedback between the volume composition of the soil and the time period. Here λ is lagrange multipilier.

In addition to second chapter The impact of specific soil resistance on corrosion in the pipeline area has been considered. First and foremost, the main factors ensuring the normal operation of the pipeline were investigated, and it was shown that the specific resistance depends on the amount, chemical composition, porosity, permeability, temperature and type of water in the soil. A new integrated indicator has been proposed, taking into account the increase in the specific corrosion resistance of the soil as the main factor, and the conditions for achieving the extremum have been determined. For this purpose, a known relationship[3] $Z = -0{,}014 \ln \rho + 0{,}2383$ between the degree of corrosion (Z) and the specific resistance (ρ) of the soil was used and taking into account the multifactorial dependence of ρ $\int_0^{R_{\max}} \rho(R) dR = C;\ C = const$ the condition was accepted. Where R is

is a geometric coordinate taken at any azimuth angle. Thus, an integral indicator of corrosion is proposed as

$$\chi(\rho(R)) = \int_0^{R_{max}} R \cdot Z(\rho(R))dR \qquad (10)$$

and the problem of unconditional optimization presented as follows.

$$Z_1 = \int_0^{R_{max}} R[-0{,}014\ln\rho(R) + 0{,}2383]dR + \lambda\left[\int_0^{R_{max}} \rho(R)dR - C\right] \qquad (11)$$

(11) shows that the maximum of the objective function is achieved by the $\rho(R) = 2CR / R_{max}^2$ solution, so this dependence is not allowed to be compensated for the normal operation of the pipeline.

This chapter also examines the main factors that shape the corrosion potential of the soil (pH, sulfate and chloride content, temperature, porosity, specific electrical resistance, geometric grain size, etc.) and determines the optimal relationship of soil specific resistance to temperature. As the acidity of the soil increases, the possibility of corrosion increases, the corrosiveness of the soil is determined by its specific resistance, and as the specific resistance of the soil increases, its corrosiveness potential weakens, it was considered not so appropriate to measure the specific resistance of the soil along the route along the length of the pipelines. With this, it was taken into account that such interventions lead to the formation of macro-corrosion cores on the metal pipe walls, on the other hand, the specific resistance of the soil has a complex dependence on temperature, on the one hand, as the temperature increases, the mobility of the salt ions in the soil increases, and on the other hand, the conductivity of the soil increases. as the temperature increases,

[3] Lim K.S. The relationship between soil resistivity and corrosion growth in tropical region / K.S. Lim, Y. Nordin, R.O.Siti [et. al.] // 13 july 2013, Vol.

the water in the pores of the soil, which plays the role of an electrolyte, evaporates, so the resistance of the soil increases as the main factor. Decreased soil permeability as a result of water evaporation in the first approach

$$\sigma_t = \sigma(25^0 C)[1 - k(T - 273)] \qquad (12)$$

linear model was used. Here σ_t is reduced value of conductivity due to evaporation; $\sigma(25^0C)$ is the value of this indicator at a temperature of 250C; k is the coefficient of proportionality. Similarly known[4]

$$\sigma^T \big/ \sigma^{25^0 C} = \exp\left[-\frac{A}{R}\left(\frac{1}{T}-\frac{1}{298}\right)\right] \quad (13)$$

The multi-criteria objective of the optimization problem using the exponential model is a functional was compiled as follows.

$$F = \alpha_1\left(\exp\left[-\frac{A}{R}\left(\frac{1}{T}-\frac{1}{298}\right)\right]\right) + \alpha_2\left[1-k(T-273)\right] \quad (14)$$

where $\alpha_1+\alpha_2=1$; A is conduction activation energy; R is universal gas constant; T is the value of the temperature represented in kelvin. The transcendental equation $\exp\left[-\frac{A}{R}\left(\frac{1}{T}-\frac{1}{298}\right)\right] = \frac{\alpha_2 \cdot k \cdot RT^2}{\alpha_1 \cdot A}$ has been obtained within the condition $dF / dT = 0$ and the maximum condition of the extremum has been received as $A / T < 2$ by calculating *d2F / dT2*.

Thus, it is shown that when the condition under consideration is met, the target F receives the maximum value of the function, so, depending on the temperature, the corrosion reaches the highest level.

The second chapter also examines the possibility of opportunities of predicting soil corrosion by space setups, the possibility of determining the degree of soil corrosion in the study area by knowing the average daily radiation at the surface and the upper limit of the atmosphere, the average monthly solar radiation, the average monthly hours of daylight hours.

[4] Liera F. J. Temperature dependence of the electrical resistivity of water-saturated rocks / F. J.Liera, M.Sato, K.Nakatsuka [et. al.] // Geophysics. 1990. - Vol.54. - p. 576-585.

area by knowing the average daily radiation at the surface and the upper limit of the atmosphere, the average monthly solar radiation, the average monthly hours of daylight hours.

At the end of the chapter, the optimal semivariogram method for the research of soil corrosion in high relief zones is explained. First of all, the Gaussian model of the semivariogram used to assess the spatial distribution of the specific resistance of the soil has been investigated, which has showed that the height of the area and the variability of the specific resistance of the soils at altitude have not been taken into account. With this in mind, a semivariogram model has been proposed and the optimal variant synthesized, allowing to make appropriate calculations. The Gaussian model of the semivariogram is presented as follows:

$$\gamma(\ell)=\begin{cases}\text{When } 0;\ \ell=0\\ C_0+C\left(1-e^{-\frac{\ell^2}{a^2}}\right);\ \text{When } \ell>0\end{cases} \qquad (15)$$

Where C_0 = const; ℓ is a distance between points; a is the maximum value of that distance; C is is an indicator that characterizes the change of $\gamma(\ell)$ with the change of the distance between the points. In addition, the experimental results of the change in the specific resistance of the soil depending on the altitude relative to sea level have been used, and in the first approximation

$$\rho=\rho_0+kh;\quad k=const \qquad (16)$$

linear dependence is taken as a basis. Taking into account the expressions of (15) and (16), a modified version of the Gaussian model of the semivariogram is proposed:

$$\gamma=\begin{cases}\text{When } 0;\ \ell=0,\\ C_{01}+(\rho_0+kh)\left(1-e^{-\ln(\rho_0+kh)}-C_1\right);\ \text{When } \ell>0\ .\end{cases}$$

The proposed model allows you to build a semivariogram both in the plains when $h = 0$, and in the elevation zones when $h \neq 0$. The synthesized optimal integral model is presented as a mathematical polynomial.

The third chapter is devoted to the development of methods for measuring the degree of soil contamination electrical conductivity and pipeline diagnostics in the area of underground gas-
-oil pipelines and their loading terminals.

First of all, typical examples of the difference between degraded lands and lands where are changed the parameters of condition by oil products as a result of natural factors have been shown, the characteristics of non-productive areas covering BP's Sangachal terminal and Baku-Ceyhan oil pipeline have been investigated. With this in mind, a new spectral index has been proposed to differentiate lands degraded by natural-climatic conditions from lands degraded by anthropogenic factors and the process of urbanization. Firstly, the shortcomings of the known ND Ball index (non-productivity index) have been investigated, using experimental measurement data to eliminate different results for the same soil types

$$Der = \left| \frac{DN(6) - DN(5)}{DN(7) - DN(6)} \right|$$

index has been proposed. Here $DN(i)$ – i = 5,6,7 is the spectral measurement data in the corresponding spectral channels. The benefits of the proposed index over the ND Ball index are shown on the basis of measurement data.

Furthermore, in the third chapter, a graph-analytical method for estimating the volume of measurements carried out for the research of soil pollution in the transport zones of hydrocarbons has been developed. The given method is based on the known dependence of the degree which has an impact on the amount of oil spilled on the soil (x) on the NDVI (Normalized Differential Vegetation Index) index[5]:

$$NDVI = -0{,}5x \cdot 10^{-5} + 0{,}3465. \qquad (17)$$

[5] Fan X., Liu Y. A global study of NDVI difference among moderate resolution satellite sensors / ISPRS Journal of Photogrammety. – 2016.- 121. - p.177-19

Then, a well-known expression of the regression dependence between the time elapsed from the moment of oil spill to the moment of measurement (t) and NDVI has been used:

$$NDVI = 0{,}0003t + 0{,}2073. \qquad (18)$$

Implementation of the method of determining the initial area of spilled oil-covered land $A_{ax} = \frac{0{,}23782 \cdot Q^{\frac{4}{5}}}{(k_i \cdot k_r)^{\frac{1}{5}}}$ (19)

based on the known expression of the dependence of the area of the spilled oil-covered area (Aax) on the volume of spilled oil (Q, m3), initial soil penetration (ki, m3) and relative oil penetration (kr, m3) algorithm has been developed (Fig.1).

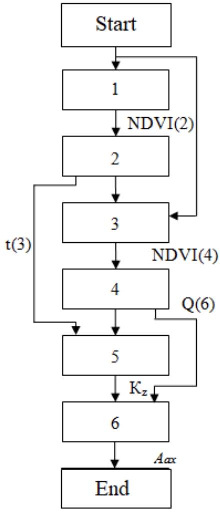

Fig 1. The set of operation of the algorithm in order to determine the initial area of land covered with spilled oil

The set of operations of the given algorithm is as follows:

1. On the basis of remote sensing or proximal sounding data, the current value of NDVI for the research area is determined.

2. Based on the known regression dependence, the time interval from the moment of oil spill to the moment of measurements is determined.

3. The relevant regression line is extrapolated to the left until it intersects the vertical axis, and NDVI is calculated at that point.

4. The initial volume of oil spilled (Q) is calculated based on the known regression relationship between the volume of spilled oil and NDVI.

5. The condition of the oil which is spilled to soil is determined on the basis of known meteorological data on precipitation.

6. The A_{ax} quantity is determined on the basis of formula (19) taking into account the calculation results of row 4 and 5.

Based on the mentioned above, model calculations have been performed to determine the oil-covered area, which $k_i = 1$, by accepted $NDVI = 0.33$, and extrapolated $NDVI = 0.19$ has been obtained. Taking into account the given value of k_i = 1,2 · 10-14 m2, Q = 416 m3. Based on the expression (19), A_{ax} = 2 · 103 = 2000 m2 has been obtained. In that case the number of measurements which are required for the calculation of *NDVI* on 100 m^2 of land has been obtained N_0 = 2 · 2000/100 = 40.

In addition, in that chapter, a new method was proposed, based on a new gas leak seal and allowing the pipe to identify leaks. In order to eliminate the impact of all kinds of accidental risks, it is assumed that most pipes are placed under the ground at a certain depth, but in this case, the main gas pipelines are not fully protected from any risk of deformation and rupture that may occur as a result of natural seismic effects. It was shown that as a result of mechanical effects, rupture of pipelines occurs, which leads to the outflow of gas under great pressure, filling the pores of the soil cover of the ravine. Such events cause a partial pressure drop in the pipeline, and the pipeline begins to operate in emergency mode. The proposed method is based on a negative correlation between methane and oxygen concentrations at the leak site and is used to calculate the

$$C_{O_2} = A\left[1 - \exp\left(-B \cdot x_0\right)\right] \qquad (20)$$

of the oxygen concentration (C_{O_2}) within the soil boundaries which is based on the given expression. In the given expression A is the maximum concentration of oxygen at a height h0 at the edge of the leak, B is an indicator of the exponential curve; x_0 is the distance between the leakage point and the horizontal projection of the measuring point of O2.

Then, by using of the known regression relationship

$$C_{O_2} = E - k \cdot C_{CH_4} \qquad (21)$$

between concentrations of oxygen and methane, concentrations of methane has been determined $C_{CH_4} = \frac{E - A\left[1 - \exp\left(-Bx_0\right)\right]}{k}$ as the mentioned formula. In the given expression (21), k is correlation coefficient ($k \neq 0$). In the absence of a correlation between CH4 and O2, the quantity E is the oxygen concentration.

Thereby, in order to optimize the detection of leakage, it has been considered that methane would be measured at a distance of x1 from the projection of the point O, and oxygen at a distance of x0. The proposed approach covered three main stages.

1. The geometric mean (Z) of C_{O_2} and C_{CH_4} is calculated as follows:

$$Z = \left(C_{O_2}\right)^{\alpha_1} \cdot \left(C_{CH_4}\right)^{\alpha_2}; \quad \alpha_1 + \alpha_2 = 1.$$

2. The connection function between x_1 and x_0 is included.

3. $F_0 = F_1 + \lambda\,(F_2 - C)$ The problem of optimization of variation is solved.

In the mentioned third stage, F_0 is the target functional leak signature, F_1 is the the main purpose of functional optimization, F_2 is constraint condition, λ is lagrange multiplier, C is constant. It is shown that the value at which the objective function reaches the extremum is taken as a sign of leakage.

$$F_0 = \int_0^{x_{0\max}} \left[A\left[1-\exp\left(-B \cdot x_0\right)\right]\right]^{\alpha_1} \cdot \left[\frac{E}{k} - \frac{A}{k}\left[1-\exp\left(-Bf\left(x_0\right)\right)\right]\right]^{\alpha_2} dx_0 - \lambda\left[\int f\left(x_0\right)dx_0 - C\right]$$

At the end of the third chapter, the results of experimental-model researches of measuring the specific resistance of the soil at 3 depths are given (Table 1). Taking into account dependence on the sign of proximity of the measurements to the pipeline and direction, the row of rods was placed in steps of 0.8 m, parallel and perpendicular to the pipeline, at a distance of 100 m from the pipeline (Table 2).

Table 1. Calculated values of specific resistance of soil depending on the depth of measurement

№	Placement of rods	Depth of measurement, *m*	The result of measurement, *R, Om*	Calculated values, *ρ*, *Om·m*
1	North – South	1,0	0,65	2,64

		1,5	0,70	2,80
		2,0	0,74	2,96
2	East – West	1,0	0,45	1,80
		1,5	0,64	2,56
		2,0	0,78	3,12

Table 2. Results of measuring the specific resistance of the soil at a distance of 100 m from the pipeline

Direction towards the pipeline	*a, m*	*R, Om*	*ρ, Om·sm*
Perpendicular	0,8	4,5	2100
Paralel	0,8	1,5	710

Thus, the received values and measurement results showed that the specific resistance of the soil in the pipeline zone is inhomogeneous. Also, based on the inverse relationship between methane and oxygen concentrations, the given method allowed to determine the location of methane leakage.

The fourth chapter of the thesis paper deals with the design of pipelines in the zone of natural-destructive processes and mechanical impacts. First of all, based on the experience of different countries, the main factors affecting the condition of the pipeline have been studied, such as pipe diameter, wall thickness, circular tension, etc. In addition,

$$R = \left[1{,}17 - 0{,}0029\left(\frac{D}{t}\right)\right](\ell + w)\cdot t \cdot \sigma_v \qquad (22)$$

proposed by other authors[6] to calculate the resistance of the pipeline to perforation dependence is taken as a basis. In the given formula, t is the thickness of the wall of pipeline; D is the outer diameter of the pipe; ℓ is the length of the tooth of the excavator which strikes the pipe; w is the width of the same tooth; σ_y is tensile strength.

At the same time to calculate the strength limit that prevents the spread of cracks in the pipe wall

$$C_v = 2{,}836 \cdot 10^{-5} \cdot \sigma_n^2 \cdot D^{\frac{1}{3}} \cdot t^{\frac{1}{3}} \tag{23}$$

The Batelle[7] formula has been used. In the mentioned expression, C_v is the Sharpe ratio of durability against impact; σ_n is circular tension; D is the diameter of the pipe; t is the thickness of the wall of pipe. Since the reliability of the pipe decreases as the CV increases, for instance, in pipes with high tension and diameter, the probability of crack propagation is high. That is why a multi-criteria method for determining the wall thickness of the pipe has been proposed.

In this case, in order to calculate the optimal value of the of thickness of pipe wall, the objective function is presented as a scalar coating of the criteria $k_1(t)$ and $k_2(t)$ defined as follows:

$$K_0(t) = \beta_1 \cdot K_1(t) + \beta_2 \cdot K_2(t); \quad \beta_1 + \beta_2 = 1. \tag{24}$$

where $\beta 1$ and $\beta 2$ are weights.

where $D_0 = const$; $a_2 = 1{,}17$; $a_3 = 0{,}0029D$; $a_4 = \sigma_n(\ell + w)$

---

[6] Greenwood R. Pipeline integrity data: management and application // AGA Operations Conference. - Dallas, Texas. April 29-May 1. - 2001.

[7] Chatain P. An experimental evalution of punctures and dents in transmission pipelines // PRC/EPRG Ninth Joint Biennial Technical Meeting on Linepipe Research. – Houston. – Texas. - May. 1993.

Taking into account the considered values (24), the objective function is presented as follows:

Based on the (22) and (23) expressions, the values of $K_1(t) = a_1 \cdot t^{\frac{1}{3}}$; $a_1 = 2{,}836 \cdot 10^{-5} \cdot \sigma_n^2 \cdot D^{\frac{1}{3}}$ have been determined.

$$K_2(t) = D_0 - (a_1 - \frac{a_3}{t}) \cdot a_4 \cdot t. \tag{25}$$

$$K_0(t) = \beta_1 \cdot a_1^{\frac{1}{3}} + \left[D_0 - \left(a_2 - \frac{a_3}{t} \right) a_4 \cdot t \right] (1 - \beta_1) \qquad (26)$$

Based on the method of derivation analysis, it has been shown that the $K_0(t)$ function reached a maximum at the value of $t = \sqrt{\left(\frac{\beta_1 \cdot \alpha_1}{3(1-\beta_1) \cdot a_4 \cdot a_2} \right)^3}$, thus, a method of optimal pipe design has been proposed, taking into account the possible mechanical effects.

Furthermore, in the same chapter, the issues of taking into account additional impacts in the design of the underground pipeline network in seismically hazardous areas have been considered. In this regard, the determination of the limit value of compression and tension stops in pipe production areas has been investigated. According to these researches, when the tensile stress limit εℓ = 2% is assumed, the compressive stress (εc) has been designated as the following formulas.

$$\varepsilon_c = 0{,}5\left(\frac{t}{D'} \right) - 0{,}0025; \quad D' = \frac{D}{1 - 3 \cdot \frac{(D - D_{\min})}{D}} \qquad (27)$$

where D is the outer diameter of the pipe; D_{min} is the minimum diameter; t is the thickness of the wall of pipe.

Thus, it was required to find such a $D = f(t)$ functional dependence that at all possible values of *t*, the integral value of ε_c reaches the extremum. Fo this purpose, the regular set of $T = \{t_i\}$, $t_i = t_{i-1} + +\Delta t$; $\Delta t = const$, $i = \overline{1,n}$; $t_0 = 0$ and $D = \{D_j\}$, $D_j = D_{j-1} + \Delta D$; $\Delta D = const$, $i = \overline{1,n}$, $D_0 = 0$ are considered. A constraint condition is applied to the discrete function Dj = f (ti). The F_1 constraint is presented as a conditionally continuous $F_1 = \int_0^{t_{\max}} f(t)dt = C$.

Taking into account the (27) expression, the objective function of optimization has been designed as

$$F_1 = \int_0^{t_{max}} \left\{ \frac{0,5t}{f(t)} \left[\frac{3D_{min}}{f(t)} - 2 \right] - 0,0025 \right\} dt + \lambda \left[\int_0^{t_{max}} f(t) dt - C \right].$$

The optimization problem was solved according to the conditions of the Euler-Lagrange equation, and when the condition $3D_{min}$ > D is true, it is shown that the objective function F_1 has a minimum value, so the compression stress ε_c reaches a minimum, and the relationship between the oval diameter and outer diameter of the pipe is determined.

Furthermore, in the fourth chhapter, the methodology for laying underground pipelines in landslide-prone areas has been described. First of all, the damage functions of underground pipelines, taking into account the SGS (strong shaking) and GF (cutting and bevelling) indicators recommended for use in the United States, have been considered:

$$R_{SGS} = k_1 \cdot 0,00241 \cdot PGV; \; R_{GF} = k_2 \cdot 11,223 \cdot PGV^{0,319} \quad (28)$$

Where R_{SGS} is frequency of recovery from damage due to concussion; R_{GF} is is the frequency of recovery from injuries due to rupture. The proposed calculations were performed in the following sequence, taking into account that the calculations of other scientists were defined as $N_1 = \sum_i \left(0,2R_{SGS_i} + 0,8R_{GF_i}\right) \cdot l_i$ which is the expected number of leakage and rupture events for sections of the same length of pipeline.

First of all, the entire length of the pipeline (L) is divided into unequal parts $l_i = l_{i-1} + \Delta l; \; \Delta l = const; i = \overline{1,n}; \; l_0 = 0$, as a result a regular set $L = \{l_i\}$ is formed. Due to the danger of slipping of the parts of the pipeline is not homogeneous, $PGV = f(l_i)$; $R_{SGS} = k_1 \cdot 0,00241 \cdot f(l_i)$ the functions are designed and taking into account the value of $R_{GF} = k_2 \cdot 11,223 \cdot f(l_i)^{0,319}$,

$$N_1 = \sum_i \left(0,2k_1 \cdot 0,00241 \cdot f(l_i) + 0,8 \cdot k_2 \cdot 11,223 \cdot f(l_i)^{0,319}\right) l_i \quad (29)$$

is determined as mentioned above.

In addition, by accepting the constraint condition $\int_0^{l_{\max}} f(l)dl = C;\ C = const$, objective function

$$N_0 = \frac{1}{l_{\max}} \int_0^{l_{\max}} \left(a_1 f(l) + a_2 f(l)^{a_3} \right) ldl - \lambda \left[\int_0^{l_{\max}} f(l)dl - C \right] \quad (30)$$

has been designed and $f(l) = \sqrt[a_3-1]{\frac{\lambda - a_1}{a_2 \cdot a_3 \cdot l}}$ has been found in order to solve the optimization problem. Thereby, given the value of a_3 = 0.319 and λ = const, the permanent displacement of the soil is directly proportional with the quantity *l*. By calculating the derivative, it is shown that the solution of (31) provides the maximum value of the function (30). Thus, a methodology has been developed that allows to determine the expected number of leaks and cracks by dividing the entire length of the pipeline into uneven and non-homogeneous sections due to the risk of landslides. Then, taking into account the cost of repairing a leak and an rupture events, a methodology for calculating the cost of restoration work has been proposed.

At the end of the fourth chapter, the issues of protection of main pipelines from landslides caused by seismic events have been considered. Firstly, the results of the research on the protection of the Sangachal terminal have been investigated and 3 factors were considered according to the Rapolla method on the risk of landslides: geotechnical indicator of the soil – (V_S); the steepness of the slope; seismic indicator (PGA_S). According to this method, the final index of landslide (SI) caused by an earthquake has been presented at the following expression.

$$SI = \frac{S_a + S_b}{2} \cdot S_c \quad (32)$$

where S_a is the lithology factor; S_b is the slope coefficient; S_c has a relationship $S_c = 0{,}04 \cdot \beta - 0{,}6$ between the seismicity and the vertical gradation (β) of the coefficient slope. Given that the S_c value is determined by the maximum intensity, that is why, *SI* has been calculated as

$$SI = \left(\frac{a_1}{V_s} - a_2 + a_3\beta \right) \cdot \left[a_4 \left[\lg PGA_s + a_5 \right] - a_6 \right] \tag{33}$$

In the expression which is mentioned above, the values of *a* are given like this a_1=0,2045/2; a_2=0,1363/2; a_3=0,04/2; a_4=0,6667/0,36; $a_5 = 0{,}408$; $a_6 = 0{,}8333$. As a result, a logarithmic relationship was obtained between the landslide index and the peak value of soil acceleration (33).

Thus, taking into account that the peak value of soil acceleration gradually decreases as it moves away from the epicenter, a methodology for determining the integrated indicator of landslide along the route of the pipeline has been developed. For this purpose, the regulated set of slope steepness in the direction of seismic wave propagation is considered:

$$B = \{\beta_i\}; \quad i = \overline{1,n}; \quad \beta_{i+1} = \beta_i + \Delta\beta; \quad \Delta\beta = const.$$

Taking into account the increase or decrease in the quantity β as the pipeline moves away from the epicenter, optimal $PGA_s = f(\beta)$ has been searched. Thereby, there is an optimization function that characterizes the integrated value of landslide exposure in a continuous form has been designated with the help of the following formula.

$$SI_{\text{int}} = \int_0^{\beta_{\max}} \left(\frac{a_1}{V_s} - a_2 + a_3\beta \right) \cdot \left[a_4 \left[\lg PGA_s(\beta) + a_5 \right] - a_6 \right] d\beta \tag{34}$$

Assuming that there is a linear relationship between β and *PGA*, and the optimization function within the $\int_0^{\beta_{\max}} f(\beta) d\beta = C; \quad C = const$ constraint condition is presented as follows:

$$F(f(\beta)) = \int_0^{\beta_{max}} \left(\frac{a_1}{V_s} - a_2 + a_3\beta \right) \cdot \left[a_4 \left[\lg PGA_s(\beta) + a_5 \right] - a_6 \right] d\beta + $$
$$+ \lambda \left[\int_0^{\beta_{max}} f(\beta) d\beta - C \right]. \quad (35)$$

A solution that maximizes the functionality (35) found as

$$PGA_s(\beta) = \frac{(a_8 + a_3\beta) \cdot a_4}{\lambda_0 \cdot \ln 10} \quad (36)$$

Where $a_8 = \frac{a_1}{V_s} - a_2$; $\lambda_0 = -\int_0^{\beta_{max}} \frac{(a_8 + a_3\beta) \cdot a_4}{C \cdot \ln 10} d\beta$

It is shown that the objective function (35) receives the maximum value within the solution of expression (36). Thus, a methodology for effective protection of the pipeline from landslides on the slopes was developed, and a model presentation of the issue was given. (36) was recommended which is based on the solution that the pipeline should be positioned relative to the projected seismic epicenter so that small acceleration peaks were recorded on high-slope slopes and high accelerations were recorded on low-slope slopes. All of them will serve to simplify measurement procedures in the planning of underground pipeline routes and improve relevant systems.

KEY CONCLUSIONS

1. Optimal time periods for monitoring the corrosion condition of underground main pipelines and oil penetration into the soil via information-measurement systems have been identified, and methods for improving geo-ecological measurements have been proposed.

2. Based on the lidar-thermal measurement data, the optimal relationship between the carrier's flight altidute and the initial ground voltage has been determined to reduce the error of the pipeline positioning method.

3. Analytical expressions of the relationships between the main soil parameters have been obtained to minimize the corrosion losses of the pipeline, an integrated model of the semivariogram has been proposed, which allows to measure the specific resistance of the soil.

4. The problem of selecting the optimal route to provide the slick operation of the pipe has been solved by determining the specific resistance of the soil on the route and the integrated corrosion index.

5. The new index, presented as a fractional combination of Landsat ETM + satellite measurements, has made it possible to differentiate between oil-covered soil types, that is why, an algorithm has been developed to detect leaks.

6. A graph-analytical method for determining the volume of spectrometric measurements required for monitoring oil-contaminated land plots was proposed, and on the basis of measurement results and model calculations, the inhomogeneity of the soil in the pipeline zone was shown.

7. Taking into account the inverse relationship between methane and oxygen concentrations, the method which is based on new signature has been developed to detect leaks from an underground gas pipeline.

8. A model solution for the design of pipelines resistant to natural and anthropogenic factors, such as landslides, slope steepness and possible mechanical effects, and the efficient selection of the laying route is presented.

The main results of the dissertation were published in the following scientific articles:

1. Насиров Х.М. Вопросы обеспечения защищенности магистральных нефтепроводов от оползней, вызванных сейсмическим событием // Проблемы сбора подготовки и транспорта нефти и нефтепродуктов. – 2020, №3.- с.74-82.

2. Насиров Х. М., Гладлин Д. Е., Чернов В. А. Разработка нового спектрального индекса для различения типов бесплодных деградированных земель в зоне загрузочного терминала магистрального нефтепровода // Сборник статей XII Международной научно – практической конференции. – Курск. – 20 мая. – 2020. - с.120-127.

3. Насиров Х.М. Графо–аналитический метод количественной оценки объема спектральных измерений для исследования загрязненности почвы в зонах транспортировки углеводородов // Нефтегазовое дело. Сетевое издание. – Россия, г.Уфа. - 2020, №4, с. 35-46.

4. Насиров Х. М. Графоаналитической метод определения необходимого объема спектральных измерений для исследования состояния почвы в зонах транспортировки углеводородов // Информационные системы и технологии: достижения и перспективы. II Международная научная конференция. Сумгаитский Государственный Университет. – Сумгаит, 2020. - с.179-181.

5. Насиров Х. М. Исследования влияния удельного сопротивления почвы на ее коррозионность в зоне прокладки трубопровода // Нефгазовое дело. Сетевое издание. - Проблемы сбора подготовки и транспорта нефти и нефтепродуктов. – Россия, г.Уфа. - 2020, №4. - с.4-14.

6. Насиров Х. М. Разработка методики определения степени коррозионности почвы в зоне прокладки трубопроводов // Транспорт и хранение нефтепродуктов и углеводородного сырья. – Москва. - 2020, №4. – с.14-17.

7. Насиров Х. М. Разработка нового спектрального индекса для определения типов бесплодных деградизированных земель в зоне загрузочного терминала магистрального нефтепровода // Нефтегазовое дело. Сетевое издание. – Россия, г.Уфа. - 2020, №2. - с.39-51.

8. Насиров Х. М., Сулейманов Т. И., Асадов Х. Г. Метод обнаружения утечек газа из подземных магистральных газопроводов // Газовая промышленности. – Москва. - 2020, №7, с.118-121.

9. Насиров Х. М., Сулейманов Т. И., Асадов Х. Г. Метод оптимальной семивариограммы для исследования коррозионности почвы в зонах прокладки трубопровода с возвышенностью рельефа // Автоматизация и информационные технологии в нефтегазовой отрасли. – Москва. - 2020, №3(41). - с.5-9.

10. Сулейманов Т. И., Асадов Х. Г, Насиров Х. М. О потенциальной точности бортового лидарно – термального контроля трассы прохождения подземных трубопроводов // Контроль. Диагностика. – Москва. - 2021, №1. – с.38-42.

11. Насиров Х. М. Исследования глубины проникновения сырой нефти в почву при аварийных разливах нефтепродуктов // Технологии нефти и газа. – Москва. - 2021, №2. – с.47-49.

12. Насиров Х. М. Методика определения основных геометрических показателей трубопровода по методике многокритериальной оптимизации // Проблемы сбора, подготовки и транспорта нефти и нефтепродуктов. - Уфа. - 2021, №1(129). - с.67-72.

13. Насиров Х. М., Сулейманов Т. И., Асадов Х. Г. Разработка методики прокладки подземных трубопроводов с учетом опасности оползневых процессов // Нефтяное Хозяйство. – Москва. - 2021, №4. - с. 114-117.

14. Сулейманов Т. И., Насиров Х. М. Вопросы оптимального проектирования сети подземных трубопроводов в сейсмически опасной зоне // Проблемы сбора, подготовки и транспорта нефти и нефтепродуктов. – Уфа. - 2021, №1(129). – с.73-78.

15. Насиров Х. М. Эксплуатации ветвей стальных магистральных трубопроводов с учетом гетерогенности свойств среды прокладки труб / Материалы международной конференции. International Journal of Advanced Studies in Computer Engineering. St. Louis, Missouri, USA, April 2022, №1, pp.60-67

Personal service of the author in scientific articles published together with co-authors:

[1,3,4,5,6,7,11,12,15] - works prepared freely by the author.
[2,8,9,10,13,14] - in his works, the author introduced new spectral indices, leak detection methodology, semivariogram optimization procedures, leader-thermal method of pipeline route control and mathematical solution of optical selection, optimal design of pipelines in seismically dangerous zones pursued the issues.

The defense will be hel[illegible] at the meeting of FD 2.25 Dissert[illegible] Sumgait State University.

Address: Sumgayit, 43th district, Baku street 1, AZ5008
e-mail: info@sdu.edu.az

The dissertation can be acquainted with at the library of Sumgait State University

Electronic versions of the dissertation and thesis have been placed on the official website www sdu.edu.az

The thesis was sent to the required addresses "___" on September 2022

Signed for print: 20.09.2022

Page format:A5

Volume: 37566

Number of hard copies:100