https://doi.org/10.52676/1729-7885-2025-1-12-20
УДК 53.083

TECHNICAL STUDY OF ENGINIREERING COMMUNUCATIONS BY ULTRASOND DEFECTOSCOPY

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The article discusses whether special attention should be paid to long-wave ultrasonic radix systems used to detect corrosion and other defects on internal and external surfaces. This allows you to monitor the presence of corrosion and other defects in long pipes in hard-to-reach places.

Currently, relevant state industry standards are being developed that are used in the design and calculations of process pipelines, but for now it is better for expert institutions to pay special attention to diagnosing the technical condition. To do this, it will be necessary to use the most precise diagnostic solutions and provide a prognosis based on the entire system.

Keywords: *remote methods, electromagnetic radiation, ultraviolet, pipelines, ultrasound, flaw detection, radiation monitoring, acoustic research.*

INTRODUCTION

The study of the technical condition of engineering systems is carried out during a comprehensive study of the technical condition of buildings and structures. The study of engineering systems and their elements is carried out to determine the actual technical condition of the systems, identify defects, damage and malfunctions, quantify physical and moral wear and tear, and establish deviations from the design.

The assessment of the technical study of engineering systems of buildings and structures is carried out taking into account the service life of elements and the average standard life of certain engineering devices.

The physical wear of the system is determined as the weighted average sum of wear of elements [11].

Ultrasonic defectoscopy is a method proposed by S. Y. Sokolov in 1928 and based on the study of the propagation of ultrasonic vibrations with a frequency of 0.5–25 MHz in controlled products with the help of special equipment – ultrasonic flaw detector. It is one of the most widespread methods of nondestructive testing.

The diagnostic device market currently offers new effective methods for diagnosing process pipelines. One of the dynamically developing areas in the field of industrial safety is the construction and modernization of life-saving equipment, assessment of the current state of equipment at hazardous production facilities. Therefore, to determine the technical condition of process pipelines, it is necessary to consider the possibility of supporting modern and effective diagnostic methods in conditions of high responsibility of expert institutions [1].

The market of diagnostic devices currently offers new effective methods for diagnostics of process pipelines. One of the dynamically developing areas in the field of industrial safety is the construction and modernization of life-saving equipment, assessment of the current state of equipment at hazardous production facilities. Therefore, to determine the technical condition of process pipelines, it is necessary to consider the possibility of supporting modern and effective diagnostic methods in conditions of high responsibility of expert institutions [2].

1. PRINCIPLE OF WORK

Sound waves do not change their trajectory in a homogeneous material. The reflection of acoustic waves occurs at the interface of media with different specific acoustic impedances. The more the acoustic impedances differ, the greater the fraction of sound waves reflected from the interface. Since inclusions in metal usually contain gas (mixture of gases) arising due to welding, casting, etc. The mixture of gases has five orders of magnitude lower specific acoustic impedance than the metal itself, so the reflection will be almost complete [5].

The resolving power of acoustic examination, i.e. the ability to detect small defects separately from each other, is determined by the sound wavelength, which in turn depends on the frequency of input of acoustic vibrations. The higher the frequency, the smaller the wavelength. The effect arises from the fact that when the size of the obstacle is less than a quarter of the wavelength, the reflection of the oscillations practically does not occur, and their diffraction dominates. Therefore, as a rule, the frequency of ultrasound tends to increase. On the other hand, when increasing the frequency of oscillations quickly increases their attenuation, which reduces the possible area of control. The practical compromise was frequencies in the range from 0.5 to 10 MHz.

Advantages

Ultrasonic inspection does not destroy or damage the sample under test, which is its main advantage. It is possible to control products from a variety of materials, both metals and nonmetals. In addition, we can emphasize the high speed of research at low cost and danger to humans (compared to X-ray flaw detection) and high mobility of ultrasonic flaw detector.

Disadvantages

The use of piezoelectric transducers requires surface preparation for ultrasound input into the metal, in particular the creation of surface roughness of at least class 5, in the case of welded joints and the direction of roughness (perpendicular to the weld). Due to the high acoustic resistance of air, the smallest air gap can become an insurmountable barrier to ultrasonic vibrations. In order to eliminate the air gap, contact liquids such as water, oil, or glue are preapplied to the area to be inspected. When inspecting vertical or highly inclined surfaces, thick contact liquids should be used to prevent rapid dripping [3].

To control products with an outer diameter less than 200 mm, it is necessary to use transducers with the radius of curvature of the sole –, equal to 0.9–1.1 R radius of the controlled object, the so-called lapped transducers, which in this form are unsuitable for control of products with flat surfaces. For example, to control a cylindrical forging, it is necessary to move the transducer in two mutually perpendicular directions, which implies the use of two lapped transducers - one for each direction.

As a rule, ultrasonic flaw detection cannot answer the question about the actual size of the defect, only about its reflectivity in the direction of the receiver [5]. These values are correlated, but not for all types of defects. In addition, some defects are practically impossible to detect by ultrasonic method due to their nature, shape or location in the object of inspection.

It is practically impossible to perform reliable ultrasonic inspection of metals with coarse-grained structure, such as cast iron or austenitic welds (thickness over 60 mm) because of the large scattering and strong attenuation of ultrasound. In addition, it is difficult to inspect small parts or parts with complex shapes. It is also difficult to ultrasonic inspection of welded joints made of dissimilar steels (for example, austenitic steels with pearlitic steels) due to the extreme heterogeneity of the weld metal and base metal.

Electromagnetic radiation can detect, compare, and analyze spectral characteristics in various ranges, as well as obtain information about objects, including their size, density, chemical composition, physical structure, and current state [7]. The *g*-band is used to search for radioactive ores and sources, and the ultraviolet part of the spectrum is used to determine the chemical composition; the light range is most informative when studying soils and vegetation cover.

Possible applications of this system:

– intersection of pipelines with roads and railways;
– section of pipe passing through the wall;
– 100% control volume straight sections of pipelines if necessary;
– ground sections of the pipeline;
– monitoring for corrosion under the insulation (with minimal insulation removal);
– cryogenic pipeline.

Obvious advantages of the system:

– ability to monitor pipelines without decommissioning them;
– the pipe is checked 100%;
– insulation cleaning is not required (only at the ring installation site);
– ability to work with dry contact and paintwork;
– you do not need to apply any effort to the pipeline, as when observing with acoustic emission systems.

The system is certified and included in the state register of measuring instruments.

The ultrasonic method of non-destructive testing (NDT) is one of the most cumbersome and difficult to understand in the learning process. Therefore, not every specialist can master a full course on this control method [7].

If a specialist has a secondary or higher technical education, for example, performs functions such as sinα, cosα, tgα, etc., then it is correct to be able to perform calculations on a calculator. The main thing is to be able to handle complex work that takes a lot of time. The traditional ultrasound method is one of the most common NDT methods in the search for internal defects. Acoustic NC methods, installations and devices that use ultrasonic frequency ranges can be called ultrasonic according to GOST 23829, for example, “ultrasonic flaw detection”, “ultrasonic flaw detector”. Ultrasonic flaw detection-violation of integrity and uniformity [9]. The principle of conducting ultrasonic echo-pulse observations is based on sending ultrasonic pulses to the irradiating product. When encountering an obstacle, such as a defect or a reverse surface, some of the energy of the ultrasonic wave is emitted and returned to the emitter. The ultrasonic vibration receiver converts ultrasonic vibrations passing through the product into electrical ones that go to the screen – the main indicator of the flaw detector. The electronic unit of the flaw detector is measured by the following calculation of the pulse travel time to the radiation reflection object and the distance according to the formula: $S=(t \cdot c)/2$, where S is the distance to the radiation object, c is the speed of ultrasound propagation in the product material, and t is the time of ultrasound travel to the radiation object and back.

Characteristic defects in welded joints, melting, packaging, as well as in suspensions of railway transport. No melting at the bottom of the welds. Do not melt the aisles. Explosions. Rupture of the disc on the Locomotive wheel in the area of the hub. Fragments of screws along the 1st and 4th turns. Layering of the base metal. Internal defects on the UT RT side frame [8].

It is believed that the twin of ultrasonic NC is radiation control (RC). However, traditional ultrasound monitoring cannot completely replace radiation monitoring or vice versa. A spherical slit-type defect “sees” ultrasound as a point, and the amplitude of the reflected signal on the flaw detector screen is within the transmission range, that is, it can be effective. When performing radiation monitoring, the same defect looks like a plane and may be inefficient in size. At this point, a vertical explosion that coincides with the direction of radioactive radiation may occur due to insufficient distribution of the intensity of the transmitted rays. When conducting ultrasound control by the "Tandem" method, vertical breaks are perfectly detected. One of the transducers is the emitter, and the other is the receiver, or vice versa. The main advantage of the radiation method of observation over ultrasound is that the obtained images analyze the defect image with the possibility of storing and re-analyzing them. When carrying out radiation monitoring, it is necessary to strictly observe the safety rules approved by regulatory documents in order to avoid dangerous exposure of employees served by harmful gases generated under the influence of ionizing radiation and radiation in the air. Currently, there are innovative technologies in combination with the use of ultrasound instead of radiation monitoring. Conducting testing of phased array technology using ultrasonic testing using innovative technologies (PAUT): a) automated monitoring with an Omniscan MX + TOFD flaw detector, b) manual monitoring with a Phasor XS flaw detector, c) manual monitoring with a VEO flaw detector. For these purposes, the ultrasonic diffraction – time observation method (TOFD) is used, as well as the ultrasonic method using phased array transducers (PAUT). There is an ASME 2235-9:2005 "Use of Ultrasonic Examination in Lieu of Radiography Section I; Section VIII, Divisions 1 and 2; and Section XII" standard for the use of ultrasound inspection instead of radiation inspection. Based on ultrasound observations, diffraction analysis is used here. A time-based method using a complex with a phased array ultrasonic transducer (PAUT), as well as traditional ultrasound observation, including observation of layers of large thickness. When applying the ultrasonic method using the diffraction-time control method and converters in the form of phased arrays, mandatory documentation of the control results with its high-level execution is carried out, in contrast to traditional manual ultrasonic control, where the performance of the control results is not particularly high. Information about the control performed can be stored by the customer and the contractor. The analysis of the observation results can be reviewed by another specialist [10].

Advantages of the system

The defect control system has a number of advantages that make this method more effective than others, using ultrasonic waves:

– prompt identification of damaged areas;
– It can be used in hard-to-reach places;
– ability to work on a free pipeline;
– the ability to detect breaks and control the thickness of the material;
– usability and system integrity;
– ability to quickly diagnose long pipes;
– effective balance of speed and quality of research;
– highly informative research.

Using this monitoring system saves time spent on studying the quality of the pipeline by additional methods that do not give such fast and accurate results.

Limitations of the ultrasonic flaw detector

Despite the obvious advantages, the system has some limitations. This method allows you to study long pipes (up to 100 meters), but the greatest efficiency is observed only when the pipe length does not exceed 50 meters.

This system quickly detects defects, but does not allow you to determine the size and depth of the violation.

Ultrasonic flaw detection is a method proposed by S. Y. Sokolov in 1928 and based on the study of the propagation of ultrasonic vibrations at a frequency of 0.5–25 MHz in controlled products using a special device-an ultrasonic flaw detector. It is one of the most common methods of non-destructive testing.

Operating principle

Sound waves do not measure the trajectories of a material of the same origin. The image of acoustic waves comes from a section of media with various inherent acoustic disturbances. As the acoustic barriers become more separated, most of the additional waves are reflected from the boundaries of the middle sections. Since compounds in metal often form a gas (a mixture of gases) formed during welding, melting, etc., the metal does not have time to come out during solidification, if the mixture of gases has five rows less of its own acoustic resistance than the metal itself, then the video will be complete.

The allowable ability of acoustic research, i.e. the ability to detect small defects separately from each other, is determined by the length of sound velocity, which, in turn, depends on the input speed of acoustic vibrations. The higher the frequency, the lower the wavelength. The effect occurs at Dam sizes smaller than a quarter of a wavelength, there was no image of oscillations, their diffraction would prevail. On the other hand, when the rate of oscillation increases, their attenuation increases rapidly, which shortens the possible area of Control [9].

Advantages

Ultrasonic testing does not spoil the studied option, which is its main advantage. Control over the product can be carried out from various materials, both metallic and non-metallic. Then a high rate of research with a low price and risk for the person will be determined.

Disadvantages

The use of piezoelectric transducers requires preparation for introducing ultrasound into a flat metal. Due to the large acoustic resistance of the air, a small air hole can be an obstacle to ultrasonic vibrations. To get rid of the air gap, contact fluids such as water, oil, and paste are introduced into the controlled area of the product. When observing vertical or highly inclined surfaces, thick contact fluids must be used to prevent rapid leakage [14].

To control products with an external diameter of less than 200 mm, it is necessary to use converters with a radius of curvature R equal to the radius of the controlled object 0.9–1.1 R, for the control of flat products, these modified converters are not suitable. this type. For example, to control a cylindrical winding, the converter must be moved in two mutually perpendicular directions, which leads to the use of two sealed converters, one for each direction.

As a rule, ultrasonic flaw detection cannot answer the question about the actual size of the defect, only about its reflectivity in the direction of the receiver. These values are correlated, but not for all types of defects. In addition, some defects are almost impossible to detect by ultrasound due to their nature, shape or location in the object of control [11].

2. Ultrasonic testing

Ultrasonic testing (UT) of nondestructive testing (NDT) is one of the most voluminous and difficult to master in the training process. Therefore, not every specialist can master the course on this method of control in full volume with the condition to successfully pass the comprehensive examination in accordance with STB EN 473:2011 or EN ISO 9712:2012. In order to master the course on ultrasonic method of NDT, the specialist must have a concept of ultrasonic control (some practical skills), technical mindset. It is good when the specialist has a secondary or higher technical education, can perform calculations on a calculator, such as functions sinα, cosα, tgα and others. And the main thing is the willingness to endure a long and complex course of study without missing any classes. The aim of the course is to obtain new and deepen the existing knowledge on ultrasonic method of control, to obtain and improve practical skills of work with ultrasonic flaw detectors such as UD2-70, UD2-102, UD3-103, UD4-T, UD4-76, USM-35, USM-GO, Sitescan 250, EPOCH 1000 Panametrics and other modern flaw detectors. The number of hours for conducting training, which includes obtaining both theoretical knowledge and practical skills:

– Level 1 – 80 hours;
– Level 2 – 80 hours (direct training for Level 2 – 160 hours) [10].

The training period is 20 days (4 weeks). The form of training is on-the-job.

Mode of training – 8–10 hours per day. Traditional ultrasonic method in the search for internal defects is one of the most common methods of NDT.

Methods, instruments and devices of acoustic NDT, using ultrasonic frequency range, according to state standard 23829 may be called ultrasonic, for example, “ultrasonic flaw detection”, “ultrasonic flaw detector”. Ultrasonic defectoscopy is the conduct of ultrasonic inspection for defects such as violation of the continuity or homogeneity of the material of the product. The principle of inspection with the ultrasonic echo – pulse method is based on the fact that the transmitter sends ultrasonic pulses into the product. When encountering an obstacle, such as a defect or back (bottom) surface, part of the ultrasonic wave energy is reflected and returned back to the transmitter. The ultrasonic receiver converts the ultrasonic vibrations passed through the product into electrical vibrations, which are fed to the screen – the main indicator of the flaw detector. The electronic unit of the flaw detector measures the time of pulse passage to the object of reflection and back with the subsequent conversion into distance by the formula: $S = (t \cdot c)/2$, where S is the distance to the object of reflection; c is the velocity of ultrasound propagation in the material of the product; t is the time passed by the ultrasonic wave to the object of reflection and back. Characteristic defects in welded joints, castings, forgings, as well as railway transport parts. However, conventional ultrasonic inspection cannot completely replace radiation inspection and vice versa. Thus, a spherical defect such as a pore ultrasound “will see” as a point, and the amplitude of the reflected signal on the flaw detector screen may be within tolerance, i.e. acceptable. When conducting radiation control, the same defect will be seen as a plane and may not be acceptable in size. At the same time, a vertical crack coinciding with the direction of radioactive radiation may be missed due to insufficient intensity distribution of the passing rays. Vertical cracks are very well detected in tandem ultrasonic inspection. One of the transducers is a radiator and the other is a receiver or vice versa. The main advantage of radiation method of control over ultrasound is that the images of defects are analyzed on the obtained images with the subsequent possibility of their storage and re-analysis. A significant disadvantage of radiation methods is that when conducting radiation control in order to avoid dangerous exposure of the operating personnel to ionizing radiation and harmful gases formed in the air under the influence of radiation, it is necessary to strictly follow safety rules established by regulatory documents. Nowadays there are innovative technologies using ultrasound instead of radiation control. For these purposes is used ultrasonic diffraction-time method of control (TOFD), as well as ultrasonic method using transducers in the form of phased arrays (PAUT). There is a standard ASME 2235-9:2005 “Use of Ultrasonic Examination in Lieu of Radiography Section I; Section VIII, Divisions 1 and 2; and Section XII” on the use of ultrasonic inspection in lieu of radiation inspection. The term ultrasonic inspection here refers to the integrated use of time-of-flight diffraction (TOFD) in conjunction with phased array ultrasonic transducers (PAUTs), as well as conventional ultrasonic inspection itself, including inspection over thick layers [12].

Sophisticated software tools allow for classification of reflections from changes in the pipe cross-section. Therefore, the system provides 100% coverage of the pipe section up to 100 m in length from the location of the sensor rings in each direction (Figure 1).

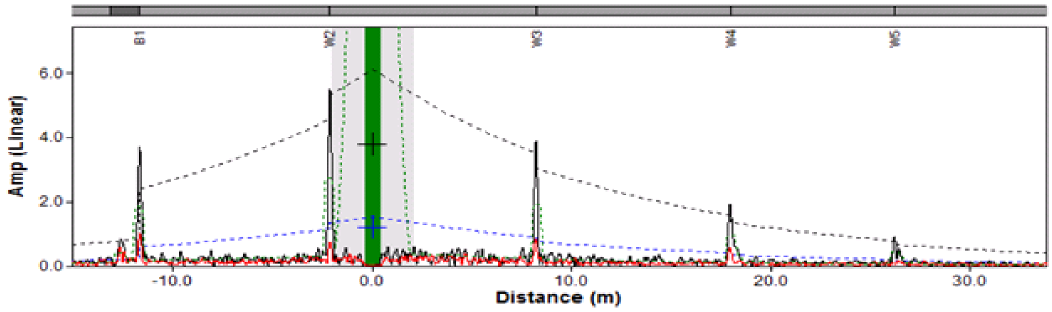

Figure 1. Classification of reflection from changes in the cross-section of the pipe

The defect inspection system through ultrasonic waves has a number of advantages that make this method more effective than others:

– prompt detection of damaged areas;
– possibility of use in hard-to-reach places;
– possibility to work on an empty (unfilled) pipeline;
– possibility of crack detection and material density control;
– ease of use and mobility of the system;
– possibility of operative diagnostics of a pipe having a long length;
– optimum balance of speed and quality of examination;
– high informativeness of the examination.

The use of this control system significantly saves the time required to investigate the pipeline quality using additional methods that do not provide such fast and accurate results.

Limitations of the ultrasonic flaw detector

Despite the obvious advantages, the system still has some limitations. This method allows the examination of pipes with a long length (up to 100 meters), but the greatest efficiency is observed when the length of the pipeline does not exceed fifty meters.

This system quickly identifies defects, but does not accurately determine the size and depth of the damage.

Briefly on the features of the method itself.

Nowadays, a significant number of pipelines of various technological purposes after long-term operation require condition assessment in order to ensure reliability, resource extension and optimization of repair, installation and construction works [13].

Traditionally, this issue has been solved mainly by using in-line diagnostics (ILD) as the most effective method of diagnostics. And it is justified. However, this method is not applicable in all cases, namely, for CTD a necessary condition is the construction of launching and receiving units, which is not always possible for one reason or another, this method is not applicable in case pipes and crane units of different diameters were used on the pipeline. And it is in these cases that the non-contact magnetometric method of diagnostics is the most effective.

Advantages of the magnetometric method of diagnostics:

– There is no need for preliminary preparation of the pipeline for inspection (cleaning, running of calibrator shells) and no change of operating modes of product transportation, i.e. there is no need to stop the pipeline operation, which significantly reduces the cost of diagnostics;
– No magnetization of the object metal is required;
– Various types of defects are detected (including longitudinal crack-like defects, defects of welded assembly joints);
– No restrictions on the diameters of surveyed pipelines (any cross-section) and their design features (angles of bends, elevations, pipe wall thickness, operating pressure in the pipeline, etc.).
– Allows to organize monitoring and fill in the database on passportization of objects, because it is carried out at any distance and with unlimited minimum periodicity;
– Accurately positions underground pipelines on the route, as it allows multiple refinements of the location of anomalies on the site, in particular, water crossings;
– It is used for objects where in-line flaw detection is not possible (equipped with start-receive chambers, markers, with unremoved lining rings, welding grit, etc.);
– Provides a significant reduction in the full cycle time of the work;
– Guarantees minimal involvement of the Customer's resources for preparatory works.

It should be noted that in order to obtain the true technical condition of gas and oil pipelines it is necessary to carry out a comprehensive survey consisting of:

– Analysis of design, executive and operational documentation, nature and scope of repairs performed during the operation period, results of technical inspections.
– Route analysis. Positioning of the pipeline location in the global coordinate system by GPS satellite navigation system. Pipeline condition diagnostics by non-contact magnetome-tric method. Pipeline condition diagnostics by non-contact electrometric method. Diagnostics of the pipeline insulation coating by corrosion monitoring device; Data processing based on the results of

inspections, preliminary assessment of the technical condition of the pipeline with identification of anomalous sections;

– Determination of anomalous pipeline sections for control pits;

– Defectoscopic inspection of the pipeline by traditional methods in control pits: visual and measuring inspection; instrumental control of adhesion and thickness of insulation coating; control by magnetic metal memory method; ultrasonic thickness measurement; radiographic inspection of welded joints; ultrasonic inspection of welded joints and base metal; capillary inspection; hardness measurements; metallographic examination of pipe metal and welded joints;

– Technical diagnostics of pipelines by acoustic emission method in sections where it is impossible to inspect by contact methods of control at crossings, water obstacles, etc.);

– Processing and analysis of technical diagnostics results, registration of inspection results.

– Assessment of residual life, development of recommendations on bringing the object in compliance with the requirements of regulatory and technical documentation [14].

This method allows for diagnostics without taking the facility out of operation for a short time or taking it out of service, which provides clear economic advantages over other methods of OB, which require stopping the facility for general inspection. Figure 2 shows the results of monitoring the condition of the insulation of various existing pipelines.

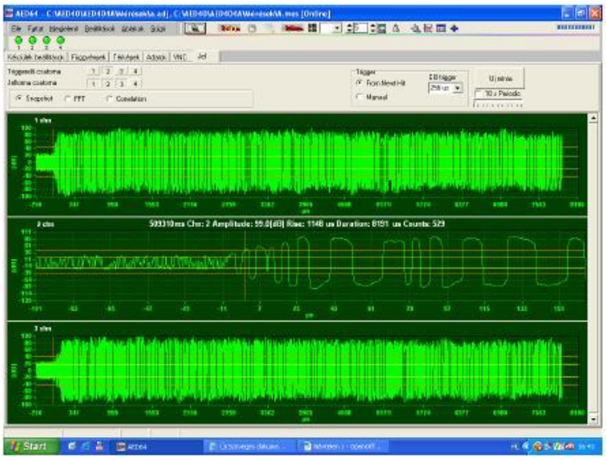

Figure 2. Results of monitoring the condition of insulation of pipelines in various uses

As can be seen from the above, the magnetometric method, despite the fact that earlier minor works in this direction have already been carried out, is a novelty in terms of wide application in the field of diagnostics of gas and oil pipelines in the territory of the Republic of Kazakhstan. Our company is actively working on the issue of popularization of this method. It should be noted that this method has wide possibilities in terms of improvement and modernization of both applied diagnostics devices and expansion of the number of obtained parameters, which can be a good topic of research and development work (R&D). It should be noted that the result of R&D on non-contact diagnostics could have a real application in the oil and gas sector.

The purpose of the method is detection, determination of coordinates and monitoring of magnetic field anomalies associated with defects of base metal, welded joint metal, as well as the general stress state of the gas pipeline.

The method provides detection and registration of defective sections of pipelines, and allows to classify incipient and developing defects by the degree of danger.

1. The hazard assessment of the detected defects is performed by the integral index F, which takes into account the extent of magnetic anomaly S in m, amplitudes and shape of distribution of the magnetic field intensity vector.

F reflects the amount of excess of the recorded values of the magnetic field over the background values, the density of typical values and the nature of their distribution are calculated by the formula:

$$F = (F + 1)\, e - K{\cdot}A/S. \tag{1}$$

K – degree of stress concentration in the stress concentration zone, in turn calculated by the formula:

$$K = \Sigma\sqrt{(\cos 2\alpha + \cos 2\beta + \cos 2\gamma)} \tag{2}$$

Where $\cos\alpha$, $\cos\beta$, $\cos\gamma$ – directing cosines of the vector of stress concentration, i.e. in the determination of the technical condition of the pipe are included quite a lot of approximate calculation data and coefficients, which does not allow to count on high accuracy of measurement results, and accordingly, the results of making adequate decisions.

2. The criterion for assessing the technical condition of the pipeline is again reduced to three states:

– Good – 0.75÷1.0;
– Acceptable – 0.45÷0.75;
– Unacceptable – 0.45.

Which approximately corresponds to the methodology according to the results of WTD (“Pre-critical”, “Critical”, “Zacritical”).

3. The assessment of the pipeline is omitted not only by condition, but also by actual operation mode, since for the last 8–10 years the pipeline has been operating in the mode of 50–60% of loading from *RPr*, this indicator is not taken into account [4].

3. TASKS OF HYDRAULIC CALCULATION OF NETWORKS

The final purpose of water supply network calculation is to determine the diameters of network lines and head losses in them. In case diameters, characteristics of pumping stations, regulating tanks, etc. are known, the calculation results in determination of true flow rates in the network lines, actual water supply by all water suppliers and pressures created by them, as well as pressures in all network nodes and non-fixed withdrawals.

The configuration, section lengths and nodal water withdrawals must always be specified for the water distribution network to be calculated, the hydraulic calculation of water distribution networks is based on the assumption that the distribution of water along the network lines takes place in accordance with Kirchhoff's laws. Thus, in accordance with Kirchhoff's I law in each node should be observed material balance, which corresponds to the principle of continuity of flow. According to the conditions of water supply network operation, it means that the algebraic sum of flow rates in any node of the network is equal to zero:

$$\sum q_{ik} - Q_i = 0 \quad (3)$$

According to Kirchhoff's II law, the condition of total zero change of pressure drop (potential difference) in any circuit of the system is required. For a ring network, this means that the algebraic sum of head losses in any circuit of the i-th network is zero:

$(\sum S_{ik} q_{ik}^{\beta})_i = 0$, , where q_{ik} – flow rate along the sections of the water supply network, m^3/s; Q_i – nodal withdrawals, Q_i/s; S_{ik} – hydraulic resistance of the line.

If there are pressure-flow characteristics of water feeders $F(Q)_M$ and non-fixed outlets $F(Q)_K$ located at the nodes of the system M and K, then in addition to the last equation the equations of the following form are used $F(Q)_M - F(Q)_K = (\sum S_{ik} q_{ik}^{\beta})_{MK}$.

The interaction between water feeders and non-fixed outlets is realized through head losses $(\sum S_{ik} q_{ik}^{\beta})_{MK}$ in the network lines connecting them. The flow distribution in a ring network, under which the above laws are observed, corresponds to the minimum of energy consumed to overcome head losses in pipes [9].

Before establishing the number of equations of Kirchhoff's I and II laws characterizing the flow distribution in the system, let us consider the properties of the water supply network. Considering the geometrical properties of a ring network, we can establish a certain relationship between the number of its elements, i.e. the number of rings, nodes and sections. By denoting the number of rings by n, the number of nodes by m, the number of sections by p and the number of water suppliers and non-fixed withdrawals by e, the following relationship can be established:

$$p = m + n + e - 1 \quad (4)$$

This provision is a consequence of Euler's theorem on the relationship between the number of faces, vertices and edges of a convex polyhedron. It allows us to establish the relationship between the number of levels of Kirchhoff's I and II laws in the calculation of water supply networks and the number of unknowns.

In case the diameters of the network lines are known, it is possible to unambiguously determine the flow rates in the network lines. Seeking costs q_{ik} are from the joint solution of the system $p = m + n + e - 1$ equations of Kirchhoff's I and II laws, of which $n + e$ – nonlinear equations and $m - 1$ – linear equations of the type.

For branched networks without rings, the number of equations is determined by the relation $p = m + e - 1$. In the absence of characteristics of water feeders and non-fixed withdrawals, their number is reduced to $m - 1$.

In finding the flux distribution, compliance with the linear equations is achieved at the preliminary flux distribution stage [8].

In general, considering the equations of Kirchhoff's II law, it becomes clear that in addition to the unknowns q_{ik} to be found, they also include unknown line diameters d_{ik}. This is due to the fact that the S_{ik} values included in the head loss formula are expressed as a function of diameters. Thus, any change in the diameters of the network lines will lead to a redistribution of the costs flowing through them. On the other hand, the redistribution of flow rates leads to the need to assign new diameters. In this situation, one is faced (as mentioned above) with the task of technical and economic calculation. As a result of this calculation, $2p$ unknowns are to be found: p values of q_{ik} and the same number of d_{ik} values. To find all $2p$ unknowns simultaneously, the obtained equations are not sufficient.

Without referring at this stage to the methods of full technical and economic calculation, it can be concluded that the hydraulic calculation of networks should be carried out by specifying diameters. As it was mentioned above, the selection of diameters of individual network sections cannot be made completely arbitrarily, since the diameter, to a certain extent, is a function of the flow rate conducted by the pipe, so for accurate selection of diameters it is necessary to assign a preliminary flow distribution [6].

Description of the projected network

On the typical floor plan, the location of the water riser is selected, from which the water connections are made to the water outlets.

An axonometric diagram of the apartment wiring is drawn.

From the typical floor plan to the basement plan water risers are transferred to the basement plan and united by a main line at the shortest distance from the entrance to the building. If the risers are located on both sides of the central axis of the building, the main line is laid above the ceiling of the basement to the central bearing wall of the building. A water meter is installed behind the inlet, but not under the living space.

An axonometric scheme of the internal water supply network is constructed.

On the axonometric diagram of the internal water supply network, the design direction and the dictating point are selected.

The dictating point is the highest and most distant from the water intake point.

The design direction is the direction of the water distribution network from the inlet to the dictating point.

The design direction is divided into design sections.

The designed network of internal water supply is a dead-end network with bottom distribution, consisting of main, distribution water pipelines and connections to water-dispensing devices [8].

The pipe runs along the shortest distance and input pipe perpendicular to the outer wall of the building, taking into account $i = 0.003–0.005$ from the building to the external water supply network, for the possibility of emptying the system. Depending on the depth of filling of pipes of the city water supply system and the depth of freezing of the ground, since we do not have data on the depth of filling of the city water supply system, we determine the depth of filling of the input as:

$$H = H + 0.3 = 1.1 + 0.3 = 1.4 \text{ m} \tag{5}$$

To account for the flow of consumed water, in the basement of the building install a water-metering unit with a branch line located at a height of 0.2 m from the floor of the basement. For the designed network of internal water supply is selected water meter VKSM-32. A booster installation is provided, as a result of calculation the pump 1,5K-8/19b is selected.

The main pipeline is laid under the ceiling of the basement with a slope $i = 0.003$ at a distance of 0.2 m, on each riser valves are installed on the supply lines to the water dispensers [15].

CONCLUSION

In general, thanks to the research conducted in the areas of underground heat pipelines, the method has received a significant boost in development, new patterns have been identified, and additional evaluation criteria have been developed-software complexes for analyzing the state of heat networks in which the presence of magnetic field anomalies has occurred.

Zones of stress – strain state of compensation pipelines that are apparently intact, but have damage, are determined. While these regions may not cause large-scale disasters in the near future, more serious disruptions may develop in the future if attempts are not made to prevent compensation violations.

So far, the remaining actual wall thickness and the exact time before disconnection cannot be determined only by processing data from non-contact magnetic diagnostics, which requires drilling holes, or an accurate description of the “cause of damage”, but now a constant set of data is required to improve the accuracy of forecasting the remaining pipeline resources and significantly develop in the future the detection of patterns of obsolescence of pipe metals in heating networks. and the analytical base extension has long been known.

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УЛЬТРАДЫБЫСТЫҚ ДЕФЕКТОСКОПИЯ ӘДІСІМЕН ИНЖЕНЕРЛІК КОММУНИКАЦИЯЛАРДЫ ТЕХНИКАЛЫҚ ЗЕРТТЕУ

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Бұл мақала ішкі және сыртқы беттердегі коррозияны және басқа ақауларды анықтау үшін пайдаланылатын ұзын толқынды ультрадыбыстық радикс жүйелеріне ерекше назар аударады. Бұл жету қиын жерлерде ұзын құбырлардағы коррозияның және басқа ақаулардың болуын бақылауға мүмкіндік береді.

Қазіргі уақытта технологиялық құбырларды жобалау мен есептеуде қолданылатын тиісті мемлекеттік салалық стандарттар әзірленуде, бірақ әзірге сараптамалық мекемелер техникалық жағдайды диагностикалауға ерекше көңіл бөлгені дұрыс. Ол үшін ең дәл диагностикалық шешімдерді пайдалану және бүкіл жүйеге болжамды қамтамасыз ету қажет болады.

Түйін сөздер: *қашықтағы метнодылар, электромагниттік сәулелену, ультракүлгін, құбырлар, ультрадыбыстық, флавты анықтау, радиациялық бақылау, акустикалық зерттеулер.*

ТЕХНИЧЕСКОЕ ОБСЛЕДОВАНИЕ ИНЖЕНЕРНЫХ КОММУНИКАЦИЙ МЕТОДОМ УЛЬТРАЗВУКОВОЙ ДЕФЕКТОСКОПИИ

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В статье рассматривается вопрос о необходимости уделять особое внимание длинноволновым ультразвуковым радиксным системам, используемым для обнаружения коррозии и других дефектов на внутренних и внешних поверхностях. Это позволяет контролировать наличие коррозии и других дефектов на длинных трубах в труднодоступных местах.

В настоящее время разрабатываются соответствующие государственные отраслевые стандарты, применяемые при проектировании и расчетах технологических трубопроводов, но пока экспертным учреждениям лучше уделить особое внимание диагностике технического состояния. Для этого необходимо будет использовать максимально точные диагностические решения и давать прогноз по всей системе.

Ключевые слова*: дистанционные методы, электромагнитное излучение, ультрафиолет, трубопроводы, ультразвук, дефектоскопия, радиационный контроль, акустические исследования.*