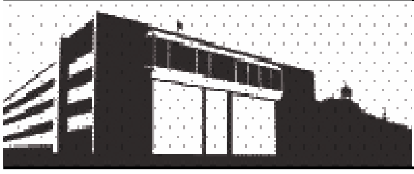

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**ТЕХНИКАЛЫҚ ҒЫЛЫМДАР ЖӘНЕ ТЕХНОЛОГИЯЛАР СЕРИЯСЫ / TECHNICAL SCIENCES AND TECHNOLOGY SERIES/ СЕРИЯ ТЕХНИЧЕСКИЕ НАУКИ И ТЕХНОЛОГИИ**

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# Calculation of the stress-strain state of an element of an underground oil pipeline, taking into account the appearance of an overpressure wave

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**Abstract.** At present, a large number of extended pipeline systems are operated in our country, which are designed for pumping energy resources. Improving the reliability of these pipelines is one of the most important tasks during the operation period. Operational regimes of oil pumping, both through main and field pipelines, provide for a change in pumping capacity, emergency shutdowns of pumping equipment, unauthorized blocking of the flow as a result of closing valves. Such events lead to the occurrence of hydraulic shock in the pipeline and its influence on the strength characteristics of pipes, which can have different material designs.

In this regard, the consideration of issues related to the influence of hydraulic shock on the strength characteristics of the pipeline is very relevant in our time.

This article is devoted to the study of the stress-strain state of an element of an underground oil pipeline, taking into account the occurrence of an overpressure wave. The paper presents calculation methods that make it possible to evaluate the effect of an overpressure wave on the structural elements of a pipeline in an underground environment. The factors influencing the dynamics of deformations and stresses in pipeline materials under various operating conditions are considered.

The analysis of the results of numerical calculations is presented, demonstrating the influence of the parameters of the overpressure wave on the reliability and safety of underground oil pipelines. The findings can be used to optimize the design and operation of pipeline systems under variable loads, thus helping to increase the resilience of the infrastructure and reduce the risk of accidents.

**Key words:** hydraulic shock, pipeline, temperature, pressure, stress-strain state, pipe wall, pressure wave.

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**Introduction**

One of the most dangerous modes during the operation of any pipeline, not without reason, is the phenomenon of hydraulic shock. Hydraulic shock can occur in liquid pipelines, as well as in gas pipelines and pipelines for transporting multiphase systems.

Hydraulic shock is a shock wave that propagates along the longitudinal axis of the pipeline, and also affects all elements installed on it: fittings, pipeline parts and branches from this pipeline.

The pressure wave is caused by a sharp change in pressure along the length of the pipeline, which occurs due to a change in the flow rate of the pumped product.

The speed of pressure wave propagation along the pipeline for oil pipelines can be 335…1372 m/s [1].

As a result, a pressure increase occurs, due to the properties of the fluid, which is practically incompressible and experiences a strong deceleration of the flow core at the moment of valve closing.

Experience in the operation of oil pipelines made it possible to establish the following main causes of hydraulic shock. These include [2, 3]:

– sharp shutoff of the flow when closing the shut-off valves installed along the route of the oil pipeline;

– switching on or off of oil pumps at oil pumping stations due to the operation of emergency protection provided by the project;

– sharp drops in the pipeline sections along the route (contamination of the pipeline section in some sections with deposits of resins, paraffins, asphaltenes);

– the occurrence of unexpected obstacles in the way of moving the fluid flow in the pipeline (possible in the plug mode and the formation of air or liquid plugs);

– opposite direction of flow (typical for branched pipeline systems);

– operation of the check valve installed on the discharge pipeline of the main pump;

– change in the amount of oil withdrawn from the main pipeline;

– enabling/disabling of individual technological units as part of the main oil pipeline;

– difference in oil consumption over a short period of time;

– increase in the flow rate of the product with a diameter of the pipeline that does not correspond to this flow rate;

– high difference in geodetic marks along the pipeline route.

The main consequences of a pressure wave that can occur in an oil pipeline as a result of hydraulic shock are:

– damage to main pumps at PS;

– formation of longitudinal cracks in the pipe body;

– separation of flange connections along their axis;

– damage to the supporting structures of pipelines in above-ground sections;

– destruction of aggregate and cut-off fittings;

– misalignment of pumping equipment with pipeline parts.

Hydraulic shock is inherent in pipelines through which fluid is pumped. This is due to the fact that the speed with which the shock wave propagates through the pipeline directly depends on the compressibility of the liquid. In addition, the speed is affected by the deformation of the pipe walls and its diameter.

At the same time, the criticality of the properties of a liquid is obvious, which is practically incompressible, unlike a gas. Therefore, the most critical phenomenon of hydraulic shock is for oil pipelines and oil product pipelines, which are widespread and of considerable length in our country.

A diagram of the occurrence of hydraulic shock is shown in Figure 1.

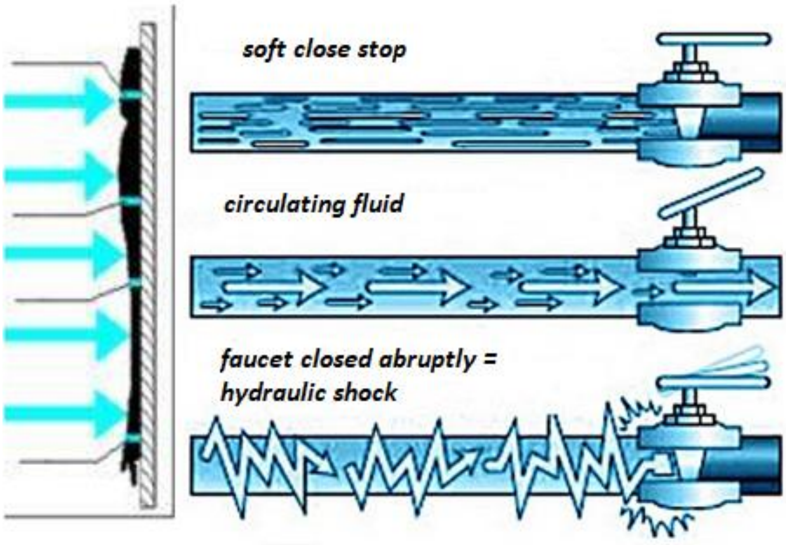


Figure 1. Scheme of the occurrence of hydraulic shock in the pipeline when shutoff valves are closed

The main purpose of the work carried out is to develop an algorithm for calculating the effect of hydraulic shock on the SSS, strength and bearing capacity of an underground pipeline.

The main requirement for the algorithm is the simplicity of calculation and practicality in use, which is necessary for engineers when designing oil pipelines.

The developed algorithm is most relevant in the conditions of commissioning of an oil pipeline when it is put into operation, testing the operation of pumping equipment, debugging software designed to operate linear shut-off valves and shut them off in various emergency situations and events that go beyond the design values.

**The methodology**

When the flow is shut off with the use of shut-off valves, its sharp deceleration occurs, which leads to an increase in fluid pressure by several times.

The pressure increase during hydraulic shock is determined by the well-known Zhukovsky formula:

$$\Delta P_{imp}=\rho\cdot\Delta v\cdot c \quad (1)$$

where $\rho$ is the density of the pumped liquid; $\Delta v$ is the change in the flow rate. When the flow stops, it will be equal to the liquid flow rate before the pumping stop; c is the velocity of shock wave propagation, which is determined by formula (2):

$$c = \sqrt{\frac{E_l}{\rho \cdot (1 + \frac{D_{in}}{\delta} \cdot \frac{E_l}{E_p})}} \tag{2}$$

where $E_l$ is the modulus of elasticity of the liquid; $D_{in}$ – inner diameter of the pipe; $\delta$ – pipe wall thickness; $E_p$ – the modulus of elasticity of the pipe material (Young's modulus).

Regulatory documentation [4] establishes the requirements for calculating the thickness of the pipeline wall according to the following relationship:

$$\delta = \frac{n \cdot p \cdot D_o}{2 \cdot (R_1 + n \cdot p)} \tag{3}$$

where $n$ is the reliability factor for the load – the internal working pressure in the pipeline, taken according to table 14 [4]; $p$ is the working pressure in the pipeline; $D_o$ – outer diameter of the pipeline; $R_1$ – calculated tensile (compression) resistance.

From this formula we express the working pressure in the pipeline:

$$p = \frac{2 \cdot R_1 \cdot \delta}{n \cdot D_0 - n \cdot \delta} \tag{4}$$

Obviously, in order for the selected wall thickness to be able to withstand the operating pressure in the pipeline and the pressure resulting from hydraulic shock, the following condition must be met

$$p + \Delta P_{imp} \leq \frac{2 \cdot R_1 \cdot \delta}{n \cdot D_o - n \cdot \delta} \tag{5}$$

Substituting in formula (5) the value for c from formula (2), we obtain:

$$p + \rho \cdot \Delta v \cdot \sqrt{\frac{E_l}{\rho \cdot (1 + \frac{D_{in}}{\delta} \cdot \frac{E_l}{E_p})}} \leq \frac{2 \cdot R_1 \cdot \delta}{n \cdot D_o - n \cdot \delta} \tag{6}$$

Comparing the left and right parts of the equation, it is necessary to strive for their equality. Table 1.1 shows the initial data for calculating the hydraulic shock in an oil pipeline and studying the effect of hydraulic shock on the strength of a pipeline made of steel 17G1SU.

Table 1. Initial data for calculation

| Parameter | Meaning |
|---|---|
| Outer diameter of the pipeline, mm | 720 |

| | |
|---|---|
| Pipeline wall thickness, mm | 10,0 |
| Load safety factor | 1,15 |
| Design tensile strength, MPa | 510 |
| Oil density, kg/m$^3$ | 835,0 |
| Pipe inner radius, mm | 350 |
| Fluid elasticity modulus, MPa | 1300 |
| Modulus of elasticity of the pipe material (Young's modulus), MPa | 206000 |
| Change in flow rate (when the flow stops, it will be equal to the liquid flow rate before the pumping stop), m/s | 1,0 |
| Working pressure in the pipeline | 6,0 |

Substituting numerical values into formula (6), we obtain:

$$835 \cdot 0{,}5 \cdot \sqrt{\frac{1300 \cdot 10^6}{835 \cdot \left(1 + \frac{700}{10} \cdot \frac{1300}{206000}\right)}} + 6{,}0 \le \frac{2 \cdot 271{,}8 \cdot 10}{1{,}15 \cdot 720 - 1{,}15 \cdot 10}$$

$$6{,}43 \text{ МПа} < 6{,}65 \text{ Мпа}$$

The condition is met. Consequently, the hydraulic shock that occurs in the pipeline under consideration does not reduce the strength characteristics of the pipeline with a diameter of 720x10 mm when the flow is decelerated as a result of hydraulic shock from 0.75 m/s to 0.

In addition to the above calculations, studies were also carried out on the effect of hydraulic shock on the strength of the pipeline with an increase in pumping speed from 0.1 m/s to 1.0 m/s.

Other sizes of pipelines and pipeline steel with strength characteristics were also considered, below those given in Table 1.

The calculation results are presented in the graphs (see Figure 2).

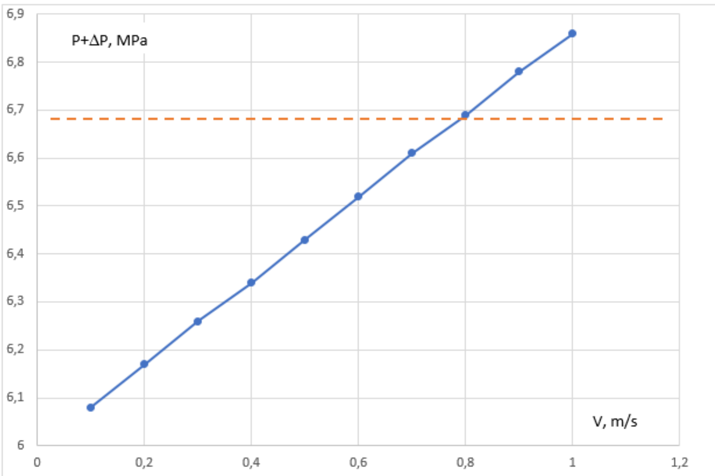


Figure 2. Graph of the dependence of the pressure increase due to hydraulic shock on the product velocity in the pipeline ∅720x10 (steel 17G1SU)

It can be seen from Figure 2 that at only a product velocity of more than 0.75 m/s, the phenomenon of hydraulic shock becomes dangerous for the strength characteristics of the pipeline. If the product speed exceeds 0.75 m/s and the flow slows down to its complete stop, the pipe wall may be destroyed due to the occurrence of hydraulic shock.

For main pipelines, the speed of the pumped product in the range from 0.3 to 0.75 m/s is acceptable. By maintaining it, it is possible to prevent the negative impact of hydraulic shock with the destruction of the pipeline wall.

Table 2 shows the characteristics of the considered pipelines, the diameters of which are most often used for the construction of trunk and field oil pipelines. The working pressure in the pipelines is assumed to be no more than 6.0 MPa.

Table 2. Piping sizes and material design

| Pipeline diameter, mm | Pipeline wall thickness, mm | Pipe material | Design tensile strength, MPa |
|---|---|---|---|
| 325 | 5,0 | Steel 20 | 218,55 |
| 426 | 7,0 | Steel 20 | 218,55 |
| 530 | 9,0 | Steel 20 | 218,55 |
| 610 | 10,0 | Steel 20 | 218,55 |
| 720 | 12,0 | Steel 20 | 218,55 |

Using formula (6), we check the strength retention of pipelines of various diameters at a product operating pressure of 6.0 MPa and a pumped oil velocity of 0.5 m/s.

The diagram shown in Figure 3 shows the excess of the impact of hydraulic shock over the allowable (in terms of pipe strength) values.

It can be seen from Figure 3 that steel 20 with lower strength characteristics used for pipelines reduces the strength of the pipeline, which cannot withstand hydraulic shock even at low speeds of the pumped product.

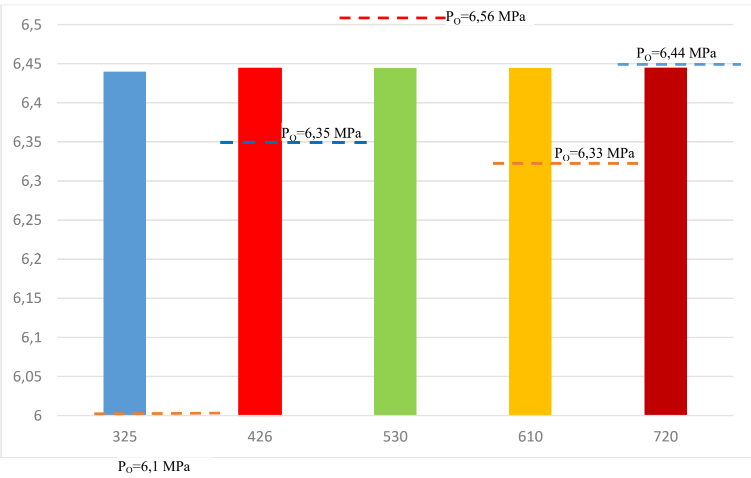


Figure 3. Diagram of pressure growth due to hydraulic shock in pipelines of various diameters at a product velocity of 0.5 m/s (the dotted line shows the allowable pressure in the pipeline)

It can be seen from the diagram in Figure 3 that only for pipeline diameters of 530x9 mm and 720x10, the pressure arising in the pipeline due to hydraulic shock does not exceed the strength characteristics of the pipe material. Therefore, this product pumping speed (equal to 0.5 m/s) can be recommended as safe for pipeline operation.

However, in accordance with the recommendations [4], it is necessary to check the strength and stability of the underground pipeline from the condition that plastic deformations are not allowed according to the following design dependencies:

$$\left|\sigma_l^S\right| \leq \psi_1 \cdot \frac{m}{0{,}9 \cdot k_S} \cdot R_2^S \tag{7}$$

$$\sigma_h^S \leq \frac{m}{0{,}9 \cdot k_S} \cdot R_2^S \tag{8}$$

where $\sigma_l^S$ – the maximum total longitudinal stresses that occur in pipelines under the action of standard loads on it; $\sigma_h^S$ – hoop stresses from the standard (working) pressure, which are determined by formula (9); $\psi_1$ – coefficient that takes into account the biaxial stress state of the pipeline material from which it is made (steel).

$$\sigma_h^S = \frac{p \cdot D_{in}}{2 \cdot \delta} \tag{9}$$

As can be seen from formula (9), hoop stresses depend on the operating pressure in the pipeline.

Under the action of hydraulic shock in the pipeline, it is proposed to switch in formulas (7) and (8) from standard longitudinal and hoop stresses to extreme longitudinal and hoop stresses that occur in the pipeline under the action of hydraulic shock. Then formulas (7) and (8) will take the following form:

$$\sigma_l^E \leq \psi_1 \cdot \frac{m}{0{,}9 \cdot k_S} \cdot R_2^S \tag{10}$$

$$\sigma_h^E \leq \frac{m}{0{,}9 \cdot k_S} \cdot R_2^S \tag{11}$$

Consequently, with its growth, due to hydraulic shock, this parameter will also increase. Let us determine the hoop stresses for the boundary value of the oil velocity in the pipeline, which is 0.75 m/s.

According to formula (9) for a 720x10 mm pipeline, we obtain:

$$\sigma_h^E = \frac{(p + \Delta P) \cdot D_{in}}{2 \cdot \delta}$$

$$\sigma_h^E = \frac{(6{,}0 + 0{,}65) \cdot 720}{2 \cdot 10} = 239{,}4 \text{ MPa}$$

In accordance with the requirements of [2], we check condition (11):

$$239{,}4 \leq \frac{0{,}825}{0{,}9 \cdot 1{,}155} \cdot 353$$
$$239{,}4 \leq \frac{0{,}825}{0{,}9 \cdot 1{,}155} \cdot 353$$
$$239{,}4 \text{ MPa} \leq 280{,}15 \text{ MPa}$$

Condition (11) is satisfied even if the boundary value of the oil velocity in the pipeline is 0.75 m/s.

It is also necessary to check condition (10). The maximum total longitudinal stresses in the pipeline from standard loads are determined by the formula given in [4]:

$$\sigma_l^E = \mu \cdot \sigma_l^E - \alpha \cdot E \cdot \Delta t \pm \frac{E \cdot D_O}{2 \cdot \rho} \quad (12)$$

where $\alpha$ – coefficient of linear expansion of the pipe metal; $\Delta t$ – calculated temperature difference (positive when heated); $\rho$ is the minimum radius of elastic bending of the pipeline *axis, cm;* $\mu$ is the Poisson's ratio.

Substituting numerical values into formula (12), we obtain:

$$\sigma_h^E = 0{,}3 \cdot 239{,}4 - 12{,}12 \cdot 10^{-6} \cdot 206000 \cdot 76{,}2 \pm \frac{206000 \cdot 72{,}0}{2 \cdot 70000} == 175{,}3 \text{ МПа}$$

Using formula (10), we check the condition according to which the extreme total longitudinal stresses in the pipeline will not exceed the standard ones:

$$175{,}3 \leq 0{,}94 \cdot \frac{0{,}825}{0{,}9 \cdot 1{,}155} \cdot 353$$
$$175{,}3 \text{ MPa} < 263{,}3 \text{ MPa}$$

Thus, a test for extreme total longitudinal stresses in the pipeline showed that they would be less than the allowable values. Therefore, a product velocity of 0.75 m/s is the maximum possible, based on the strength characteristics of the pipeline.

When choosing a product pumping speed, it is also necessary to check the overall stability of the pipeline in the longitudinal direction according to the condition set out in [4]:

$$S \leq m \cdot N_{cr} \quad (13)$$

where S is the equivalent longitudinal axial force in the pipeline section. It is determined by the formula [4]:

$$S = 100 \cdot [(0{,}5 - \mu) \cdot \sigma_h + \alpha \cdot E \cdot \Delta t] \cdot F \quad (14)$$

where $F$ is the cross-sectional area of the pipe, cm$^2$; $N_{cr}$ – critical longitudinal force. Under its influence, there is a loss of longitudinal stability of the pipeline. Determined by the formula:

$$N_{cr} = \frac{2 \cdot \pi \cdot E \cdot \delta^2}{\sqrt{3 \cdot (1-\mu^2)}} \tag{15}$$

Based on the results of the analysis of formulas (14) and (15), it can be concluded that only the value of $S$ is affected by the value of hydraulic shock in the pipeline.

Thus, by analogy with the above calculated dependences, we obtain the value of the extreme equivalent longitudinal axial force $S_{extr}$:

$$S_{extr} = 100 \cdot [(0{,}5 - \mu) \cdot \sigma_h^E + \alpha \cdot E \cdot \Delta t] \cdot F \tag{16}$$

Making successive calculations according to formulas (16), (15) and (13), we obtain:

$$S_{extr} = 100 \cdot [(0{,}5 - 0{,}3) \cdot 239{,}4 + 12{,}12 \cdot 10^{-6} \cdot 206000 \cdot 76{,}2] \cdot 54{,}95 = 5{,}33 MN$$

$$N_{cr} = \frac{2 \cdot 3{,}14 \cdot 206000 \cdot 10^2}{\sqrt{3 \cdot (1 - 0{,}3^2)}} = 78{,}3 \text{ MN}$$

Under the action of hydraulic shock, it becomes extreme. Then:

$$5{,}33 \leq 0{,}825 \cdot 78{,}3$$
$$5{,}33 \text{ MN} < 64{,}6 \text{ MN}$$

Thus, when exposed to extreme pressure in the pipeline caused by water hammer, the overall stability of the pipeline in the longitudinal direction is maintained.

Therefore, calculations confirm that the value of extreme pressure increase due to water hammer will be safe for a 720x10 mm pipeline at a product pumping speed of 0.75 m/s.

The article presents mathematical models for estimating pressure increase in an oil pipeline due to hydraulic shock. In particular, formulas are given for calculating the pressure change and the velocity of propagation of the shock wave.

The study shows that with certain parameters of the oil pipeline and the flow rate of the product, the strength characteristics of the pipe can remain within safe values.

The analysis of the conditions necessary to ensure the strength and stability of the oil pipeline in the conditions of hydraulic shock is made.

Thus, the study provides important data for engineers and specialists in the oil industry to ensure the safety and efficiency of pipeline operations.

## Findings/Discussion

As a result of the study of the effect of hydraulic shock on the strength characteristics of an underground oil pipeline, it is shown that for an oil pipeline with parameters 720x10 mm, at a product velocity of up to 0.75 m/s, hydraulic shock does not lead to a violation of strength.

If the product velocity exceeds 0.75 m/s, there is a threat of destruction of the pipe walls due to exceeding the permissible stresses.

The safe product speed range for the main pipelines has been determined: from 0.3 to 0.75 m/s. Within this range, the negative effects of hydraulic shock are prevented.

Steel with low strength characteristics (for example, steel 20) has shown an inability to withstand the pressure of hydraulic shock at low product speeds.

High-strength steels, such as 17G1SU, exhibit the best performance to prevent accidents.

Graphs of pressure versus flow velocity have confirmed that an increase in velocity of more than 0.75 m/s in pipes of smaller diameter leads to dangerous loads.

A hydraulic shock occurs when the product speed changes abruptly, which requires strict control of operating modes.

The main causes of hydraulic shock include emergency closure of shut-off valves, starting/stopping of pumps and sudden changes in geodetic markings of the pipeline.

The research results are useful for designing new pipeline systems and upgrading existing ones.

Automatic protection systems, such as alarm devices and software that monitors speed limits, are needed to prevent damage.

Technical limitations, such as the immutability of pipe diameter and thickness, require a detailed calculation of the permissible product velocity.

The use of high-strength materials is recommended to minimize the effects of accidental hydraulic shocks.

Additional research needs to be conducted to study the effects of material heterogeneities and prolonged cyclic loads.

The introduction of dynamic monitoring systems in real time can further enhance operational safety.

**Conclusion**

According to the results of the calculations, it can be concluded that during the operation of pipelines, it is of practical importance to determine the mode of oil pumping with the calculation of the allowable flow rate.

Such regimes can occur during commissioning, during which there is an uncontrolled change in the speed of the product in the pipeline. In addition, at this time there is a debugging of software designed to control the shut-off valves installed along the pipeline route. During the debugging period, its unauthorized closing is possible, which can cause a hydraulic shock.

In this regard, it is proposed to implement the following compensatory measures [5, 6, 7]:

– installation of such modes of operation of pumping equipment at the pumping station, in which the pump will not exceed the calculated pumping capacity, which determines the extreme speed of the product in the pipeline;

– signaling the extreme speed of the product in the pipeline by the equipment of the operational (or commercial oil metering unit) located at the outlet of the pumping station.

The described automatic protections and alarms make it possible to prevent the occurrence of hydraulic shock during the period of unstable operation of the pipeline.

Ceteris paribus, when the diameter of the pipeline, the thickness of the pipe wall and its material design cannot be changed due to technical and economic reasons, the most rational way to prevent hydraulic shock is to calculate the allowable fluid flow rate in the pipeline and prevent the causes that can lead to it achievement.

However, it should be noted that in order to absorb hydraulic shock, which cannot be prevented during the entire period of operation of the pipeline, since it is random, it is recommended to use steel with high strength characteristics. These steels include 17G1SU, 13KhFA, 05KhGB and others.

**The contribution of the authors.**

**Zabiyeva K. –** contribution to the concept; execution of the claimed scientific research; creation of a scientific article.

**K. Shetiyeva –** contribution to the concept.

**References**

1. Mansuri, Behnam & Salmasi, Farzin & Oghati, Behrooz. (2014). Sensitivity Analysis for Water Hammer Problem in Pipelines. 10.5829/idosi.ijee.2014.05.02.03.

2. Ledovskij G.N. Obosnovanie sposoba zashhity` osnovnogo oborudovaniya nefteperekachivayushhikh stanczij ot voln davleniya. / Dissertacziya na soiskanie uchenoj stepeni kandidata tekhnicheskikh nauk. Sankt-Peterburg 2016. – 124 s.

3. Lur`e M.V. Metod rascheta perekhodny`e proczessov v nefteprovodakh s vozmozhny`m obrazovaniem i ischeznoveniem parogazovy`kh polostej. / M.V.Lur`ev // Nauka i tekhnologii truboprovodnogo transporta nefti i nefteproduktov. – 2011. - №4. S. 58-63. ISSN: 2221-2701 eISSN: 2541-9595

4. SP 36.13330.2012. Magistral`ny`e truboprovody`. Aktualizirovannaya redakcziya SNiP 2.05.06-85*. Utverzhden prikazom Federal`nogo agentstva po stroitel`stvu i zhilishhno-kommunal`nomu khozyajstvu (Gosstroj) ot 25 dekabrya 2012 g. N 108/GS i vveden v dejstvie s 1 iyulya 2013 g.

5. Sumskoj S.I., Agapov A.A., Sof`in A.S. O kriticheskikh zamechaniyakh po stat`e «Modelirovanie avarijny`kh utechek na magistral`ny`kh nefteprovodakh». / Bezopasnost` truda v promy`shlennosti. - 2015. - №7 S. 66-71. ISSN: 0409-2961eISSN: 2658-5537

6. Modelirovanie perekhodny`kh i avarijny`kh proczessov v magistral`ny`kh nefteprovodakh s pomoshh`yu metoda S.K.Godunova / S.A.Gubin, T.V.Guina, S.I.Sumskoj i dr. // Bezopasnost` truda v promy`shlennosti. – 2013. - #10. S. 65-72.

7. Kaliczun V.I., Drozdov E.V., Komarov A.S., Chizhik K.I. Osnovy` gidravliki i ae`rodinamiki. M.: Strojizdat, 2001 – 296 s.

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**Жер асты мұнай құбыры элементінің жоғары қысым толқынының пайда болуын ескере отырып кернеулі-деформациялық күйін есептеу**

**Аңдатпа.** Қазіргі уақытта біздің елде энергия ресурстарын айдауға арналған көптеген кеңейтілген құбыр жүйелері жұмыс істейді. Бұл құбырлардың сенімділігін арттыру пайдалану кезеңіндегі ең маңызды міндеттердің бірі болып табылады. Магистральдық және шаруашылық құбырлар арқылы мұнай айдаудың жұмыс режимдері айдау қуатының өзгеруін, сорғы жабдықтарының апаттық тоқтатылуын, вентильдердің жабылуы нәтижесінде ағынның рұқсатсыз бітелуін қарастырады. Құбырдағы ағынның тоқтатылуымен сипатталатын мұндай оқиғалар құбырда гидравликалық соққының пайда болуына әкеледі және де ол құбырдың беріктік қасиеттеріне әсер етеді.

Сол себепті, гидравликалық соққының құбырдың беріктік сипаттамаларына әсеріне қатысты мәселелерді қарастыру қазіргі уақытта өте өзекті болып табылады.

Бұл мақала артық қысым толқынының пайда болуын ескере отырып, жер асты мұнай құбыры элементінің кернеулі деформацияланған күйін зерттеуге арналған. Жұмыста жер асты ортасындағы құбырдың құрылымдық элементтеріне артық қысым толқынының әсерін бағалауға мүмкіндік беретін есептеу әдістері келтірілген. Әр түрлі жұмыс жағдайында құбыр материалдарындағы деформациялар мен кернеулердің динамикасына әсер ететін факторлар қарастырылады.

Артық қысым толқыны параметрлерінің жер асты мұнай құбырларының беріктігі мен қауіпсіздігіне әсерін көрсете отырып, сандық есептеулер нәтижелерінің талдаулары келтірілген. Алынған қорытындылар жер асты құбырының беріктігін арттыруға және авариялық жағдайлардың туындау қаупін азайтуға ықпал ете отырып, ауыспалы жүктемелер жағдайында құбыр жүйелерін жобалау мен пайдалануды оңтайландыру үшін пайдаланылуы мүмкін.

**Түйін сөздер:** гидравликалық соққы, құбыр, температура, қысым, кернеулі-деформациялық күй, құбыр қабырғалары, қысым толқындары

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## Расчет напряженно-деформированного состояния элемента подземного нефтепровода с учетом появления волны повышенного давления

**Аннотация.** В настоящее время в нашей стране эксплуатируется большое количество протяженных трубопроводных систем, которые предназначены для перекачки энергоресурсов. Повышение надежности этих трубопроводов является одной из важнейших задач в период эксплуатации. Эксплуатационные режимы перекачки нефти, как по магистральным, так и по промысловым трубопроводам предусматривают изменение производительности перекачки, аварийные отключения насосного оборудования, несанкционированное перекрытие потока в результате закрытия запорной арматуры. Подобные события ведут к возникновению гидравлического удара в трубопроводе и влияние его на прочностные характеристики труб, которые могут иметь различное материальное исполнение.

В связи с этим, рассмотрение вопросов, связанных с влиянием гидроудара на прочностные характеристики трубопровода, является в наше время весьма актуальным.

Данная статья посвящена исследованию напряженно-деформированного состояния элемента подземного нефтепровода с учетом возникновения волны избыточного давления. В работе представлены методы расчета, позволяющие оценить воздействие волны избыточного давления на структурные элементы трубопровода в подземной среде. Рассматриваются факторы, влияющие на динамику деформаций и напряжений в материалах трубопровода при различных условиях эксплуатации.

Приведены анализы результатов численных расчетов, демонстрируя влияние параметров волны избыточного давления на надежность и безопасность подземных нефтепроводов. Полученные выводы могут быть использованы для оптимизации проектирования и эксплуатации трубопроводных систем в условиях переменных нагрузок, способствуя повышению стойкости инфраструктуры и снижению риска возникновения аварийных ситуаций.

**Ключевые слова:** гидроудар, трубопровод, температура, давление, напряженно-деформированное состояние, стенка трубы, волна давления.

**References**

1. Mansuri, Behnam & Salmasi, Farzin & Oghati, Behrooz. (2014). Sensitivity Analysis for Water Hammer Problem in Pipelines. 10.5829/idosi.ijee.2014.05.02.03.

2 . Ledovskij G.N. Obosnovanie sposoba zashhity` osnovnogo oborudovaniya nefteperekachivayushhikh stanczij ot voln davleniya. / Dissertacziya na soiskanie uchenoj stepeni kandidata tekhnicheskikh nauk. Sankt-Peterburg 2016. – 124 s.

3. Lur`e M.V. Metod rascheta perekhodny`e proczessov v nefteprovodakh s vozmozhny`m obrazovaniem i ischeznoveniem parogazovy`kh polostej. / M.V.Lur`ev // Nauka i tekhnologii truboprovodnogo transporta nefti i nefteproduktov. – 2011. - №4. S. 58-63. ISSN: 2221-2701 eISSN: 2541-9595

4. SP 36.13330.2012. Magistral`ny`e truboprovody`. Aktualizirovannaya redakcziya SNiP 2.05.06-85*. Utverzhden prikazom Federal`nogo agentstva po stroitel`stvu i zhilishhno-kommunal`nomu khozyajstvu (Gosstroj) ot 25 dekabrya 2012 g. N 108/GS i vveden v dejstvie s 1 iyulya 2013 g.

5. Sumskoj S.I., Agapov A.A., Sof`in A.S. O kriticheskikh zamechaniyakh po stat`e «Modelirovanie avarijny`kh utechek na magistral`ny`kh nefteprovodakh». / Bezopasnost` truda v promy`shlennosti. - 2015. - №7 S. 66-71. ISSN: 0409-2961eISSN: 2658-5537

6. Modelirovanie perekhodny`kh i avarijny`kh proczessov v magistral`ny`kh nefteprovodakh s pomoshh`yu metoda S.K.Godunova / S.A.Gubin, T.V.Guina, S.I.Sumskoj i dr. // Bezopasnost` truda v promy`shlennosti. – 2013. - #10. S. 65-72.

7. Kaliczun V.I., Drozdov E.V., Komarov A.S., Chizhik K.I. Osnovy` gidravliki i ae`rodinamiki. M.: Strojizdat, 2001 – 296 s.

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