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# Investigation of gas gathering pipelines operation efficiency and selection of improvement methods

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## ABSTRACT

**Purpose:** The article implies theoretical and experimental studies of the liquid pollution accumulations impact on the efficiency of gathering gas pipelines operation at the Yuliivskyi oil and gas condensate production facility (OGCPF). Research of efficiency of gas pipelines cleaning by various methods.

**Design/methodology/approach:** The research methodology consists of determining the hydraulic efficiency of gathering gas pipelines before and after cleaning of their internal cavity by different methods and comparing the obtained results, which allows to objectively evaluate the efficiency of any cleaning method. CFD simulation of gas-dynamic processes in low sections of gas pipelines with liquid contaminants.

**Findings:** Experimental studies of cleaning efficiency in the inner cavity of the gas gathering pipelines of the Yuliivskyi OGCPF by various methods, including: supply of surfactant solution, creating a high-speed gas flow, use of foam pistons were performed. It was established that cleaning the inner cavity of gas gathering pipelines by supplying a surfactant solution leads to an increase in the coefficient of hydraulic efficiency by 2%-4.5%, creating a high-speed gas flow by 4%-7%, and under certain conditions by 8%-10 % and more. However, for two gas pipelines the use of foam pistons allowed to increase the coefficient of hydraulic efficiency from 5.7 % to 10.5 % with a multiplicity of foam from 50 to 90. be recommended for other deposits.

The results of CFD simulation showed that the accumulation of liquid contaminants in the lowered sections of gas pipelines affects gas-dynamic processes and leads to pressure losses above the values provided by the technological regime. With the increase in liquid contaminants volume the pressure losses occur. Moreover, with a small amount of contamination (up to 0.006 $m^3$), liquid contaminants do not have a significant effect on pressure loss. If the contaminants volume in the lowered section of the pipeline is greater than the specified value, the pressure loss increases by parabolic dependence. The increase in mass flow leads to an increase in the value of pressure loss at the site of liquid contamination. Moreover, the greater the mass flow, the greater the impact of its changes on the pressure loss.

The CFD simulation performed made it possible not only to determine the patterns of pressure loss in places of liquid contaminants accumulation in the inner cavity of gas pipelines, but also to understand the gas-dynamic processes in such places, which is an unconditional advantage of this method over experimental.

**Research limitations/implications:** The obtained simulation results showed that the increase in the volume of liquid contaminants in the inner cavity of gas gathering pipelines leads to an increase in pressure losses above the value provided by the technological regime. To achieve maximum cleaning of gas gathering pipelines, it is necessary to develop a new method that will combine the considered.

**Practical implications:** The performed experimental results make it possible to take a more thorough approach to cleaning the inner cavity of gas gathering pipelines and to forecast in advance to what extent the hydraulic efficiency of gas gathering pipelines can be increased.

**Originality/value:** The obtained results of CFD simulation of gas-dynamic processes in lowered sections of gas pipelines with liquid contaminants, experimental studies of the effectiveness of various methods of cleaning the inner cavity of gas gathering pipelines has original value.

**Keywords:** Gas, Gas gathering pipeline, Hydraulic efficiency, Liquid contaminations, Foam, Inner cavity cleaning

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**ANALYSIS AND MODELLING**

## 1. Introduction

Nowadays PJSC “Ukrgasvydobuvannya” owns and develops a large number of fields. Most of them are already depleted and at the final stage of development. However, three gas production division (GPD) GPD "Shebelinka-gasvydobuvannya", GPD "Poltavagasvydobuvannya" and GPD "Lvivgasvydobuvannia" provides over 70% of the total natural gas production in Ukraine. GPD "Shebelinkagasvydobuvannya" provides 55 % of natural gas production in PJSC “Ukrgasvydobuvannya” [1,2]. This department consists of three oil and gas condensate production facility (OGCPF), that is: Shebelunskyi OGCPF, Efremivskyi OGCPF та Yuliivskyi OGCPF.

During the development of the Yuliivskyi OGCPF, in particular Yuliivske, Skvortsivske, Narizhnianske, Nedilne and others, there are many complications that negatively affect the volume of production, including during the transportation of hydrocarbons by pipelines.

One of the important tasks – is to ensure reliable transmission of hydrocarbons to gas collection and preparation systems. Given this, there is a need to maintain the maximum possible values of hydraulic efficiency of flowlines and gas gathering pipelines.

## 2. Literature review

At present, PJSC "Ukrgazvydobuvannya" remains the leader in natural gas production. For this purpose, the equipment is modernized using the latest technologies, the productivity of wells is increased, etc. [3]. Therefore, for both stabilization and increasing the production of hydrocarbons, it is advisable to consider all alternative ways of solving this problem, in particular, increasing the hydraulic efficiency of gas gathering pipelines by means of high-quality cleaning of their inner cavity. Because it is known that the presence of contamination in the pipeline increases its hydraulic resistance and leads to a decrease in its transmission capacity [4].

In world practice, many different methods of cleaning gas pipelines are known, consider the main ones, namely [5]:

- creating a high-speed gas flow;
- use of various chemical reagents (surfactant solution);
- use of various cleaning devices;
- use of various devices for liquid drainage.

In practice, only some of the presented methods are applied for gas gathering pipelines of the Yuliivskyi OGCPF. Before applying of any cleaning method, it is advisable to analyse the current state of gas gathering pipelines, which was performed in [6]. The operational parameters of the gas gathering pipeline were considered, by which the gas from the gas-gathering station (GGS) of Narizhnianske oil and gas condensate field (OGCF) entered the installation of complex gas treatment unit - 2 (CGTU-2) of Yuliivske OGCF. The hydraulic efficiency of the gas gathering pipeline and the volume of contaminants were calculated. It was found that the results of calculating the volume of contaminants were approximate, as they differed from the results of the measured volume of liquid extracted from the gas gathering pipeline to the measuring line CGTU-2 (including the separator and segregator). To ensure the reliable operation of the gas gathering pipeline, it was proposed: to connect two separators in series (main GZ-1 and experimental GZ-2), periodically inject a solution of surfactants (SAA) and according to research results to choose the optimal mode for high-speed gas flow and removal of fluid from the internal cavity on CGTU-2 at Yuliivske OGCF.

In [7], the state of the gas gathering pipeline by which gas from CGTU-1 of Skvortsivske OGCF is transported to CGTU-2 of Yuliivske OGCF was analysed. The gas flow rate and hydraulic efficiency of the inter-industrial gas pipeline were calculated. It was established that liquid contaminants in the internal cavity were formed as a result of: mechanical drip removal of liquid from the separation equipment, condensation of liquid from the gas flow by the route, reducing the gas flow rate. According to the results of research, it was established that the most effective way of the internal cavity cleaning was the generation of a high-speed gas flow to remove the liquid.

In [8] the technology of cleaning the inner cavity of the flowlines at gas condensate wells with foam was investigated. According to the results of experimental studies, as a result of cleaning the flowlines of wells 85 and 60 of Yuliivske OGCF from fluid accumulations, the coefficients of their hydraulic efficiency increased by 12% and 7%, respectively. The measures taken to clean the inner cavity of the flowlines from the liquid justified their effectiveness and were recommended for other wells flowlines at different fields.

In [9], an experimental-industrial test was carried out to determine the efficiency of cleaning the inner cavity of gas gathering pipelines with foams of different expansion ratio. According to the results of experimental and industrial tests for cleaning the inner cavity of gathering gas pipelines with foams, positive results were obtained. It is established that cleaning the inner cavity of gathering gas pipelines with foams with expansion ratio of 80 to 90 leads to an increase in the coefficient of hydraulic efficiency by 10.5%, and foams with expansion ratio of 50 to 60 by 5.7%. The measures taken to clean the inner cavity of gathering gas pipelines from liquid contaminants have proven their effectiveness and can be recommended for other fields.

In [10] comprehensive measures are proposed to increase the operation efficiency of gas condensate wells. One of such measures is monitoring of operational parameters of wells by pressure and temperature sensors installed at the wellhead and at the inlet gas pipelines of the gas treatment unit; calculation of the volume of accumulated fluid in the wellbore and flowline; installation of a complex for automated supply of a surfactant solution both in the annulus of the wells and in the flowline. For this purpose, two options are proposed for the complex to be equipped. The proposed options involve the use of various equipment and have a different principle of operation.

Above all, various measures are being developed and taken to clean the gas pipelines of the Yuliivskyi OGCPF. In [11] the state of gas gathering pipelines, which transmitted gas from Skvortsivske oil and gas condensate field, was analysed. It was established that during the operation of gas gathering pipelines there were complications associated with the accumulation of liquid in the internal cavity, resulting in a decrease in the volume of gas transmitted and hydrocarbon production. Based on the results of the technical and economic calculation, the authors proposed comprehensive measures, which include: construction of a compressor station, change in the connection of the existing gas gathering pipeline from complex oil and gas treatment unit – 2 (COGTU-2) to the CGTU-1 of Skvortsivske OGCF and construction of additional gas gathering pipeline from CGTU-1 of Skvortsivske OGCF to CGTU-2 of Yuliivske OGCF. The implementation of the proposed measures will allow to optimize the operation of wells by reducing operating pressures, selecting the optimal mode of gas gathering pipelines operation, which will prevent the accumulation of liquid contaminants and obtain additional hydrocarbon production.

Therefore, in order to ensure the stable production of hydrocarbons at Yuliivskyi OGCPF, comprehensive measures were taken to maintain the maximum value of hydraulic efficiency of gas gathering pipelines.

Given the above, it is important to find new approaches to increase the hydraulic efficiency of gas gathering pipelines. One of such approaches is CFD simulation of gas-dynamic processes by means of modern software complexes.

Apparently, the simulation of gas pipelines is becoming more widespread today, due to the increasing capacity of computer technology. Increasing the power of computer equipment allows to significantly reduce simulation time, solve more complex problems. CFD simulation is the closest to reality and makes it possible to consider the studied processes in three-dimensional positioning, as well as understanding the dynamics of the pipeline flows. It allows to see in detail a complex three-dimensional single-phase or multiphase flow inside gas pipelines and to study the distribution of pressure, flow rate. In [12] by using CFD simulation the patterns of flow velocity distribution, pressure in the inner cavity of the shaped elements of gas pipelines were identified. The regularities of the influence of all factors on the pressure losses of single- and two-phase flows in the inner cavity of the studied shaped elements were determined. Also, CFD simulation made it possible to forecast the erosive wear of shaped elements of gas pipelines [13], which is an extremely difficult and currently less studied task due to a wide range of parameters that affect its location and intensity. Erosion, corrosion wear, uneven pressure distribution in the internal cavity, geometric shape are factors that affect the stress-strain state of gas pipelines and its separate elements. Therefore, the assessment of gas pipelines and their individual elements strength requires a synergy of hydrogas-dynamic processes in their inner cavity, processes of erosion, corrosion wear and stress-strain state in a three-dimensional setting, i.e. it is necessary to perform multidisciplinary simulation. Such synergy for shaped elements of gas pipelines was performed by simulation in [14]. Trenchless technologies, in particular, the technology of pulling a new polyethylene pipe into a defective steel pipeline, are effective to restore the efficiency of sections of pipelines that have lost strength [15].

## 3. Methods and materials

Currently, the urgent task of gas companies is to determine a strategy for achieving high hydrocarbon extraction ration. However, given that the fields of Yuliivskyi OGCPF are in the final stages of development, it is necessary to develop and take various measures due to the gradual reduction of hydrocarbon production [16].

At present, there is a system of gas pipelines between production facilities at Yuliivskyi OGCPF, which provides gas supply from various fields at CGTU-2 of Yuliivske OGCF, where liquid hydrocarbons (hydrocarbon condensate and propane-butane fraction) are extracted, and gas is prepared and transmitted to consumers. Therefore, it is necessary to determination of natural gas quality [17], to monitor the hydraulic state of gas pipelines to ensure stable transmission of natural gas and, accordingly, the planned volume of production.

It was confirmed that adjusting gas pressure at the outlet to the design pressure is a promising direction for energy efficiency increasing [18].

The hydraulic efficiency of six gas gathering pipelines of Yuliivskyi OGCPF was calculated, the results of which are given in Table 1.

The results analysis shows that the lowest value of hydraulic efficiency coefficient was obtained on gas gathering pipelines (4, 3, 2). Therefore, the optimal mode of operation should be chosen to prevent the contaminants accumulation. For this purpose, the appropriate measures must be developed and taken.

Table 1.
Gas gathering pipelines specifications at Yuliivskyi OGCPF and calculated hydraulic efficiency coefficients

| Pipeline name | Length of the pipeline, m | Outer diameter, mm | Thickness of walls, mm | Hydraulic efficiency coefficient E,% |
|---|---|---|---|---|
| 1 | 19360 | 114 | 12 | 88 |
| 2 | 5520 | 114 | 12 | 77 |
| 3 | 4975 | 114 | 12 | 74 |
| 4 | 5450 | 159 | 6 | 72 |
| 5 | 11280 | 114 | 10 | 80 |
| 6 | 12465/350 | 159/114 | 8/12 | 86 |

It should be noted that hydraulic efficiency was studied on gas gathering pipelines (1-6) at different times of the year. The purpose of these studies was to determine the volume of fluid that accumulates in the internal cavity, both by calculation and experimentally. Thus, according to the results of experimental studies, the amount of accumulated pollution in gas gathering pipelines was higher than the calculated one – 6-15%.

During experimental studies on the measuring lines CGTU-2 fluid samples from the segregator measuring RZ-1, RZ-2 were taken to analyse the content of contaminants. The result of contaminants analysis indicates that they are a complex multicomponent composition that contains: stratal and condensation water, hydrocarbon condensate, mechanical impurities, methanol in different ratios.

It should be noted that during the measurement of liquid volume transmitted together with the gas on the measuring line CGTU-2, its composition changed in percentage. A number of studies have shown that the main component is stratal and condensation water, which takes a significant volume and varies in the range from 50% to 65%. Given that the hydrocarbon condensate has a density within the range from 0.736 g/cm$^3$ to 0.748 g/cm$^3$, less than water (the density of which is more than 1.010 g/cm$^3$), it can be assumed that the actual mode of operation of the gas flow from the internal cavity of the gas gathering pipelines carries more gas condensate than water. Therefore, there is a need to take appropriate measures to clean the inner cavity of gas gathering pipelines from liquid contaminants.

In-depth knowledge of the relationship between flow geometry, pressure field, and flow kinematics is required to investigate the effect of contaminants accumulated in pipeline on pressure losses [19]. This information will help to understand the mechanisms of pressure loss. Flows in such places are complex and three-dimensional, and therefore they must be studied experimentally or hydraulic analysis of CFD simulation must be performed. For the in-situ conditions of gas pipelines such experiments cannot be performed because:

- it is impossible to determine the precise value of speed, pressure at any 3D point of the pipeline;
- gas pipelines are under high pressure and are explosive.

CFD simulation gives an understanding of the dynamics of gas flows, allows to observe the flow in the inner cavity of the pipeline and study the pressure loss, the laws of change of its speed and so on. Therefore, CFD simulation of gas-dynamic processes by the finite volume method was used to determine the magnitude of the influence of liquid contaminants accumulated in the lowered sections of the pipeline route on the magnitude of pressure loss and flow rate. CFD simulation was performed by means of ANSYS Fluent 2020 R2 Academic software package. Modern software is one of the best options for complex and accurate calculations and allows to save a lot of time and minimize the number of experiments.

Three-dimensional CFD simulation of gas flows in low sections of the pipeline route, where liquid contaminants were accumulated, was performed by numerical solving the Navier-Stokes equation (1), which expresses the law of momentum conservation and flow continuity (2), which is the law mass conservation:

$$\frac{\partial}{\partial t}(\rho u_i)+\frac{\partial}{\partial x_j}(\rho u_i u_j)+\frac{\partial}{\partial x_j}(\rho u_i' u_j')= \\ =-\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)\right)+f_i \quad (1)$$

$$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x_j}(\rho u_j) \quad (2)$$

where $x_i$, $x_j$, – coordinates; t – time; $u_i$, $u_j$, $u_i'$, $u_j'$ – velocity components; ρ – density of gas; μ – molecular dynamic viscosity of the gas; $f_i$ – a term that takes into account the effect of mass forces; p – pressure [20].

To describe turbulence in CFD simulation, a standard and the most common *k* – ε (*k* – turbulent kinetic energy, ε – dissipation rate of turbulent kinetic energy) turbulence model was used, which involves solving the following equations:

- equation of transfer of turbulent energy $k$

$$\frac{\partial(\rho k)}{\partial t}+\nabla(\rho u k)=\nabla\left(\left(\mu+\frac{\mu_t}{\sigma_k}\right)\nabla k\right)+\mu_t G-\rho\varepsilon \quad (3)$$

- equation of transfer turbulent dissipation $\varepsilon$

$$\frac{\partial(\rho \varepsilon)}{\partial t}+\nabla(\rho u \varepsilon)=\nabla\left(\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\nabla \varepsilon\right)+C_1\frac{\varepsilon}{k}\mu_t G-C_2\rho\frac{\varepsilon^2}{k} \quad (4)$$

where u – flow rate of gas; $\mu_t$– turbulent dynamic viscosity of gas; $\sigma_k$ – coefficient equal to one; G – design variable; $\sigma_\varepsilon$ – coefficient equal to $\sigma_\varepsilon$=1.3; $C_1$ – coefficient equal to $C_1$=1.44; $C_2$ – coefficient equal to $C_2$=1.92 [20].

To study the gas-dynamic processes in the lowered sections of gas pipelines, where liquid contaminants accumulate, it is necessary to take into account the influence of the amount of contaminants on the formation of the flow. For this purpose, three-dimensional models of lowered sections of the gas pipeline with an internal diameter of 143 mm with liquid contaminants were drawn (Fig. 1a). The outer diameter of the investigated section of the pipeline was 159 mm, and the nominal wall thickness was 8 mm. These characteristics correspond to the gas gathering pipeline № 6 (Tab. 1).

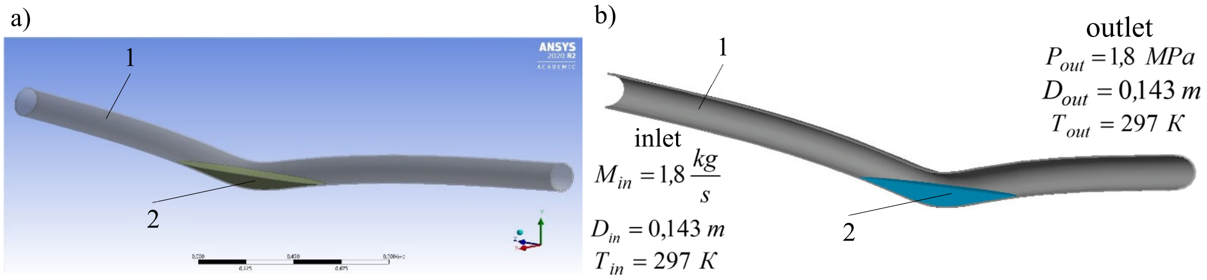


Fig. 1. Lowered section of gas pipelines with liquid contamination: a) – geometrical model; b) – calculation chart; 1 – gas pipeline; 2 – liquid contamination

To study the influence of the contaminants amount on the flow parameters, geometric models of the internal cavity of the gas pipeline sections with different amounts of contamination were drawn. Four different volumes of liquid contaminants were selected (0.0035 $m^3$, 0.0051 $m^3$, 0.0084 $m^3$ and 0.0118 $m^3$).

Limit conditions were set in the ANSYS Fluent preprocessor. Natural gas was set as the working medium, the movement of which was simulated by the gas pipeline. The equivalent roughness coefficient of the pipe wall was set equal to 0.03 mm. Mass flow was set at the inlet to the studied section of the gas pipeline, and pressure was set at the outlet. The calculation chart is shown in Figure 1b. The mass flow rate at the inlet to the studied section of the gas pipeline varied and was assumed to be equal to 1.8 kg/s, 2.5 kg/s and 3.2 kg/s. The pressure was assumed to be 1.8 MPa. A separate simulation was performed for each value of mass flow. It should be noted that the initial data were set from the actual mode of operation of the gas gathering pipeline.

Also, at the inlet to the studied section of the gas pipeline the temperature of natural gas was set, which was assumed to be 297 K. At the inlet and outlet of the pipeline the turbulence intensity as for 5% (for this value the flow is considered to be completely turbulent) and hydraulic diameter were set. The hydraulic diameter was assumed to be equal to the inner diameter of the pipeline.

The velocity of the gas flow through the studied section of the gas pipeline and the pressure loss in it are two indicators that characterize the gas-dynamic processes. Therefore, in the postprocessor of the ANSYS Fluent software package, the simulation results were visualized by constructing a velocity field and a pressure field in the longitudinal cross sections of the studied section. The visualized simulation results made it possible to see the structure of the flow in the investigated section of the gas pipeline and to collect comprehensive data about it. For example, the simulation results are considered when the mass flow rate of the gas flow at the inlet of the studied section of the pipeline was 1.8 kg/s. The velocity fields in the longitudinal cross sections of the studied section for such mass flow are shown in Figure 2, and the pressure fields in Figure 3. It was determined that at the entrance to the study area the gas flow velocity along the axis is 8.9 m/s. From the flow axis in the direction of the wall there is a slight decrease in the flow rate, and near the wall the gas flow rate decreases sharply. The presence of contaminants in the lower (middle) part of the investigated section of the gas pipeline causes an acceleration of gas flow in this place, which is due to a decrease in the cross-section of the gas pipeline (Fig. 2). A detailed analysis of the gas flow velocity fields shows a significant dependence of the gas flow velocity value in the average time of the studied section of the gas pipeline on the contamination volume. For the considered mode of transmission if the contamination volume in the inner cavity of the lowered section of the gas pipeline is 0.0035 $m^3$, the maximum value of the gas flow rate over the contaminants is 11 m/s (Fig. 2a). For the volume of contaminants of 0.0051 $m^3$, the maximum velocity is 14.1 m/s (Fig. 2b), for the volume of 0.0084 $m^3$ – 21.4 m/s (Fig. 2c), and for the volume of 0.0118 $m^3$ – 43.2 m/s (Fig. 2d).

During the transmission of the gas flow through the lowered section of the pipeline, where liquid contaminants are accumulated, a complex pressure field occurs, and pressure loss is formed (Fig. 3). Over liquid contaminants in the lowered (middle) part of the studied section of the pipeline there is a decrease in pressure, and the greater the volume of contamination, the greater the magnitude of the pressure drop. The volume of contamination also affects the value of pressure loss in the studied section. The increase in the volume of contamination leads to an increase in the value of pressure loss. The value of pressure drop at the site of liquid contaminants can be determined by subtracting from the value of the pressure in the pipeline prior to the moment of liquid contaminants from the value of the pressure after its occurrence. Thus, for the considered mode of transmission, if the volume of contamination in the inner cavity of the lowered section of the gas pipeline is 0.0035 m$^3$, the pressure loss is 38 Pa (Fig. 3a), if the volume of contamination is 0.0051 m$^3$ – 99 Pa (Fig. 3b), if 0.0084 m$^3$ – 873 Pa (Fig. 3c) and if 0.0118 m$^3$ – 1857 Pa (Fig. 3d).

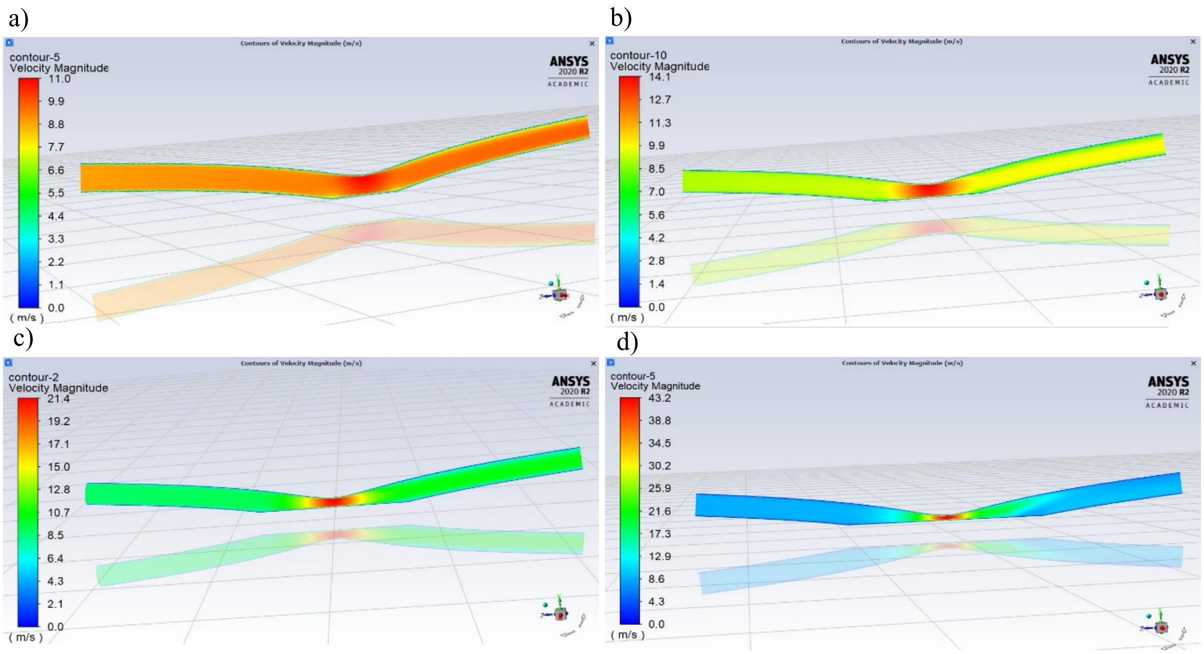


Fig. 2. Velocity fields in longitudinal cross sections of the studied lowered section of the gas pipeline for different volumes of liquid contaminants in its inner cavity a) – $V_{liq}$=0.0035 m$^3$; b) – $V_{liq}$=0.0051 m$^3$; c) – $V_{liq}$=0.0084 m$^3$; d) – $V_{liq}$=0.0118 m$^3$

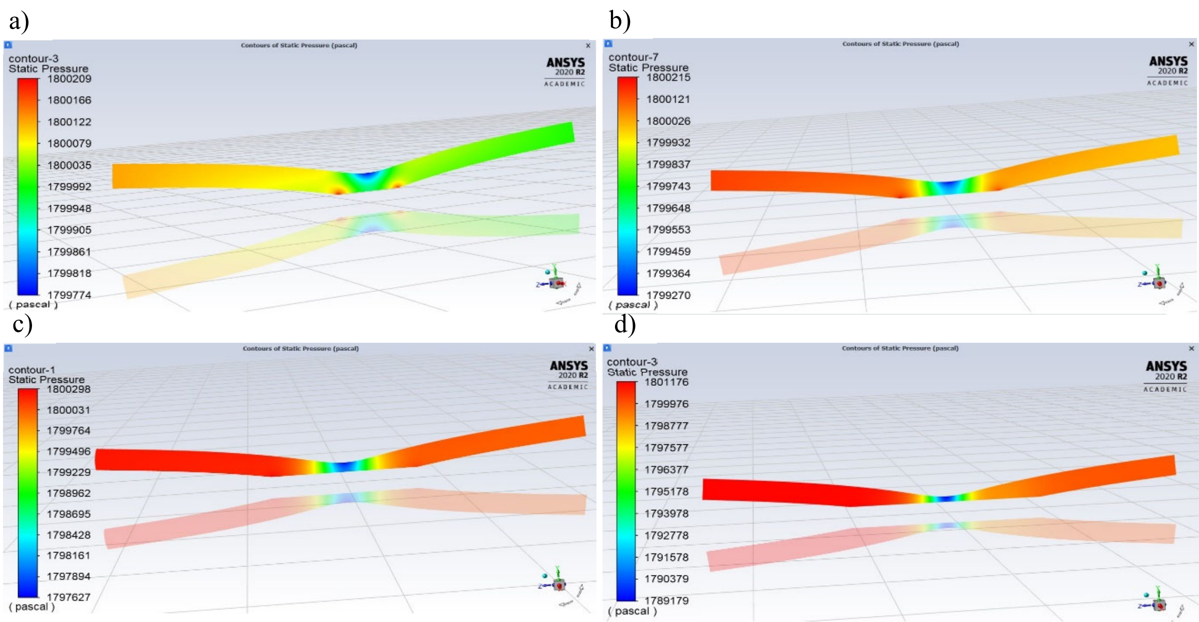


Fig. 3. Pressure fields in longitudinal cross sections of the studied lowered section of the gas pipeline for different volumes of liquid contaminants in its inner cavity a) – $V_{liq}$=0.0035 m$^3$; b) – $V_{liq}$=0.0051 m$^3$; c) – $V_{liq}$=0.0084 m$^3$; d) – $V_{liq}$=0.0118 m$^3$

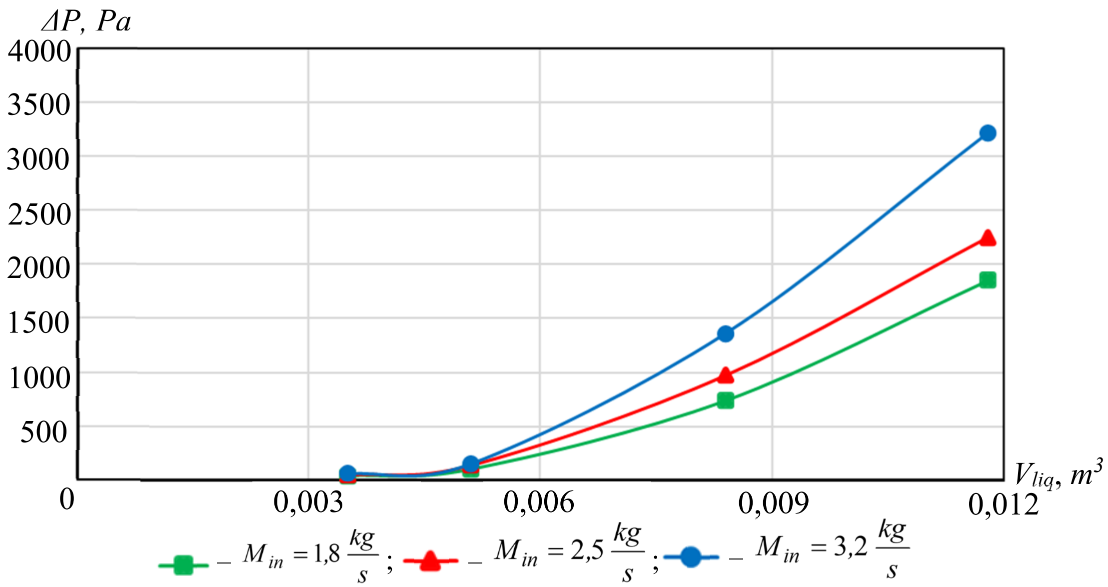


Fig. 4. Dependence of the pressure flow rate at the location of liquid contaminants in the lowered section of the gas pipeline *ΔP* on the volume of liquid contaminants $V_{liq}$ for different mass flow rates at the inlet of the studied section of the $M_{in}$ pipeline

Based on the results of CFD simulations, a graphical dependence of the pressure flow rate at the location of liquid contaminants in the lowered section of the gas pipeline *ΔP* on the volume of liquid contaminants $V_{liq}$ for different mass flow rates at the inlet of the studied section of the $M_{in}$ pipeline (Fig. 4) was obtained. The volume of liquid contaminants has a significant effect on the pressure flow. With small volumes of contamination in the inner cavity of gas pipelines at the point of the route lowering (up to 0.006 $m^3$), they do not have a significant impact on pressure losses. With a further increase in the volume of liquid contaminants in the lowered section of the pipeline, the pressure loss at the site of these contaminants increases with parabolic dependence. The mass flow at the inlet of the studied section of the pipeline also has an impact on the value of pressure loss at the site of liquid contamination. With its increase there is an increase in pressure loss at the site of liquid contamination. Moreover, the larger it is, the greater the impact of its changes on the pressure loss at the site of liquid contamination.

The obtained simulation results showed that the increase in the volume of liquid contamination in the inner cavity of gas gathering pipelines leads to an increase in pressure losses above the value provided by the technological regime, and, accordingly, to irrational use of reservoir energy. This is confirmed by the obtained low coefficients of hydraulic efficiency of the gas gathering pipelines of the Yuliivskyi OGCPF due to the presence of accumulated liquid in the internal cavity. Therefore, it is necessary to monitor the hydraulic condition of gas pipelines and clean them in a timely manner.

## 4. Results and discussion

Different techniques and technologies are used to clean the inner cavity of gas pipelines, taking into account a number of factors. To improve the hydraulic characteristics of gas gathering pipelines, for example, various devices for liquid removal, various cleaning devices (pistons): mechanical, rubber, foam, gel, visco-elastic, etc. can be used.

The method of cleaning the inner cavity of gas pipelines by means of cleaning devices, mechanical pistons in particular, is widely used. In comparison with other methods, it has the following advantages: simplicity, significant efficiency and the ability to automate the process. In case of this method, there are certain complications, such as rapid wear of the working units, the possibility of hydraulic shocks and jamming of the cleaning device in the pipe, as well as the fact that this method can be implemented only in gas pipelines with smooth valves and smooth crossings. Given that gas gathering pipelines contain both straight and curved sections and have a significant number of local resistances (valves, tees, taps, extensions, narrowing, etc.), upstream and downstream sections, there is a risk of cleaning device jamming. Obviously, it is impractical to use such a method for cleaning of gas gathering pipelines at Yuliivskyi OGCPF with an internal diameter from 90 mm to 147 mm.

Another method of gas pipelines cleaning is the installation of devices for drainage of various structures in lowered sections of pipelines, i.e. rags, expansion chambers, traps, drainage tubes and the like. These devices have a simple design, relatively small dimensions, they are easy to maintain, and they require relatively small investment. However, the use of such devices can lead to unauthorized removal of liquid deposits that contain hydrocarbon condensate by unauthorized persons, as well as their operation adversely affect the operation of the pipeline, pipeline depressurization and the like. Therefore, such devices are installed mainly in the most problematic areas, the accumulation of fluid in the inner cavity of which can lead to the stopping of gas transportation or accident or failure.

To ensure reliable transportation of gas through inter-industrial gas pipelines, it is advisable to clean the inner cavity along their entire length. Therefore, it is advisable to use simple cleaning methods, relatively cheap and those that ensure minimal loss of hydrocarbons.

In view of the above-mentioned details, the most acceptable methods for cleaning the inner cavity of gas gathering pipelines for the conditions of the Yuliivskyi OGCPF are:

1) supply of a surfactant's solution;
2) creating a high-speed gas flow;
3) the use of foam pistons.

The proposed methods of cleaning gas gathering pipelines, which increase their hydraulic efficiency are considered in more detail. To implement these methods, it is recommended to prepare gas pipelines (1-6) of Yuliivskyi OGCPF for connecting with the special equipment directly to the gas pipeline at the outlet of the gas treatment unit (GTU) and take the necessary measures (injection of solutions, etc.).

Before applying any of the proposed methods, the efficiency of operation of gas gathering pipelines was determined, namely: the gas flow rate, hydraulic efficiency and the volume of accumulated liquid in the inner cavity of the gas pipeline were calculated. After that, the effectiveness of the selected method was industrially investigated.

The first method involves the removal of liquid from the internal cavity of the gas pipeline by supplying a surfactant solution. This method was used for gathering gas pipelines (1-6). The following means were used: a tank truck with technical water, a mobile pumping unit (PU), SAA. The sequence of the work involved connecting the pumping unit of the technological line at the GTU with the installation of a back valve on the discharge line, pressure testing of the discharge line, preparing the SAA solution in the PU meter and pumping it into the internal cavity of the gas pipeline.

At the first stage, the volume of accumulated liquid in the inner cavity of the inter-industrial gas pipelines was calculated, and then the volume and concentration of the surfactant solution for its removal were determined. Thus, the volume of liquid contains both stratal and condensation water, as well as hydrocarbon condensate, Solpen-10 T was used as a surfactant.

Surfactant Solpen-10T is a foaming composition that consists of a mixture of surfactants and is designed for foaming and removal of highly mineralized water (up to 350 g/l) from the bottom of gas and gas condensate wells at elevated temperatures (up to 120°C) with the content of gas condensate (up to 60% mass) in the mixture . Foaming agent Solpen-10T is manufactured according to specification (TU U 24.6-23913269-001-2001).

In practice, the surfactant solution was pumped by the mobile pumping unit under the following conditions:

- after the commissioning of the gas gathering pipeline, various concentrations were supplied, from 3.0% to 5.0% with total volume from 80 l to 100 l ;
- under the actual mode of gas gathering pipeline operation, various concentrations were supplied, from 3.0% to 5.0% with total volume from 80 l to 100 l ;
- in case of gas pipeline operation mode changing with pressure decrease in at the inlet to CGTU-2 various concentration were supplied, from 3.0% to 5.0% with total volume from 80 l to 100 l;
- under the actual mode of gas gathering pipeline various concentrations were supplied, from 3.0% to 5.0% and in portions of 20 l- 30 l with a holding time (5, 10, 15 min.).

According to the results of experimental studies for gas gathering pipelines, the volume and concentration of surfactant solution and the frequency of its injection were determined. Recommendations for the use of surfactant solution for gas gathering pipelines of Yuliivskyi OGCPF are given in Table 2.

The use of surfactant solution in practice ensures the removal of liquid from low areas by gas flow on the GTU. This method is simple and effective. During its application, positive results were obtained regarding the stable operation of gas gathering pipelines. Due to the supply of surfactant solution to the gas gathering pipelines, the internal cavity was repeatedly cleaned of the accumulated liquid and their hydraulic efficiency was increased by 2%-4.5%.

For steady operation of gas gathering pipelines the following measures are proposed to supply the surfactant solution into the internal cavity in various ways. These methods are discussed below on the example of one of the gas gathering pipelines of Yuliivskyi OGCPF.

Table 2.
Recommendations for the use of surfactant solution for gas gathering pipelines of Yuliivskyi OGCPF

| Pipeline name | Surfactant volume Vsur, l | Concentration of the solution N, % | Surfactant injection periodicity | Method of surfactant injection |
|---|---|---|---|---|
| 1 | 120 | 6,0 | 1 time per 12 days | Surfactant must be injected by the PU in portions over two periods with exposure for 5 minutes |
| 2 | 80 | 5,0 | 1 time per 15 days | |
| 3 | 80 | 5,0 | 1 time per 15 days | |
| 4 | 80 | 5,0 | 1 time per 15 days | |
| 5 | 100 | 5,5 | 1 time per 12 days | |
| 6 | 150 | 6,5 | 1 time per 12 days | |

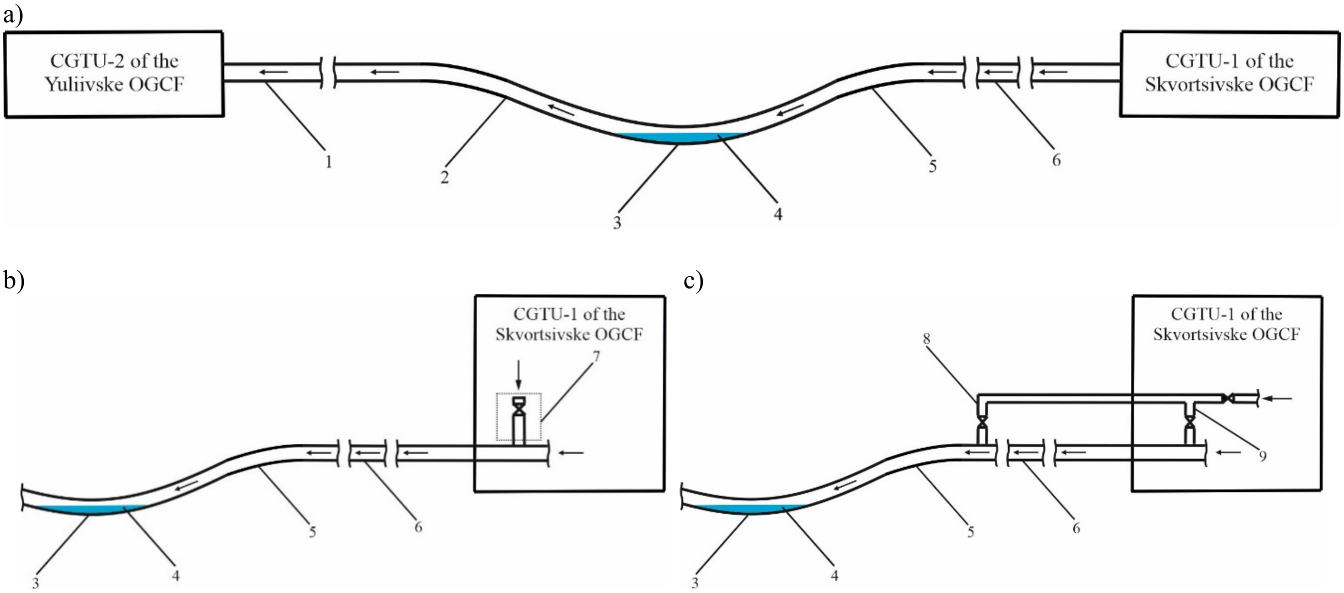


Fig. 5. Chart of the gas gathering pipeline from CGTU-1 of the Skvortsivske OGCF to the CGTU-2 of the Yuliivske OGCF: a) general chart; b) arrangement of a unit for connection of special equipment; c) arrangement of a pipeline for surfactant injection. 1 – in-line section; 2 – upstream section; 3 – lowered section; 4 – accumulated liquid; 5 – downstream section; 6 – area with a significant number of local resistances (branches, etc.); 7 – unit for connection of special equipment (coil, latch with return flanges and nipple of quick-disconnect connection with cap); 8, 9 – pipelines from pumping unit to gas gathering pipeline

Figure 5 shows a chart of gas gathering pipeline from CGTU-1 of the Skvortsivske OGCF to CGTU-2 of the Yuliivske OGCF. The various sections available in the gas gathering pipeline are depicted:

- in-line;
- upstream;
- lowered;
- downstream;
- with the presence of a significant number of local resistances.

It can be assumed that different volumes of liquid accumulate in the inner cavity of all lowered sections of the gas gathering pipeline. During the transmission of hydrocarbons by the gas gathering pipeline, this liquid can be partially or completely removed by the gas flow in the direction of its movement. The liquid can accumulate again over time, under various factors, until the overlap of the internal section of the gas gathering pipeline. As a result, it is possible to reduce the capacity of the gas gathering pipeline and, consequently, the volume of transmitted gas. Therefore, it is advisable to take measures to clean the inner cavity of gas gathering pipeline, for example, the use of surfactant solution.

Here are the following proposed methods of surfactant solution injection to the inner cavity of the gas gathering pipeline:

a) arrangement of a unit for connection of special equipment (mobile pumping unit, etc.) on CGTU-1 of Skvortsivske OGCF. Due to the mounting of this unit, it is possible to periodically inject the surfactant solution at CGTU-1 into the internal cavity during gas transmission (Fig. 5b).
b) arrangement of a pipeline for surfactant solution injection to gas gathering pipeline by means of pumps from CGTU-1 of Skvortsivske OGCF (Fig. 5c):
   - installation of the pipeline from the pumping unit to the gas gathering pipeline at a considerable distance from CGTU-1 for surfactant solution injection (pos. 7 Fig. 5c). The implementation of this will make it possible to inject the surfactant solution to places with a significant number of lowered sections along the gas gathering pipeline;
   - laying of the pipeline from the pumping unit to the gas gathering pipeline at the outlet of CGTU-1 (pos. 8 Fig. 5c). This measure made it possible to inject the surfactant solution into the inner cavity of the gas pipeline, which will allow the gas flow to transmit the solution to the areas with accumulated liquid;
   - similar methods can be implemented on CGTU-2, i.e. in the opposite place of gas gathering pipeline connection.

The application of the given measures contributes to both periodical and continuous injections of surfactant solution, as well as maintaining the control of the surfactant consumption and change it if necessary.

The second method involves cleaning the inner cavity of the pipelines by creating a high-speed gas flow. This requires individual suspension of operation of gas gathering pipelines (1-6) for some time by shutting the shut-off valves at the inlet to CGTU-2, and then its opening and restart of gas transmission. A number of studies were conducted, which provided the shutdown of gas gathering pipeline at different pressures. During the shutdown of gas transmission, the static pressure in the wells and, accordingly, in the gas gathering pipeline increases. Subsequently, after some time, the transmission of gas through the gas gathering pipeline was resumed, which ensured the creation of a high-speed flow and removal of liquid from the internal cavity in the direction of gas flow on CGTU-2. The range of pressure increase values in gas gathering pipelines was determined individually. According to the study results, the frequency of this measure and the maximum value of the pressure increase under the condition of gas transmission shutdown were determined. During the studies, the pressure of the first stage of separation of CGTU-2 was 4.0 MPa. After the restart of gas transmission at each of gas gathering pipeline (1-6), the gas flow rate and the hydraulic efficiency ratio were determined.

To implement this method, the following procedure was performed:

- duration and range of pressure increase values in gas gathering pipelines from 4.0 MPa to 6.5 MPa were determined;
- gas transmission by gas gathering pipelines was resumed at different values of pressure increase in the range from 4.5 MPa to 6.5 MPa and the decrease in pressure was monitored in time to the pressure of the first stage of separation of 4.0 MPa on CGTU-2;
- gas transmission by gas gathering pipelines was resumed under the condition of reducing the pressure of the first stage of separation on CGTU-1 (from 4.0 MPa to 3.9-3.8 MPa);
- gas transmission by gas gathering pipelines was resumed due to the transfer to the lower pressure of the first stage of separation at CGTU-1, which was 3.5 MPa, as at CGTU-2 – 4.0 MPa;
- switching of gas gathering pipelines was performed to the mode of self-cleaning (purge), i.e. from CGTU-2 to CGTU-1 and a flare barn (under these conditions there was a sharp decrease in pressure from 4.0 MPa to atmospheric).

According to the study results, the maximum value of pressure increase was established for gas pipelines (1-6), at which gas transmission was resumed and the frequency of this measure was determined. Based on the study results, recommendations for the formation of a high-speed gas flow in the gas gathering pipelines of the Yuliivskyi OGCPF are developed and given in Table 3.

Table 3.
Recommendations for the formation of a high-speed gas flow in the gas gathering pipelines of the Yuliivskyi OGCPF

| Pipeline name | Pressure control location | Duration of gas pipeline shutdown t, min | Control periodicity |
|---|---|---|---|
| 1 | Inlet gas pipelines at the installation of CGTU-2 disconnectors | 55 | 1 time per 7 days |
| 2 | | 30 | 1 time per 10 days |
| 3 | | 30 | 1 time per 10 days |
| 4 | | 30 | 1 time per 10 days |
| 6 | | 50 | 1 time per 7 days |

Due to the formation of a high-speed gas flow in the gas gathering pipelines, their internal cavity was cleaned from accumulated liquid, which made it possible to increase the hydraulic efficiency by 4%-7%. In the case of switching the gas gathering pipelines to the mode of self-cleaning (purging to the flare barn), their hydraulic efficiency was increased by 8%-10% and more than 10%, which depended on the pressure and duration of the operation.

When applying the first and second methods for gas gathering pipelines, positive results were obtained in terms of removal of the accumulated liquid from the inner cavity and, accordingly, increase of hydraulic efficiency. The effectiveness of these methods depends on the presence of high operation pressures on wells. It is proposed to use such methods with a certain frequency.

The third method involves cleaning the inner cavity of the pipeline by means of foam pistons. Various technologies for foam formation of various multiplicity (low, medium and high) can be used to clean the inner cavity of wells and gas gathering pipelines.

Prior to conducting the experiment, it was necessary to select the optimal surfactant based on the studies of its properties. For this purpose, the specialists of the Ukrainian Scientific Research Institute of Natural Gases (UkrNDIgaz) performed laboratory studies on the properties of various surfactants, which can be further used to create foam and clean the internal cavities of gas gathering pipelines. Therefore, the laboratory studies of foam-forming properties of Stinol-NG, Savinol, Sulfanol and Solpen-10T surfactants were carried out. The foaming properties of the surfactants were studied in different environments according to technical conditions, which valid in Ukraine. The laboratory studies involved a model of reservoir water with a specific gravity ρ = 1.080 g/cm$^3$, which has the composition: $Na^{++}$ $K^+$ – 26300 mg/l; $Ca^{2+}$ – 5045 mg/l; $Mg^{2+}$ – 3100 mg/l; $Cl^-$ – 59950 mg/l. The results of laboratory tests are presented in Table 4.

The results of the laboratory tests established that the provided sample of Solpen-10T surfactant met the requirements of TU 24.6-23913269-001-2001 and the quality passport, but the results of the two samples were slightly different.

According to the laboratory studies it was found that the best characteristics out of the four surfactants in terms of foam stability had Solpen-10 T. It was also determined that at a surfactant concentration of 4% the stability of the foam is 545 s, and in the case of increasing the surfactant concentration to 6% the stability decreases and is 503 s.

In addition, UkrNDIgaz specialists conducted laboratory tests to determine the physical and chemical parameters for compliance with specifications and quality passport. A model of mineralized formation water with a specific weight of 1087 kg/m$^3$ containing 50 g/l of calcium chloride ($CaCI_2$) and 100 g/l of sodium chloride (NaCI) was used for study. In addition, stable condensate with a specific gravity of 789 kg/m$^3$ was used. The laboratory results of two sample surfactants are presented in Table 5.

According to the results of laboratory tests, it is established that the provided sample of surfactant Solpen-10 T meets the requirements of TU U 24.6-23913269-001-2001 and quality passport, but the results of two samples are slightly different.

Table 4.
Comparative foaming properties surfactant Solpen-10T, Stinol-NG, Savinol and Sulfanol

| No. | Substance foaming mixture | | Surfactant | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Solpen-10T | | Stinol-NG | | Savinol | | Sulfanol | |
| | Substance | Concentration surfactant, mass. % | Expansion ratio, ER | Foam stability, s | Expansion ratio, ER | Foam stability, s | Expansion ratio, ER | Foam stability, s | Expansion ratio, ER | Foam stability, s |
| 1 | Model of reservoir water 20ºC | 1 | 2.0 | 101 | 0 | 0 | 5.2 | 288 | 1.4 | 0 |
| 2 | | 2 | 4.9 | 326 | 1.2 | 20 | 5.4 | 298 | 1.8 | 10 |
| 3 | | 4 | 6.0 | 545 | 1.3 | 20 | 4.9 | 324 | 2.0 | 20 |
| 4 | | 6 | 7.6 | 503 | 1.5 | 25 | 5.2 | 328 | 2.0 | 26 |
| 5 | | 8 | 9.0 | 510 | 1.6 | 22 | 5.4 | 347 | 4.4 | 41 |
| 6 | Model of reservoir water + 10 % diesel fuel 20ºC | 2 | 1.3 | 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | | 4 | 2.5 | 35 | 0 | 0 | 1.5 | 70 | 0 | 0 |
| 8 | | 6 | 3.8 | 43 | 1.1 | 0 | 1.5 | 85 | 0 | 0 |
| 9 | | 8 | 4.8 | 60 | 1.2 | 0 | 1.6 | 88 | 0 | 0 |

Table 5.
Laboratory results of SAA physical and chemical parameters

| No. | Indicator | Specification norm | SAA Solpem - 10 T (sample 1) | SAA Solpen - 10 T (sample 2) |
|---|---|---|---|---|
| 1 | Physical form and colour | Brown liquid. Allows precipitation | Correspond | Correspond |
| 2 | Specific weight for 20º C, kg/m$^3$ | Not less than 1040 | 1050 | 1047 |
| 3 | Concentration of hydrogen ions pH 1% solution | 5-10 | 8 | 6 |
| 4 | Stability of the foam of 0.5% solution at 20ºC and at a hydrocarbon condensate content of 10%, s | Not less than 300 | 1440 | 1200 |
| 5 | Stability of the foam of 0.5% solution at 60ºC and a hydrocarbon condensate content of 10%, s | Not less than 150 | 840 | 417 |
| 6 | Stability of the foam of 1.0% solution at 60ºC and a hydrocarbon condensate content of 30%, s | Not less than 150 | 900 | 475 |

After conducting laboratory research and analysis of the results obtained at two gas gathering pipelines of Yuliivskyi OGCPF, UkrNDIgaz specialists together with specialists of Yuliivskyi OGCPF conducted two experiments to investigate the technology of cleaning the inner cavity by means of foam with a multiplicity of 50 to 90.

According to the results of the first experiment, it was found that the hydraulic efficiency of gas gathering pipeline from the GGS of the Eastern block of wells to the CGTU-2 of the Yuliivske OGCF (foam multiplicity ranged from 80 to 90) increased by 10.5%. Instead, according to the results of the second experiment, it was found that the hydraulic efficiency of gas gathering pipeline from the CGTU-1 of the Skvortsivske OGCF to the CGTU-2 of the Yuliivske OGCF (foam multiplicity ranged from 50 to 60) increased by 5.7%. It is expedient to use this technology both for evenly passing sections, and for sites with many local resistances.

The following tools were used for this method: a tanker with technical water, a mobile pumping unit, two mobile nitrogen compressor stations (NCS), a device [21], a surfactant, a back valve. The sequence of works involved the connection of PU and NCS to two individual lines of the device [21] (hereinafter – foam generator) to inject the surfactant solution and non-explosive gas mixture, respectively, and the third line – to the gas gathering pipeline with installation of back valve for injecting the formed foam. After that, the injection line was pressed, a surfactant solution was prepared in PU chamber, an non-explosive gas mixture (composition by volume: nitrogen not less than 90% and oxygen not more than 10%) was fed into the foam generator, and then a surfactant solution was fed. After that the foam was fed into the inner cavity of the gas gathering pipeline. A 2% aqueous surfactant solution was used to generate foam.

Gas gathering pipeline can be cleaned similarly to one of the two experiments performed:

1) termination of gas transportation by gas gathering pipeline for the time of purification. Reducing the pressure to atmospheric or partial reduction, and then the constant injection of non-explosive gas mixture and periodic injection of foam.
2) switching of the gas gathering pipelines for the supply of gas transmitted from the main to the measuring line CGTU-2 through the separator and to CGTU-1 without reducing the pressure under the actual mode of operation. The non-explosive gas mixture and foam are injected periodically.

In both cases, contaminants from the inner cavity of the gas gathering pipeline enter the GTU, where they are collected.

The results of the performed works testify to the cleaning efficiency and the expediency of further testing on gas gathering pipelines of different diameters. The volume of surfactant solution and its concentration to generate foam and clean the internal cavity depends on the diameter, length of the pipeline and the volume of accumulated contaminants to be removed.

Summing up the results of laboratory and experimental studies, the following provisions are formulated:

- before the use of surfactants, it is necessary to perform laboratory tests of the sample to determine the physical

and chemical parameters for quality compliance in accordance with the passport provided by the manufacturer;
- surfactant provided by the manufacturer may differ in physical and chemical parameters, but within the norm in accordance with the manufacturing specifications;
- the use of surfactant solution at different ambient temperatures affects the foaming properties;
- the volume and concentration of surfactant solution for removal of accumulated liquid in the inner cavity of gas gathering pipeline should be selected based on the results of liquid measurement during research on the measuring line with separator and segregator. The reason is that the measured and calculated volumes of liquid differ from each other;
- the stability of the foam increases with the increase in concentration of surfactant solution to a certain limit (maximum saturation of the adsorption layer), and then decreases;
- increasing the multiplicity of foam helps to improve the cleaning of the inner cavity of gas gathering pipeline;
- the multiplicity of the foam depends on both the foaming properties of the surfactant solution and the method of generating the foam, which in turn depends on the ratio of the volume of gas and liquid.

## 5. Conclusions

1. Currently, for the development of fields at Yuliivskyi OGCPF various complex measures are taken to provide stable extraction of hydrocarbons, one of which is in increasing of operation efficiency of gas gathering pipelines that allows to provide stable extraction of hydrocarbons.
2. The coefficient of hydraulic efficiency of gas gathering pipelines is calculated. According to the results of the calculation, it was found that for gas pipelines 2, 3, 4, 5 the value of the hydraulic efficiency coefficient is low and ranges from 72% to 80%. To maintain the maximum possible values of the hydraulic efficiency of the gas gathering pipeline of the Yuliivskyi OGCPF, the authors proposed measures to monitor these gas pipelines, namely:
   - installation of additional measuring devices, in particular pressure and temperature sensors at the inlet and outlet of gas gathering pipelines;
   - control of pressure, temperature at the inlet and outlet of gas pipelines, as well as the volume of gas transmitted in real time from the control room;
   - analysis of archival data on pressure, temperature and volume of transported gas during a given period of time with the derivation of graphical dependencies;
   - development and implementation of a software package for monitoring the parameters of gas pipelines operation and provided that the values of pressure, temperature and accumulation of contaminants in the internal cavity approach the set critical values of signalling: "warning of possible emergency" and "emergency".
3. The results of CFD simulation showed that the accumulation of liquid contaminants in the lowered sections of gas pipelines affects the gas-dynamic processes and leads to pressure losses above the value provided by the technological regime. As the volume of liquid contaminants increases, so does the pressure loss. Moreover, with a small volume of contamination (up to 0.006 $m^3$), there is not significant effect on pressure loss. If the volume of contamination in the lowered section of the pipeline is greater than the specified value, the pressure loss increases by parabolic dependence. The increase in mass flow leads to an increase in the value of pressure loss at the site of liquid contamination. Moreover, the greater the mass flow, the greater the impact of its changes on the pressure loss.

   The performed CFD simulation made it possible not only to determine the patterns of pressure loss in places of liquid contaminants accumulation in the inner cavity of gas pipelines, but also to understand gas-dynamic processes in such places, which is an unconditional advantage of this method over experimental.
4. In practice, experimental studies of various methods of cleaning the inner cavity of gas gathering pipelines were performed and positive results – increased hydraulic efficiency were obtained. The following methods were tested:
   a. injection of surfactant solution into the inner cavity of gas gathering pipelines to remove the accumulated liquid from the lowered sections. The surfactant solution was injected using a mobile pumping unit. Due to the application of this method in gas gathering pipelines, the internal cavity was cleaned of accumulated liquid and the hydraulic efficiency of these gas pipelines was increased by 2%-4.5%. Various methods of surfactant solution injection into the inner cavity of gas gathering pipelines are proposed, in particular:
      - to arrange a unit for connecting a mobile pumping unit;
      - to arrange the pipeline for surfactant solution injection by means of pumps from GTU;

b. generation a high-speed gas flow. A number of studies were conducted to determine the duration and range of pressure rise values in gas gathering pipelines, and then their commissioning at different pressure values of the first stage of separation CGTU-2, CGTU-1. Due to the generation of a high-speed gas flow in gas gathering pipelines, the internal cavity was cleaned of the accumulated liquid and their hydraulic efficiency was increased by 4%-7%;
c. the use of medium multiplicity foam. The first experiment was performed for gas gathering pipeline from the GGS of the Eastern block of wells to the CGTU-2 of the Yuliivske OGCF, and the second experiment was performed for the gas gathering pipeline from CGTU-1 of the Skvortsivske OGCF to the CGTU-2 of the Yuliivske OGCF. According to the results of experiments on cleaning the inner cavity of two gas gathering pipeline from the accumulated liquid, an increase in their hydraulic efficiency by 10.5% and 5.7%, respectively.

The application of the given methods will allow to remove the accumulated liquid from the lowered sections of gas gathering pipelines on GTU and to provide stable operation of these gas pipelines.

5. CFD modelling makes it possible to predict pressure losses in places of accumulation of accumulated liquid in the inner cavity of any section of the gas gathering pipeline. Such forecasting is essential for the timely implementation of appropriate measures to cleaning such sections.
6. The proposed methods of cleaning the inner cavity of gas gathering pipelines are effective but do not allow to completely remove all accumulated liquid. Currently there is no method that would make it possible to completely remove all accumulated liquid from gas gathering pipelines. With this in mind, it is advisable to further improve existing cleaning methods and develop new ones. It is advisable to develop a set of measures for cleaning gas gathering pipelines by combining foams and gel pistons.

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