EFFECTIVENESS STUDY ON THE SYSTEM FOR GAS GATHERING, TREATMENT AND TRANSPORTATIONS FROM GAS PRODUCTION COMPANY

In the paper, the results of the analysis of the existing system for gas gathering, preparation, and transportation from the Opishnyansky, Kotelovsky, and western section of the Berezinsky gas-condensate fields of JSC «UkrGasVydobuvannya» (Kyiv, Ukraine) are presented. The main issues identified during the operational stage of the fields are discussed and preventive measures for minimizing the negative impact on the production levels are proposed.

At the first stage of the research, field measurements of the system operation were conducted in the summer and winter periods. Experimentally, it was established that gas separation process on the separator equipment occurs more qualitatively in the winter period of operation than in the summer period. This is due to the impact of reduced temperatures on the liquid phase precipitation from natural gas.

The main idea of the work is the introduction of continuous monitoring of the gas gathering system for the purpose of detecting changes in the thermobaric regime of operation. Such changes may signal a high probability of the formation of liquid accumulations, which will cause additional hydraulic resistance.

The results of monitoring changes in pressure, temperature, dew points, and composition of natural gas allow for their comprehensive analysis and accurate estimation of the possibility of the formation of liquid masses in certain sections of the gas pipeline system. This excludes the need for confirmation of their presence through equipment and additional human resources, as well as reduces the time of response to the problem.

Such an approach will be of interest to large international companies, since natural gas reserves are constantly being depleted, and the extraction of residual reserves is an attractive goal for producers. In addition, the use of simple methods of cleaning on the basis of hydraulic efficiency of pipelines allows for a significant reduction of both time and material resources.

Key words: system for gas gathering, multiphase flow, industrial gas pipeline, pipeline section, hydraulic efficiency.

1. Introduction

The deposits of the extracting region of Ukraine have been exploited for quite a long time. The vast majority of them entered the stage of final development in the gas regime for attrition. Consequently, the level of gas production, first of all, will depend on the level of working pressure at the wellhead, the volume of its consumption and the efficiency of the equipment of the facilities of the ground part of the fields where the gas is collected, prepared and transported.

To date, JSC «UkrGasVydobuvannya», Kyiv, Ukraine (further – the Company) has a powerful system for collecting, preparing and transporting gas among gas producing companies in Ukraine. It includes 9272 kilometers of field pipelines (inter-field gas pipelines, trains, gas pipelines for connection, collectors, etc.), More than 2,700 wells, 140 fields, 39 booster compressor stations, 184 complex gas treatment units. The structure of the gas producing company includes three gas industrial departments (GID) ShebelynkaGasVydobuvannya (Donetsk, Kharkiv region), PoltavaGasVydobuvannya and LvivGasVydobuvannya, which carry out the main functions of gas production, preparation and transportation to points of transfer to main gas pipelines. The volume of gas produced by the company in 2017 is 15.25 billion m³ [1].

Considering the strategy of increasing production «20/20», in recent years, Ukraine has been increasing gas production:
– by exploring new promising gas producing regions;
– increase in the scope of drilling and the commissioning of new wells;
– capital repair of wells;
– reduction of well head pressure to minimum allowable values, taking into account the natural drop in reservoir pressures of fields (operating mode of deposits for «depletion»);
– by establishing wellhead low-pressure booster compressor stations (LPBCS), zero degrees of existing booster compressor stations (BCS), etc.

But on the basis of these methods, with increasing gas production, the problem arises of ensuring as low as possible pressure differences along the gas pipeline route:
– gas pipeline transports gas from the producers to consumers;
– or a gas pipeline (trail) transports gas from the wellhead to the complex gas processing plant (CGPP) or from CGPP to BCS.

The motion of gas-liquid flows in the pipeline cavity can have three structures from annular to cork and stratified, which in any case are characterized by the presence of localized liquid in the lowered and upward sections of
те газопровода. Результатом является образование гидравлических пробок, частично или полностью перекрывающих сечение трубы, которые характеризуются ростом гидравлического сопротивления и гидростатического давления.

Основными причинами увеличения потерь давления при транспортировке газа являются:
– уменьшение рабочего давления при константе объема, что влияет на потерю давления на трение;
– образование определенного числа загрязнений в трубной камере, образующих дополнительные локальные гидравлические опоры.

Кроме того, следует отметить, что присутствие локальных сопротивлений в трубном ряду приводит к изменению температурного режима, вызывая выделение тяжелых фракций из двухфазных потоков. Роль таких локальных сопротивлений может играть отложение жидкости в низких местах газопровода.

В свою очередь, полная газовая развязка — сложная технологическая операция и связана с большими капиталовложениями, которые существенно увеличат стоимость газа.

То есть газ, поступающий в газопровод, содержит определенное количество жидкости,��оявляющегося в газовом потоке в форме мелких капель.

Следуя за тем, что история добычи газа в Украине началась в начале прошлого века, в результате которой большинство освоенных месторождений находятся на финальной стадии эксплуатации и имеют повышенный влажностный фактор.

Таким образом, повышение эффективности работы системы «резервуар-вель-трейн-ТГХ-сеть газопроводов» остается актуальной задачей, и также обеспечивая его функционирование на минимальных затратах на транспортировку и обеспечение транспортной ёмкости на сегодняшних режимах эксплуатации.

2. Объект исследования и его технологический аудит

Объектом исследования является система между промышленными газопроводами Котелевского месторождения и газотранспортная система Котелевской ГГЭС, которая собирает газ из Березовской, Котелевской и Опшинской газовых обогатительных комплексов газотранспортного предприятия и транспортирует газ в состав подготовительных установок Солокской ГС (рис. 1) [2].

Газовая отрасль ПГВ производит около 5,8 млрд кубометров природного газа в 2017 году, что составляет 40% от общего объема производства [1].

Исследование системы сбора, подготовки и транспортировки газа было выполнено в 1960-х и 1970-х годах и, соответственно, предусматривает различные эксплуатационные режимы. В то же время, на сегодняшний день, из-за естественного снижения давления на входе, а также увеличения влажности газа, качество газа заметно ухудшается из-за нерациональной работы системы сбора и подготовки на существующих режимах работы.

Условное наличие жидкости в трубном ряду является одним из факторов, которые значительно сокращают эффективность газодобывающей системы. В условиях эксплуатации промышленных газопроводов, это важно определить объем жидкости в их камерах, так как ее присутствие негативно влияет на работу всех компонентов газодобывающей системы.

3. Цель и задачи исследования

Цель исследования состоит в оценке возможности самоочищения системы между промышленными газопроводами путем введения ряда мер, обеспечивающих гидравлического режима между различно ориентированными участками в масштабе.
To achieve this aim, it is necessary to perform the following tasks:

1. To investigate the operation modes and hydraulic state of the system of industrial gas pipelines of the Kotelva group of deposits («PoltavaGasVydobuvannya») and process, systematize and analyze the data.

2. To assess the hydraulic efficiency of operation of the system of industrial gas pipelines and thermobaric and high-speed operation in winter and summer.

3. To determine the natural liquid traps and the volume of contaminants.

4. To make an assessment of the reliability of the gas pipeline system in terms of the occurrence of massive emissions and the formation of hydrates.

5. To simulate the decrease in the wellhead pressure of the Kotelva group of deposits.

4. Research of existing solutions of the problem

The efficiency of gas collection and transportation systems from the fields of a gas producing company depends on the hydraulic state of the aggregate sections of the linear part of the gas pipelines (industrial, between industry and others). Therefore, it is necessary to carry out periodic monitoring of the hydraulic state in order to evaluate the actual hydraulic characteristics (determination of pressure drops, actual coefficients of hydraulic resistance of the site and hydraulic efficiency, approximate amount of contamination).

Since deviations from the nominal operating mode indicate the formation of two-phase currents, which significantly reduces the efficiency and reliability of the system operation. As of the 80–90’s, in the last century, much attention is paid to the research of a two-phase flow. The models of gas and liquid flow in the pipes have been developed, new methods have been developed for determining the amount of liquid in the cavity of the gas pipeline and methods for extracting liquid from the gas pipeline, and devices for removing liquid have been modernized. One of these methods is the method of creating a pulsed regime of the working gas flow (the method of high-velocity gas flow) [3].

Outside of Ukraine, much attention has been paid to the cleaning of the internal cavity of the gas pipeline by passing purification devices of various designs. Methods have been developed for cleaning the cavity of loops and gas lines with gel pistons [4] and surface-active substances [5], as well as methods for refined calculations of the hydraulic state of gas-condensate gas pipelines [6, 7]. In addition, due to the creation of modernized separation equipment, the gas cleaning in the fields is significantly improved. As for Ukraine, today the only normative document regulating the procedure for performing hydraulic calculations is VSN 51.1–85 [8], which provisions and own development of specialists of the Ukrainian Scientific Research Institute of Natural Gases (UkrNDIGas) (Kharkiv) are laid in creation of a software-calculation complex «Control of massive emissions of liquid from the cavity of the gas pipeline». This complex consists of three interrelated programs: hydraulic efficiency, the volume of contamination and hydrate formation, on the basis of which the calculations presented in [9] are performed. All hydraulic calculations of gas pipelines are made in accordance with the requirements [8, 10].

Therefore, solving the problem of analyzing the operating modes of the gas gathering and gas transmission system, identifying problem areas in terms of deteriorating hydraulic efficiency, and justifying the feasibility of implementing measures for cleaning gas pipelines is a promising issue.

When solving the problem of cleaning the gas pipeline, it is necessary to find out the causes of liquid ingress and quantity. This will make it possible to monitor any changes in the operation process and make a timely decision about the time of the cleaning. It should also be noted that the amount of contamination in gas pipelines, calculated theoretically, differs from the experimental one. Therefore, this problem requires detailed study.

In addition, attention should be paid to the differences in the approach to cleaning the internal cavity of field pipelines. In accordance with the requirements of regulatory documents, the decision to clean this type of pipeline is taken solely on the basis of an internal pipe inspection [11], in fact it is impossible to carry out in Ukrainian specific conditions detailed in [12].

Nevertheless, it should be noted that in all conditions, a multiphase medium will form in the cavity of the pipelines. This medium is considered relatively immobile in the conditions of exploitation of mature deposits, or it constantly changes its shape when localized in lowered areas, subject to changes in the thermobaric operating regime [13]. Although, on the other hand, the problem of the behavior of multi-phase media under conditions of changing the thermobaric operating conditions of the pipeline is mainly considered for oil pipelines and collector threads collecting oil, taking into account the possibility of formation of both paraffin deposits [14] and resins [15, 16].

The processes of proliferation and formation of liquid clusters in gas gathering networks are more specific. Such contamination is more mobile when the main pollutant is gas condensate, and more resistant to localization at the final stage of field development, when it will be formed exclusively from water fractions with only traces of condensate. In any case, experts recommend conducting a comprehensive survey of pipeline sections where liquid accumulation is possible [17].

It is shown in [18] that in order to prevent the accumulation of liquid contaminants in the pipeline cavity in the ascending sections of the pipelines, measures were taken to replace large-diameter plumes with smaller ones. Accordingly, these measures were carried out with the goal of providing the minimum necessary gas velocities to ensure the delivery of liquid to the CGPP.

In the absence of clear regulatory guidance on how to carry out such diagnostics, the analysis of hydraulic efficiency should be considered a fairly simple and economical method, despite its significant error and the need to carry out quite often.

5. Methods of research

To study the dynamics of the hydraulic efficiency coefficient between industrial gas pipelines in the framework of this work, the actual technological parameters are measured in separate sections. In order to assess the effect of changing the ambient temperature on the hydraulic efficiency coefficient, the measurements are carried out during the winter and summer periods of operation.

Table 1, 2 presents the output data of the system between industrial gas pipelines, collects gas from the CGPP and transports gas to the integrated preparation of the Solokha GS.
The study is based on the measurement of process parameters at the control points of the following sections between industrial gas pipelines:

- High-pressure:
  1. Berezivka CGPP – crane (cr.) No. 6 connection point (c. p.) Kotelva CGPP;
  2. cr. No. 6 c. p. of Kotelva CGPP – c. p. of Opishnia CGPP;
  4. Opishnia CGPP – Solokha GS.

- Low-pressure:
  5. Opishnia CGPP – Kotelva CGPP;
  6. Berezivka – Kotelva CGPP.

6. Research results

The results of calculating the hydraulic efficiency of the system between industrial gas pipelines are carried out on the basis of technological measurements during the winter and summer period of operation. The results include the determination of excessive pressure losses, the estimation of the operating speed regime, the calculation of the indicative volume of contaminants, and the verification of the conditions for the passage of the volley process of liquid discharges and the conditions for the formation of hydrates, which present in Tables 3, 4 [2].

From the results of calculating the hydraulic efficiency of the system between industrial gas pipelines during the winter operation period (Table 3), it can be seen that the section of the Berezivka CGPP – c. p. of Kotelva CGPP (cr. No. 6) is contaminated (excess pressure loss is $1.39 \text{ kgf/cm}^2 (94.5 \%)$, $V_{\text{cont}} = 29.9 \text{ m}^3$, $E = 23.5 \%$) and requires constant monitoring of the accumulation of liquids and the introduction of clean-up measures.

The site of the low-pressure gas pipeline Berezivka CGPP – Kotelva CGPP is also contaminated. Excess pressure loss is $0.78 \text{ kgf/cm}^2 (92 \%)$, $V_{\text{cont}} = 5.21 \text{ m}^3; E = 30.47 \%$ with a high probability of redistribution of pollutants (due to volley ejection) through a gas pipeline. This requires constant monitoring of the hydraulic state.

<table>
<thead>
<tr>
<th>Pipeline section number</th>
<th>Initial pressure, kgf/cm² (at)</th>
<th>Final pressure, kgf/cm² (at)</th>
<th>Initial temperature, °C</th>
<th>Final temperature, °C</th>
<th>Gas consumption, thousand m³/day</th>
<th>Gas density at standard conditions, kg/m³</th>
<th>Dew-point temperature, °C</th>
<th>Technical specifications</th>
<th>Year of commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27.94</td>
<td>26.47</td>
<td>16.37</td>
<td>3.3</td>
<td>623.33</td>
<td>0.783</td>
<td>0</td>
<td>10.25</td>
<td>530</td>
</tr>
<tr>
<td>2</td>
<td>26.47</td>
<td>26.16</td>
<td>3.3</td>
<td>3.2</td>
<td>1748.0</td>
<td>0.783</td>
<td>0</td>
<td>10.92</td>
<td>530</td>
</tr>
<tr>
<td>3</td>
<td>26.61</td>
<td>26.47</td>
<td>11.0</td>
<td>3.3</td>
<td>1124.68</td>
<td>0.783</td>
<td>0</td>
<td>10.6</td>
<td>530</td>
</tr>
<tr>
<td>4</td>
<td>26.16</td>
<td>25.54</td>
<td>3.2</td>
<td>3.1</td>
<td>2232.24</td>
<td>0.783</td>
<td>-2.3</td>
<td>7.3</td>
<td>530</td>
</tr>
</tbody>
</table>

The data of hydraulic efficiency of the system between industrial gas pipelines connecting Berezivka CGPP, Kotelva CGPP, Opishnia CGPP of «PoltavaGasVydobuvannia» and transport gas for the integrated preparation of Solokha GS in winter operation

<table>
<thead>
<tr>
<th>Pipeline section number</th>
<th>Initial pressure, kgf/cm² (at)</th>
<th>Final pressure, kgf/cm² (at)</th>
<th>Initial temperature, °C</th>
<th>Final temperature, °C</th>
<th>Gas consumption, thousand m³/day</th>
<th>Gas density at standard conditions, kg/m³</th>
<th>Dew-point temperature, °C</th>
<th>Technical specifications</th>
<th>Year of commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.68</td>
<td>8.44</td>
<td>3.47</td>
<td>3.3</td>
<td>148.6</td>
<td>0.783</td>
<td>0</td>
<td>20.2</td>
<td>228 eq.</td>
</tr>
<tr>
<td>2</td>
<td>9.6</td>
<td>8.75</td>
<td>-2.07</td>
<td>3.3</td>
<td>90.00</td>
<td>0.783</td>
<td>0</td>
<td>9.782</td>
<td>273</td>
</tr>
</tbody>
</table>

The data of hydraulic efficiency of the system between industrial gas pipelines connecting Berezivka CGPP, Kotelva CGPP, Opishnia CGPP of «PoltavaGasVydobuvannia» and transport gas for the integrated preparation of Solokha GS in summer operation

<table>
<thead>
<tr>
<th>Pipeline section number</th>
<th>Initial pressure, kgf/cm² (at)</th>
<th>Final pressure, kgf/cm² (at)</th>
<th>Initial temperature, °C</th>
<th>Final temperature, °C</th>
<th>Gas consumption, thousand m³/day</th>
<th>Gas density at standard conditions, kg/m³</th>
<th>Dew-point temperature, °C</th>
<th>Technical specifications</th>
<th>Year of commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.15</td>
<td>31.06</td>
<td>19.26</td>
<td>13.8</td>
<td>726.453</td>
<td>0.771</td>
<td>13.8</td>
<td>10.25</td>
<td>530</td>
</tr>
<tr>
<td>2</td>
<td>31.06</td>
<td>30.29</td>
<td>13.8</td>
<td>12.9</td>
<td>1814.973</td>
<td>0.771</td>
<td>12.9</td>
<td>10.92</td>
<td>530</td>
</tr>
<tr>
<td>3</td>
<td>31.72</td>
<td>31.06</td>
<td>33.01</td>
<td>13.8</td>
<td>1088.520</td>
<td>0.779</td>
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<td>10.6</td>
<td>530</td>
</tr>
<tr>
<td>4</td>
<td>30.54</td>
<td>29.01</td>
<td>12.9</td>
<td>12.7</td>
<td>2255.234</td>
<td>0.757</td>
<td>12.7</td>
<td>7.3</td>
<td>530</td>
</tr>
</tbody>
</table>

The site of the low-pressure gas pipeline Berezivka CGPP – Kotelva CGPP did not work.
Table 3

<table>
<thead>
<tr>
<th>Pipeline section number</th>
<th>Initial pressure, kgf/cm² (at)</th>
<th>Real pressure, kgf/cm² (at)</th>
<th>Differential pressure, kgf/cm² (at)</th>
<th>Excessive pressure drop due to contamination, kgf/cm² (at)</th>
<th>Conclusion</th>
<th>Gas velocity, m/s</th>
<th>Hydraulic efficiency of the gas pipeline, %</th>
<th>Estimated volume of contamination, m³</th>
<th>Critical amount of contamination, m³</th>
<th>Probability of massive emission of liquid</th>
<th>Condition of hydrates formation in the period of research</th>
<th>Conclusion on the operation of the system</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27.94</td>
<td>26.47</td>
<td>1.47</td>
<td>1.39</td>
<td>Virtual</td>
<td>1.14</td>
<td>23.5</td>
<td>29.9</td>
<td>30.3</td>
<td>99 %</td>
<td>Performed</td>
<td>The section is contaminated, requires cleaning, constant monitoring of the accumulation of liquid, hydrates formation at temperatures below 7.6 °C</td>
</tr>
<tr>
<td>2</td>
<td>26.47</td>
<td>26.16</td>
<td>0.31</td>
<td>0.0</td>
<td>There</td>
<td>3.22</td>
<td>96.75</td>
<td>0</td>
<td>0</td>
<td>Absent</td>
<td>Performed</td>
<td>The gas pipeline section is clean, does not require cleaning, of hydrates formation at a temperature below 7.27 °C</td>
</tr>
<tr>
<td>3</td>
<td>26.61</td>
<td>26.47</td>
<td>0.14</td>
<td>0.02</td>
<td>Excessive</td>
<td>2.04</td>
<td>92.25</td>
<td>5.26</td>
<td>37.07</td>
<td>14.2 %</td>
<td>Performed</td>
<td>The hydraulic state of the section is satisfactory, it does not require cleaning, hydrates formation at a temperature below 7.35 °C</td>
</tr>
<tr>
<td>4</td>
<td>26.16</td>
<td>25.54</td>
<td>0.62</td>
<td>0.01</td>
<td>Excessive</td>
<td>4.20</td>
<td>99.33</td>
<td>0</td>
<td>12.85</td>
<td>Absent</td>
<td>Performed</td>
<td>The gas pipeline section is clean, constant monitoring of the fluid accumulation at a temperature below 7.09 °C</td>
</tr>
<tr>
<td>5</td>
<td>9.68</td>
<td>8.44</td>
<td>1.24</td>
<td>0.22</td>
<td>Excessive</td>
<td>3.97</td>
<td>90.84</td>
<td>1.84</td>
<td>8.34</td>
<td>22 %</td>
<td>Absent</td>
<td>The hydraulic condition of the section is satisfactory, it requires constant monitoring of the fluid accumulation</td>
</tr>
<tr>
<td>6</td>
<td>9.6</td>
<td>8.75</td>
<td>0.85</td>
<td>0.78</td>
<td>Virtual</td>
<td>1.82</td>
<td>30.47</td>
<td>5.21</td>
<td>7.11</td>
<td>73 %</td>
<td>Performed</td>
<td>The section is contaminated, requires constant monitoring of fluid accumulation</td>
</tr>
</tbody>
</table>

On all sections of high-pressure and low-pressure gas pipelines, except for the gas pipeline Opishnia CGPP – Kotelva CGPP, hydrate formation conditions are met.

Low-pressure gas pipeline Opishnia CGPP – Kotelva CGPP works with optimal pressure losses, caused mainly by local resistance (diameter transitions) and minor liquid contamination.

The research results, in the summer period of operation (Table 4), indicate that the section of the high-pressure gas pipeline of c. p. of Kotelva CGPP (No. 6) – Opishnia CGPP has a small degree of contamination (excess pressure loss is 0.24 atm, \( V_{cont} = 8.34 \, m³ \), \( E = 82.58 \% \)). It has been experimentally confirmed that the site requires constant monitoring of the accumulation of liquid [2].

The most contaminated are such sections of the gas pipeline system:
- a section of the high-pressure gas pipeline Kotelva CGPP – c. p. to the Berezivka CGPP – Opishnia CGPP, the excess pressure loss is 0.49 atm, \( V_{cont} = 22.33 \, m³ \); \( E = 51.27 \% \), requires cleaning and constant monitoring of the hydraulic state;
- a section of the high-pressure gas pipeline Opishnia CGPP – Solokha GS, the excess pressure loss is 0.99 atm, \( V_{cont} = 11.14 \, m³ \); \( E = 64.33 \% \) with a high
the probability of redistribution of pollutants (due to massive emission) through the gas pipeline, requires cleaning and constant monitoring of the hydraulic state.

Low-pressure gas pipeline Opishnia UKPG – Kotelvaya USP works with optimal pressure losses, caused mainly by local resistance (diameter transitions) and minor liquid contamination.

The site of the low-pressure gas pipeline Opishnia CGPP – Kotelvaya CGPP at the time of the research did not work. On all sections of high-pressure and low-pressure gas pipelines, the conditions for hydrate formation are absent. In addition, it should be noted that, compared with the winter period, pressure losses from 0.44 atm to 0.09 atm have decreased in the section of the CGPP – c. p. of CGPP (crane No. 6). This is due to the self-cleaning of the section and the redistribution of liquid to neighboring areas due to increased loading.

On the basis of the analysis of the research results carried out during the different periods of operation, it should be noted that in the winter (at low ambient temperatures) the gas separation process at the gas pre-treatment facilities is more qualitative. So, the gas that enters the pipeline during winter operation is less voluminous and the total amount of condensed liquid phase is less compared to the summer period of operation. This condition is experimentally confirmed by the studies carried out in this paper, since the hydraulic efficiency coefficient in the sections of this gas gathering unit and the estimated amounts of contamination in the cavity pipelines are significantly less than in the summer period of operation.

The corresponding increase in the temperature of gas separation affects the drop in the coefficients of hydraulic efficiency and a significant increase in the amount of contamination in the summer. Subsequently, the gas enters the gas pipelines, where its temperature decreases, resulting in favorable thermodynamic conditions for phase transformations, the result of which is the accumulation of liquid contaminants in the cavity pipelines. These contaminations accumulate in the lower sections of the pipeline in the form of slugs, can be redistributed while moving along the ascending sections of the pipeline route profile. This leads to the creation of excessive fluctuations, and eventually the complete overlapping of the section of the pipeline in the natural gas trap following the movement of the gas.

### Table 4

<table>
<thead>
<tr>
<th>Pipeline section number</th>
<th>Checking the basic operating pressure</th>
<th>Velocity mode</th>
<th>Hydraulic operation mode</th>
<th>Conclusion</th>
<th>Condition of hydrates formation in the period of research</th>
<th>Probability of massive emission of liquid</th>
<th>Conclusion on the operation of the system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial pressure, kgf/cm² (at)</td>
<td>Final pressure, kgf/cm² (at)</td>
<td>Differential pressure, kgf/cm² (at)</td>
<td>Excessive pressure drop due to contamination, kgf/cm² (at)</td>
<td>Gas velocity, m/s</td>
<td>Estimated volume of contamination, m³</td>
<td>Critical amount of contamination, m³</td>
</tr>
<tr>
<td>1</td>
<td>31.15</td>
<td>31.06</td>
<td>0.09</td>
<td>0.02</td>
<td>1.19</td>
<td>95</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The gas velocity facilitates the precipitation of liquid from the gas stream</td>
<td></td>
<td>Conclusion</td>
</tr>
<tr>
<td>2</td>
<td>31.06</td>
<td>30.29</td>
<td>0.77</td>
<td>0.24</td>
<td>3.23</td>
<td>82.58</td>
<td>8.54</td>
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<td></td>
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<td></td>
<td>Gas velocities are sufficient for the redistribution of liquid masses</td>
<td></td>
<td>Conclusion</td>
</tr>
<tr>
<td>3</td>
<td>31.72</td>
<td>31.06</td>
<td>0.66</td>
<td>0.49</td>
<td>1.81</td>
<td>51.27</td>
<td>22.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The gas velocity facilitates the precipitation of liquid from the gas stream</td>
<td></td>
<td>Conclusion</td>
</tr>
<tr>
<td>4</td>
<td>30.54</td>
<td>29.01</td>
<td>1.53</td>
<td>0.99</td>
<td>4.17</td>
<td>64.33</td>
<td>11.14</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gas velocities are sufficient for the redistribution of liquid masses</td>
<td></td>
<td>Conclusion</td>
</tr>
<tr>
<td>5</td>
<td>11.38</td>
<td>9.84</td>
<td>1.54</td>
<td>0</td>
<td>3.96</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gas velocities are sufficient for the redistribution of liquid masses</td>
<td></td>
<td>Conclusion</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>Absent</td>
<td>The gas pipeline section is clean, no cleaning is required</td>
</tr>
</tbody>
</table>

At the time of the research, the gas pipeline did not work.
When accumulation of contaminants accumulates, the working pressure in the gas pipeline begins to pulsate with a sudden drop below the condensation pressure or an increase above the evaporation pressure of the liquid phase, which, in such cases, changes into a gaseous phase and vice versa. Taking into account the continuous inflow of the liquid phase into the cavity of the pipelines, the accumulation of the critical volume leads to a redistribution of the liquid phase, which results in volley emissions to the process equipment at the outlet of the pipeline.

Such cumulative effect of the mechanical supply of liquid to the cavity of pipelines and phase transformations forms various structures of motion of the gas-liquid mixture along the length of the pipeline, depending on the speed mode of operation. It is clearly noted that in sections 1, 6 in the winter operation period, the gas flow rate contributes to the accumulation of liquid droplets in the lower part of the gas pipeline, «ascending areas». Whereas at the sections 2, 3, 4, 5, during the winter operation period, the gas flow rate contributes to the fact that most of the liquid is collected in a reduced section of the gas pipeline with a wave-like distribution of phases and subsequent displacement into the «ascending areas» in the form of a plug during «massive emission». The efficiency of the system during the summer period of operation is characterized by slightly different values, since in all parts of the system the gas flow rate facilitates the passage of the above process. It should be noted that the efficiency of gas pipelines, in the winter and summer period of operation, varies within the limits of 49 %. The gas flow velocity is inherent in the stratified structures of the gas-liquid flow (below 3.5 m/s) or the floor (up to 8.2 m/s) for this case, but is not able to create an annular flow structure in one of the differently oriented areas in space. In the course of this work, the places of the most probable localization and accumulation of liquid that correspond to natural fluid traps are formed in the cavity of the pipeline as the trail passes through valleys, tracts, ravines, floodplains of rivers and the like. Plans-profiles of the traces of the constituent gas pipelines for tracking the localization of the liquid are shown in Fig. 2–6 [2].

![Fig. 2. Plan-profile of the route of the high-pressure gas pipeline Berezivka CGPP – c. p. of Opishnia CGPP (section No. 1, 2)](image)

![Fig. 3. Plan-profile of the route of the high-pressure gas pipeline Kotelva CGPP – crane No. 6 of c. p. to the gas pipeline Berezivka CGPP – c. p. of Opishnia CGPP (section No. 3)](image)

![Fig. 4. Plan-profile of the route of the high-pressure gas pipeline Opishnia CGPP – Solokha GS (section No. 4)](image)

![Fig. 5. Plan-profile of the route of the high-pressure gas pipeline Opishnia CGPP – Solokha GS (section No. 5)](image)
Such approach to assessing the impact of the high-speed mode of operation on the formation of structural forms of motion in the sections of the system makes it possible to develop a set of measures to increase the loading of the system and increase the linear velocities of the gas.

The package of measures for re-planning the flow included the reconstruction of the collection system and inter-field transportation of gas with an increase in its loading:

1) additionally produced gas with a decrease in working pressure from 26 to 12 atm;

2) the construction of a new gas pipeline for gas supply to consumers, and also as a fuel gas from the Solokha GS to Solokha BCS, cr No. 2 of the Kotelva CGPP, the Opishnia CGPP, which envisages an increase in the volumes of gas transportation that was previously used for industrial and technological needs;

3) construction of a new gas pipeline Opishnia CGPP – Solokha CS, which provides for separation of high-pressure and low-pressure gas flows and increase of gas loading from the Kotelva gas condensate field;

4) construction of a new gas pipeline Zakhidna-Berezivka CGPP – Zakhidna-Berezivka CGPP with the aim of dosing out BCS and gas system in the amount of up to 20% of current productivity.

Simulation of the process of fluid movement and its redistribution between the sections of the system indicates the possibility of reducing the volume of contaminants when the load and working pressure change by a factor of 3.5. This almost doubles the pressure drop across the sections, leading to an increase in gas production volumes by an additional 5–20%, depending on the current working pressure of the wells (Tables 5, 6).

From the results of the presented studies (Tables 5, 6), it is noted that when the input pressure on the Solokha BCS is reduced to 2 atm, the gas velocity of the low-pressure sections of the pipelines will reach extremely low values. This will negatively affect the operation mode of low pressure wells. As a result, the energy of the formation will not be sufficient to remove the gas-liquid mixture from the bottom of the well. This will lead to a complete shutdown of the well and loss of gas production.

![Fig. 6. Plan-profile of the route of the low-pressure gas pipeline Berezivka CGPP-Kotelva CGPP (section No. 6)](image-url)

Table 5

<table>
<thead>
<tr>
<th>Name of deposit</th>
<th>Production (under the established operating conditions of the Solokha BCS), mln. m³</th>
<th>Production (with a decrease in the input pressure on the Solokha BCS to 12 atm), million m³/day</th>
<th>Production (with a decrease in the input pressure on the Solokha BCS to 5 atm), million m³/day</th>
<th>Production (with a decrease in the input pressure on the Solokha BCS to 2 atm), million m³/day</th>
<th>Additional production, %/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kotelva GCF</td>
<td>0.92554646</td>
<td>1.0808466</td>
<td>1.1053702</td>
<td>1.0813344</td>
<td>16.43</td>
</tr>
<tr>
<td>Zakhidna-Berezivka GCF</td>
<td>0.55133620</td>
<td>0.64357610</td>
<td>0.64781770</td>
<td>0.64744850</td>
<td>18.21</td>
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<tr>
<td>Opishnia GCF</td>
<td>0.62547870</td>
<td>0.72330250</td>
<td>0.7308310</td>
<td>0.71348870</td>
<td>16.17</td>
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<tr>
<td>Total</td>
<td>2.10236136</td>
<td>2.44772520</td>
<td>2.46527100</td>
<td>2.44227160</td>
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</tr>
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</table>

Table 6

<table>
<thead>
<tr>
<th>Name of deposit</th>
<th>Production (under the established operating conditions of the Solokha BCS), mln. m³</th>
<th>Production (with a decrease in the input pressure on the Solokha BCS to 12 atm), million m³/day</th>
<th>Production (with a decrease in the input pressure on the Solokha BCS to 5 atm), million m³/day</th>
<th>Production (with a decrease in the input pressure on the Solokha BCS to 2 atm), million m³/day</th>
<th>Additional production, %/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kotelva GCF</td>
<td>0.92554646</td>
<td>1.1294586</td>
<td>1.1551746</td>
<td>1.1556903</td>
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</tr>
<tr>
<td>Zakhidna-Berezivka GCF</td>
<td>0.55133620</td>
<td>0.64939290</td>
<td>0.65432150</td>
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</tr>
<tr>
<td>Opishnia GCF</td>
<td>0.62547870</td>
<td>0.73227000</td>
<td>0.74185810</td>
<td>0.72030760</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2.10236136</td>
<td>2.51012150</td>
<td>2.55135420</td>
<td>2.53145040</td>
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</tr>
</tbody>
</table>

The results of simulating the distribution of working pressure on production volumes with a decrease in working pressure from 25 to 12.5, 5, 2 atm at the entrance to the Solokha BCS, respectively (current systems are contaminated):
The most optimal mode of operation is reducing the input pressures up to 5 atm, at which the increase in gas production is clearly noted. As well as ensuring the optimal gas velocity for delivering a gas-liquid mixture from low-pressure wells and in areas of low-pressure pipelines.

7. SWOT analysis of research results

Strengths. Carrying out cyclical studies of the effectiveness of the gas production system primarily leads to the prevention of abnormal situations, which in turn results in sustainable gas production and avoidance/prevention of additional costs of the company.

As a research result, the dependence of the influence of the ambient temperature on the quality of gas preparation, as well as the influence of the gas flow rate on the formation of liquid contaminants in the cavity gas pipeline, is experimentally confirmed.

The main manifestation of economic efficiency for the gas pipelines of the system for collecting and inter-field transportation of gas from the fields that are at the final stage of operation is the reduction of the excess (or excessive) pressure losses that arise in this process. Leveling or virtually complete elimination of their influence is achieved through the implementation of the above activities.

Weaknesses. The results of the research differ somewhat from the actual data, and require detailed study in the future.

Opportunities. Considering the fact that the majority of the world’s explored deposits are currently at the final stage of operation, research into the effectiveness of the gas production system is promising, as it is not for gas producers in Ukraine, but for the whole world.

Threats. When implementing this research, additional human resources are needed.

8. Conclusions

1. At the first stage of the research, field measurements of the operating modes of the system in summer and winter have been carried out. It has been experimentally established that during the winter operation the process of gas separation on separating equipment is performed more qualitatively than in summer operation, which is associated with a decrease in the operating pressure in it will lead to an increase in the linear velocities sufficient for the transition of the structural form of the flow from the stratified (wave) to the cork and ring flow. Consequently, the provision of traffic contamination and self-cleaning of the system.

2. It is established that the hydraulic efficiency of gas pipelines in winter and summer periods of operation fluctuates within 49%, that is, the speed of the gas flow contributes to the accumulation of liquid contaminants. However, it should be noted that in all sections of the gas pipelines there are no conditions ensuring the transfer of liquid with the gas flow in the form of films on the walls of pipelines in a dispersed state. It has been experimentally confirmed that during the winter operation, the ambient temperature creates favorable thermodynamic conditions for the «dropping out» of the liquid phase from the gas on separation equipment, that is, the separation equipment works more efficiently. It follows that the gas that enters the pipeline during the winter operation has a lower moisture content of the liquid phase compared to the summer period of operation. Accordingly, it is also clearly noted that the improvement in the coefficient of hydraulic efficiency in the sections of the gas gathering unit is confirmed by a much smaller volume of contamination in the cavity pipelines.

3. In the course of the research, the estimated and critical levels of contamination were experimentally calculated. Also, the places of the most probable localization and accumulation of liquid corresponding to natural traps that are formed in the cavity of the pipeline are lowered, as the trail is lowered through valleys, tracts, ravines, floodplains of rivers. It is established that the actual amount of contamination is slightly different from the calculated one.

4. It is confirmed that the probability of a «volley» discharge of liquid in the winter period of operation is somewhat lower than in summer. It is established that the inclination ofhydrate formation is present only in the winter period of operation.

5. Taking into account the hydraulic state of the gas production system, which is considered in the work, the self-cleaning process of the sections of the gas pipelines is modeled. The operating modes of these sections significantly influence the distribution of pressure on the CGPP and the operation of low-pressure and medium-pressure wells due to re-planning of gas flows in the system with justification of their feasibility in technical and economic calculations. In fact, a change in the loading of the system and a decrease in the operating pressure in it will lead to an increase in the linear velocities sufficient for the transition of the structural form of the flow from the stratified (wave) to the cork and ring flow. Consequently, the provision of traffic contamination and self-cleaning of the system.

References

12. Horin P. V., Tymkiv D. F., Holubenko V. P. Systematizatsia metodov ochystki hazobzirnykh merezh dlia transportuvannia
1. Introduction

Global trends in increasing the energy efficiency of heating supply systems in general are aimed at the utilization of natural renewable energy sources, damped secondary energy resources, decentralization of heat supply, as well as a transition to low-temperature heating systems. When applying heat pump installations as part of heat supply systems, assembled dry heat pump installations as part of heat supply systems, assembled dry