Calculation of gas supply pressure using plastic pipes for preventing accidental emissions

Marufjan Musaev, Sevarakhon Khodjaeva, and Azizjon Boboev

Tashkent State Technical University named after Islam Karimov, 100095 Tashkent, Uzbekistan
JSC “HUDUDGAZTA’MINOT”, 100115 Tashkent, Uzbekistan
Navoi State Mining and Technology University, 230140, Navoiy, Uzbekistan

Abstract. Technological (production, operational and repair) risks come to the fore, minimizing which requires optimization of the work of structural units responsible for a reasonable assessment of the technical condition, maintenance and repair of facilities, timely renewal of production facilities with minimization of wear and tear of equipment, which is a risk factor in the failure of the gas transmission system. In addition, based on the noted features of gas transportation enterprises, in the risk management block, logistics risks, safety risks, environmental, social and (in a certain aspect) financial risks should play a significant role.

Objectively, in order to establish an acceptable range of risks, it is necessary to collect statistical data on the occurrence of risk factors for the foreseeable period in order to leave for constant monitoring those risk factors that appear regularly in the gas transmission system. The construction and operation of gas pipelines play an important role in the reasonable and technical transportation of gaseous substances. Noteworthy, algorithm for calculating the proposed medium pressure gas pipeline was developed, accordingly, in this research, the gas flow area was determined. The results showed that based on the calculations of underground average pressure of polyethylene pipes, the average gas pressure was 5,733 Pa, withstands pressure was up to 8009.7 Pa, withstands stress on the pipe wall was up to 0.024 MPa, and emission loss was 3964.4 m³ when there was an accident.

1 Introduction

The key performance indicator of a gas transmission company is the fulfillment of the plan for gas transportation in the given volumes, terms and quality of gas, and the target indicator of the risk management unit in the gas transmission system is the minimum of failures (losses from realized risks) in gas supplies (maximum reliability) [1-3]. As a result, technological (production, operational and repair) risks come to the fore, minimizing which requires optimization of the work of structural units responsible for a reasonable assessment of the technical condition, maintenance and repair of facilities, timely renewal of production facilities with minimization of wear and tear of equipment, which is a risk factor.*

* Corresponding author: marufjan.musaev@yandex.ru

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).
2 Materials and Methods

“Khududgaz Fergana”, of “Hududgaztaminot” was selected as a study site, where all research experiments conducted, especially on gas supply polyethylene pipe for medium pressure pipeline (PE 159). Clearly, the specific pressure loss was carried out according to the methodology “Calculation of a gas pipeline in accordance with SP 42-101-2003” [15]. Besides, algorithm for calculating the proposed medium pressure gas pipeline was developed, accordingly, in this research, the gas flow area was determined, followed by a section with a medium pressure polyethylene pipe, determination of the coefficient of friction of gas in the gas pipeline, calculation of hydraulic gas requirement, and calculation of the gas pressure on the gas pipeline (Fig. 1).
Furthermore, the pressure drop of the gas pipeline section was determined as following:

\[ P_n - P_k = 626,1 \lambda \frac{Q_0^2}{d^2 \rho_0 l} \]

Where:
- \( P_n \) - gas pressure in the design area, Pa;
- \( P_k \) - final gas pressure in the design area, Pa;
- \( \lambda \) - coefficient of hydraulic friction;
- \( l \) - estimated length of a gas pipeline of constant diameter, m;
- \( d \) - internal diameter of the gas pipeline, cm;
- \( \rho_0 \) - gas density under normal conditions, kg/m\(^3\);
- \( Q_0 \) - gas consumption, m\(^3\)/h, under nominal conditions.

Moreover, the final gas pressure in the gas pipeline section was calculated using the below given formula:

\[ P_k = P_n - R \cdot \rho_p l \]

Where:
- \( P_n \) - initial gas pressure in the gas pipeline, Pa;
- \( R \) - actual specific pressure drop in this section, Pa/m;
- \( \rho_p \) - length of the gas pipeline, m.

The strength of the gas pipeline calculation was carried out according to the following formulas:

\[ MRS = \frac{P_E}{10} = \frac{80}{10} = 8 \text{ MPa} \]

Besides, the strength of the gas pipeline was also calculated using the algorithm developed in this research (Fig. 2).
Fig. 2. Algorithm for calculating the strength of the proposed medium-pressure gas pipeline.

Clearly, the longitudinal axial stress from the force and deformation stress was calculated using the following formula:

\[
\sigma_{npNS} = \frac{2\mu P}{2S_{DR} - 2} \Delta E(\epsilon) \cdot \Delta t; \quad (4)
\]

Where:

- \( \mu \) - Poisson’s ratio of pipe material according to SP 42-101-2003 is taken equal to 0.43;
- \( P \) - working pressure, MPa;
- \( S_{DR} \) - standard dimensional ratio;
- \( \alpha \) - coefficient of linear thermal expansion of the pipe material, taken according to the method of SP 42-101-2003 is 2.2 \( \times 10^{-4} \);
- \( E(\epsilon) \) - creep modulus of pipe material at operating temperature, MPa;
- \( \Delta t \) - temperature difference [4-6, 11].

Fig. 3. Calculation of the volume of emergency gas release.

The calculation is carried out according to the methodology of RD 159-39.4-079-01 “Methodology for determining gas consumption for technological needs of consumers”.

Next, the speed of sound in natural gas was calculated using the following formula:

\[
W_{sound} = 18.591 \cdot (T_r \cdot k \cdot Z/\rho_0)^{0.5}; \quad (5)
\]

Where;
3 Results and discussions

According to Table 1, the initial pressure was 6000 Pa, followed by the final pressure (2370 Pa), gas density (0.685 kg/m$^3$), and kinematic viscosity was 14.39·$10^{-6}$ m$^2$/s. Moreover, the data of estimated hourly gas consumption was obtained from “Hududgaztaminot (Territory gas supply)”. Accordingly, the estimated hourly gas consumption was 20 m$^3$/hour.

Table 1. Initial data for hydraulic calculation.

<table>
<thead>
<tr>
<th>Initial pressure, Pa</th>
<th>Final pressure Pa</th>
<th>Gas density, kg/m$^3$</th>
<th>Kinematic viscosity, m$^2$/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>6000</td>
<td>2370</td>
<td>0.685</td>
<td>14.39·$10^{-6}$</td>
</tr>
</tbody>
</table>

It was found that the pressure drop of the gas pipeline section was determined (Table 2).

$P_n - P_k = 626.1 \cdot 0.043 \frac{34}{15.9^2} \cdot 0.685 \cdot 1000 = 0.267 \text{ Pa/m}$. Where:

$\lambda = \frac{1}{(1.82 \cdot lgRe - 1.64)^2} = \frac{1}{(1.82 \cdot lg3540 - 1.64)^2} = 0.043$.

According to Table 3, the pressure in pipeline was 6000 Pa, followed by pipeline diameter (0.159 m), material (PE 80, SDR11-9.1), operating temperature (10 °C), Δt (20), and Elastic bending radius of the pipeline was 10 m.

Table 2. The results of research experiments on pressure in the gas pipelines.

<table>
<thead>
<tr>
<th># of study site</th>
<th>Length of the study site, m</th>
<th>Gas consumption, m$^3$/h</th>
<th>Diameter, mm</th>
<th>Number $Re$</th>
<th>$\lambda$, coefficient of friction</th>
<th>Pressure drop R, Pa/m</th>
<th>Node pressure, Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1000</td>
<td>34.0</td>
<td>159</td>
<td>3540</td>
<td>0.043</td>
<td>0.267</td>
<td>5733</td>
</tr>
</tbody>
</table>

Table 3. Initial data for the calculation of the gas pipeline.
Pressure in pipeline, P
Diameter of the gas pipeline Dc, m
Material
Operating temperature °C
Temperature difference Δt
Elastic bending radius of the pipeline, m

<table>
<thead>
<tr>
<th>Pressure in pipeline, P</th>
<th>Diameter of the gas pipeline Dc, m</th>
<th>Material</th>
<th>Operating temperature °C</th>
<th>Temperature difference Δt</th>
<th>Elastic bending radius of the pipeline, m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Noteworthy, the strength of the gas pipeline calculation was carried out. It was found that the strength of the gas pipeline was:

\[ MRS = \frac{P}{10} = \frac{80}{10} = 8 \text{ MPa} \]

Moreover, the stresses on the pipe wall of the proposed gas pipeline are determined by the following formula:

\[ \sigma_{n_p N_S} = \frac{P \cdot (SDR - 1)}{2} = \frac{0.006 \cdot (9.1 - 1)}{2} = 0.024 \text{ MPa} \]

\[ \sigma_{n_p N_S} = \frac{2 \cdot 0.43 \cdot 6000}{\left[1 - \frac{2}{9.1}\right] - 1} = 8009.7 \text{ Pa} \]

### Table 4. Initial data for calculating the loss in the gas pipeline.

<table>
<thead>
<tr>
<th>Atmospheric pressure Pa, Pa</th>
<th>Gas temperature, °C</th>
<th>Gas release time, s</th>
<th>Gas density, kg/m³</th>
<th>Molar component of nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ W_{\text{sound}} = 18,591 \cdot (4,5 \cdot 1,428 \cdot 0,104/0,685)^{0.5} \]

\[ K = 1,556 \cdot (1 + 0,074 \cdot x_n) - 3,9 \cdot 10^{-4} \cdot T_r \cdot (1 - 0,68 \cdot x_n) - 0,2 \cdot \rho_0 + \left(\frac{P_0}{T_r}\right)^{1.43} \cdot \left[384 \cdot (1 - x_n) \cdot \left(\frac{P_0}{T_r}\right)^{0.38} + 26,4 \cdot x_n\right] \]

Where:
- \( x_n \) is the molar component of nitrogen;
- \( P_0 \) is the absolute gas pressure, MPa.

According to the results, the absolute gas pressure in the Fergana region was 0.001 MPa.
\[ K = 1,556 \cdot (1 + 0,074 \cdot 0,21) - 3,9 \cdot 10^{-4} \cdot 4,5 \cdot (1 - 0,68 \cdot 0,21) - 0,2 \cdot 0,685 \\
\quad + \left( \frac{0,001}{273,15} \right)^{1,43} \cdot \left[ 384 \cdot (1 - 0,21) \cdot \left( \frac{0,001}{273,15} \right)^{0,38} + 26,4 \cdot 0,21 \right] \]
\[ = 1,428 \]

\[ Z = 1 - \left( (10,2 \cdot P_a - 6) \cdot (0,00345 \cdot \Delta - 0,000446) + 0,015 \right) \cdot \left( 1,3 - 0,01444 \cdot (T_g - 283,2) \right); \]

Where: \( \Delta \) is the relative density of the gas.

\[ \Delta = \frac{\rho_0}{1,2044}; \]
\[ \Delta = \frac{0,685}{1,2044} = 0,568 \]
\[ Z = 1 - \left( (10,2 \cdot 0,001 - 6) \cdot (0,00345 \cdot 0,568 - 0,000446) + 0,015 \right) \cdot \left( 1,3 - 0,01444 \cdot (277,65 - 283,2) \right) = 0,104 \]

\[ V_e = 110 \cdot S \cdot P_a \cdot \tau; \]

\[ V_e = 110 \cdot 0,0003 \cdot 100 \cdot 1200 = 3960 \]

\[ S = \frac{\pi d^2}{4} = \frac{3,14 \cdot 20^2}{4} = 314 \]

\[ V_p = 0,0029 \cdot k \cdot V_n \cdot \frac{(P_a + P_{atm})}{T_r}; \]

\[ V_p = L \cdot \pi \cdot r^2; \]
Where:

\[ L \text{ is the distance between the disconnecting devices, m.} \]

In this case, the gas pipeline is taken at medium pressure:

\[ V_p = 500 \cdot 3.14 \cdot 0.002 = 3.14 \text{ m}^3 \]

It was found that the gas purge in the gas pipeline was calculated and the results was:

\[ V_p = 0.0029 \cdot 1.25 \cdot 3.14 \cdot \frac{100190 + 7080}{277.65} = 4.40 \text{ m}^3 \]

In the final stage of the research experiment, the volume of loss of natural gas was determined, which was 3964.4 m\(^3\):

\[ V_p = 3960 + 4.40 = 3964.4 \text{ m}^3 \]

It was reported that based on the calculations of underground average pressure of polyethylene pipes, the average gas pressure was 5.733 Pa, withstands pressure was up to 8009.7 Pa, withstands stress on the pipe wall was up to 0.024 MPa, and emission loss was 3964.4 m\(^3\) when there was an accident.

4 Conclusions

As a result of the current study, risk management algorithms were calculated and created along with identification based on medium pressure gas pipelines, calculation of the strength of the gas pipeline, calculation of the volume of emergency gas release, geographical information systems and the spatial situation are more possible using the created risk maps.

It was found that the pressure drop of the gas pipeline section was 0.267 Pa/m. Moreover, the coefficient of friction was also determined by the movement of gas in the gas pipeline, which was 3540. It was reported that the longitudinal axial stress from the force and deformation stress was calculated, and the result was 8009.7 Pa. Besides, the speed of sound in natural gas was calculated, accounted for 18.350 m/s.

Based on the calculations of underground average pressure of polyethylene pipes, the average gas pressure was 5.733 Pa, and emission loss was 3964.4 m\(^3\) when there was an accident.

References

https://doi.org/10.1051/e3sconf/202337101040
1. S.S. Timofeeva, I.V. Drozdova, A.A. Boboev, E3S Web of Conferences 177 (2020)


11. E3S Web of Conferences 371, 01040 (2023) https://doi.org/10.1051/e3sconf/202337101040