EUROPEAN JOURNAL OF LIFE SAFETY AND STABILITY (EJLSS)
ISSN 2660-9630
www.ejlss.indexedresearch.org Special Issue, 2022 ||

"Challenges and Innovative Solutions of Life Safety in Ensuring Sustainability in Economic Sectors"

Development of an Algorithm and Mathematical Modeling for the Process of Pipeline Gas Supply with Medium Pressure Using Plastic Pipes in Order to Prevent Emergencies on the Ground

Musaev Marufjan Nabievich
Professor Tashkent State University named after I.A.Karimov
Khodjaeva Sevarakhon Ilkhomovna
Join Stock Company "Hududgaztaminot"
Boboev Azizjon Azimzhonovich
Navoi State Mining Institute

Abstract: *The article describes the gas transportation of Central Asia. The calculation of the underground average pressure of the gas pipeline for strength, for pressure endurance, vibration, gas friction on the wall of the proposed polyethylene pipe, leaks, emissions into the environment and accidents is given.*

Keywords: *gas transportation, polyethylene pipe, average pressure, leakage, vibration, discharge, gas pipeline, gas density, gas temperature, strength, gas pipeline.*

Date of Submission: 25-4 -2022 ***Date of Acceptance: 28-5-2022***

Central Asia has a great potential of gas fields and a convenient geographical location for its transportation [1, 2]. Uzbekistan's economy is more diversified than that of its neighbors and has a larger population. The economy of Uzbekistan is characterized by openness and policy changes in recent years due to investments and non-export extraction and processing, the development of the gas chemical industry to support the electric power industry. In this case, Uzbekistan can act as a transit country, depending on its geographical location. In many countries - and especially in urban areas - the further development of the gas industry is facing declining public recognition and increased safety requirements. Due to the lack of confirmed statistical data on the safety of gas distribution, the authorities and some public opinion leaders began to challenge the safety of gas and adopt laws based on simple disputes and unrealistic scenarios [3].

The construction and operation of gas pipelines play an important role in the reasonable and technical transportation of gas substances. In addition, from an economic point of view, this transfer can have a significant negative impact on nature due to its serious vulnerability to the process under study [4].

Polyethylene pipes that are intended for gas supply are first of all tested for strength. Polyethylene pipes, due to their exceptional plasticity, are resistant to dynamic influences and therefore have proven themselves well in seismic hazardous areas. For example, according to the Colombian Environmental Protection Agency on the accident rate of pipelines made of various materials during an earthquake in this country, steel pipes had 0.52 failures per 1 km, gray cast iron pipes – 0.97 failures, polyvinyl chloride pipes - 0.8 failures. No damage was recorded on polyethylene gas pipelines [5].

The current state of the gas pipeline system of gas supply is characterized by a long service life of existing gas pipelines with a significant increase in gas volumes through them and the construction of new powerful systems operating at elevated pressure. Ensuring the operational reliability of gas pipelines in these conditions is becoming increasingly relevant.

The object is a section of polyethylene pipe for medium pressure pipeline (PP 159).

The specific pressure loss was carried out according to the methodology "Calculation of the gas pipeline according to SP 42-101-2003» [6].

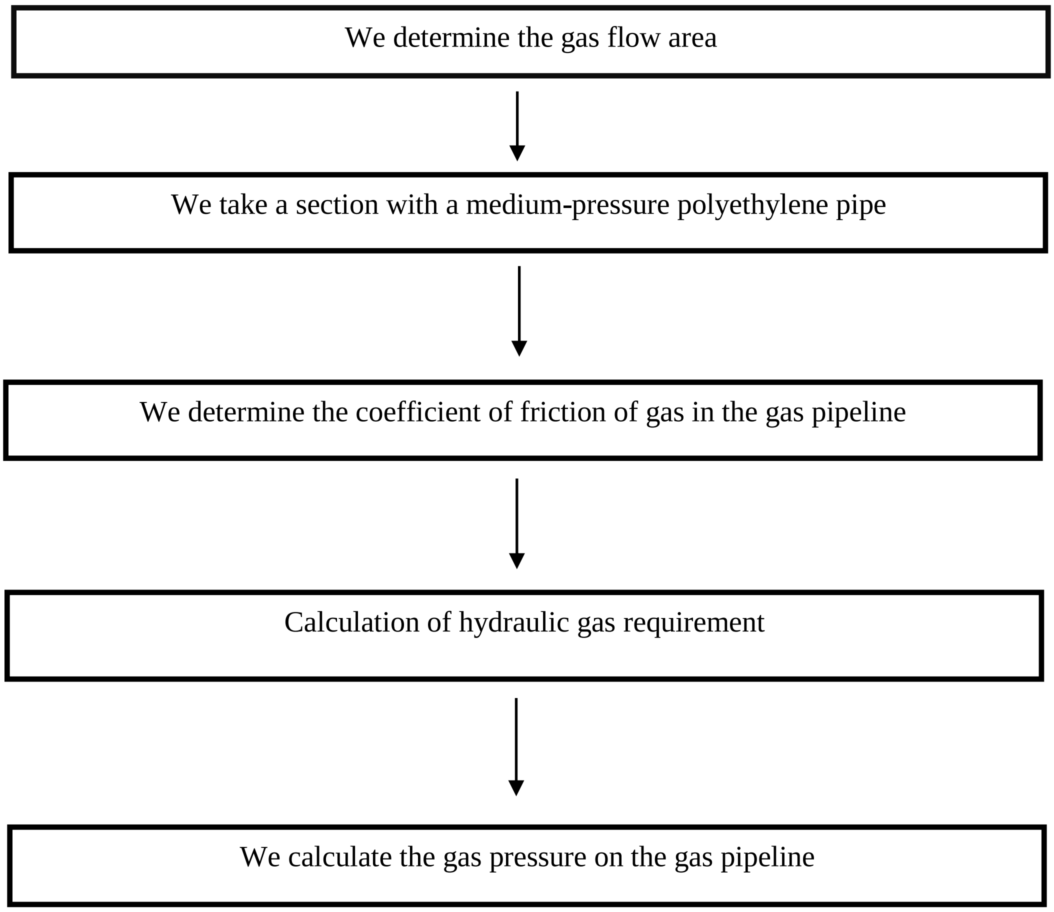

Figure 1. – Algorithm for calculating the proposed medium pressure gas pipeline

Initial data for hydraulic calculation

Initial pressure, Pa	Final pressure, Pa	Gas density, kg/m^3	Kinematic viscosity, m^2/s
6000	2370	0,685	$14{,}3\cdot10^{-6}$

The estimated hourly gas consumption is 20 m^3/hour according to information taken from JSC "Hududgaztaminot".

We determine the pressure drop of the gas pipeline section:

$$Р_н - Р_к = 626{,}1\lambda \frac{Q_0^2}{d^2}\rho_0 l$$

Where: $Р_н$ - gas pressure at the design site, Pa;

$Р_к$ – final gas pressure at the design site, Pa;

λ – coefficient of hydraulic friction;

l – estimated length of a constant diameter gas pipeline, m;

d – internal diameter of the gas pipeline, sm;

ρ – gas concentration under normal conditions, kg/m^3

Q_0 - gas consumption, m^3/hours, a nominal conditions.

$$Р_н - Р_к = 626{,}1 \cdot 0.043\ \frac{34}{15{,}9^2}0{,}685\ \cdot 1000 = 0{,}267\ Pa/m$$

The coefficient of friction is determined by the movement of gas in the pipeline:

$$R_e = \frac{Q_0}{9\pi \cdot d\ \cdot \nu} = 0{,}0354\ \frac{Q_0}{d\nu}$$

$$R_e = 0{,}0354\ \frac{20}{15{,}9 \cdot 14{,}3\ \cdot 10^{-6}} = 3540$$

Where υ – coefficient of kinematic viscosity of the gas, m^2/s, a nominal conditions for natural gas is $14{,}3\cdot10^{-6}$.

hydraulically frictional the offered gas pipeline λ:

$$\lambda = \frac{1}{(1{,}82\ \cdot lgRe - 1{,}64)^2} = \frac{1}{(1{,}82\ \cdot lg3540 - 1{,}64)^2} = 0{,}043$$

We calculate the ultimate gas pressure on the gas line segment:

$$Р_к = P_H - R\ \cdot l_p$$

where: P_H – starting gas pressure in the gas pipeline, Pa;

R – actual specific pressure drops at this site, Pa/m;

$l_р$ – length of the gas line, m.

$$Р_к = 6000 - 0{,}267\ \cdot 1000 = 5733$$

Result:

№ land plot	Plot length, m	Gas consumption, m^3/hours	Gas pipeline diameter, mm	R_e number	ʎ, coefficient of friction	drop pressure R, Pa/м	Pressure at the node, Pa
1	1000	34,0	159	3540	0,043	0,267	5733

We will calculate the strength of the gas pipeline

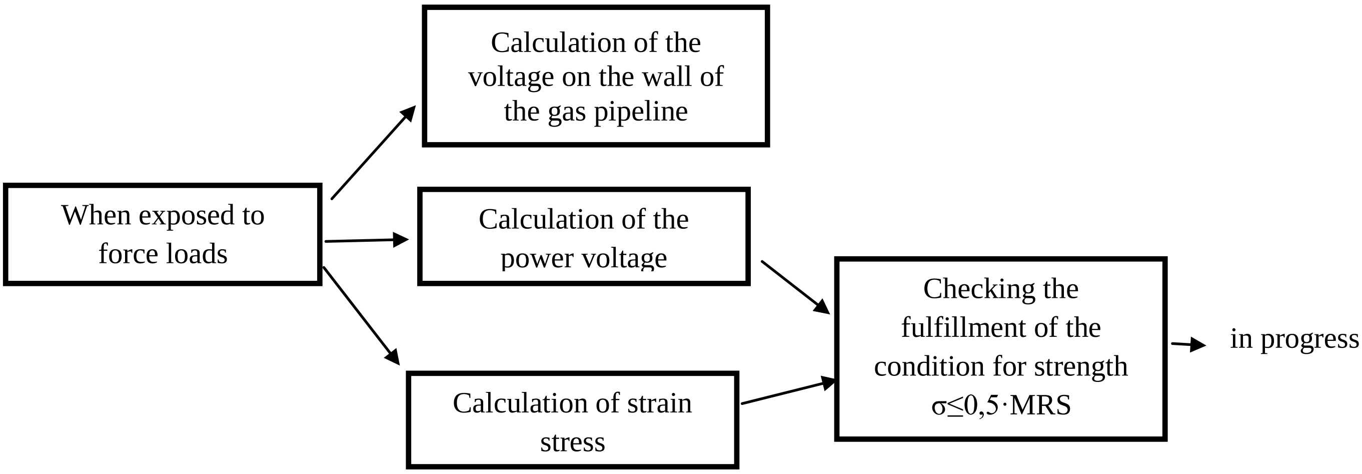

Figure.2. – Algorithm for calculating the proposed medium pressure gas pipeline for strength

The calculation is carried out according to the method of SP 42-103-2003. Initial data for the calculation of the gas pipeline:

Working pressure $P_{working}$	Gas pipeline diameter D_c, m	Material	Temperature °C	The temperature difference Δt	The radius of elastic bending of the pipeline, m
6000	0,159	PP 80, SDR11-9,1	10	20	10

The strength of the gas pipeline is calculated according to the following formulas.

Minimum long - term strength is determined by the formula:

$$MRS = \frac{PP}{10} = \frac{80}{10} = 8\ \text{M}P\text{a}$$

Stresses on the pipe wall of the proposed gas pipeline are determined by the following formula:

$$\sigma_{\text{пр}NS} = \frac{P\ \cdot (SDR - 1)}{2} = \frac{0{,}006\ \cdot (9{,}1 - 1)}{2} = 0{,}024\ \text{M}P\text{a}$$

We count the longitudinal axial stress from the force and deformation stress:

$$\sigma_{\text{пр}NS} = \frac{2 \cdot \mu \cdot P}{\left[1 - \frac{2}{SDR}\right]^{-2} - 1} - \ \alpha \cdot E(te) \cdot \Delta t;$$

where: μ – the Poisson's coefficient of the pipe material according to SP 42-101-2003 is assumed to be 0,43;

P - operating pressure, MPa;

SDR - default dimensional ratio;

a - the ratio of linear thermal expansion of the pipe material, $°C^{-1}$; accepted according to the SP method-42-101-2003 is equal to $2{,}2 \cdot 10^{-4}$.

$E(te)$ – the creep modulus of the pipe material at operating temperature, MPa;

Δt - temperature, °C.

$$\sigma_{\text{пр}NS} = \frac{2 \cdot 0{,}43 \cdot 6000}{\left[1 - \frac{2}{9{,}1}\right]^{-2} - 1} - 2{,}2 \cdot 10^{-4} \cdot 12000 \cdot 20 = 8009{,}7\ Pa$$

As a result of the calculation, it can be concluded that the proposed polyethylene pipe can withstand pressure up to 0.08 kPa. All the strength conditions are met.

we will also make a calculation of the natural gas loss of the proposed pipe. The payment is made in accordance to the documents RH 159-39.4-079-01.

Basic data for computing losses in a gas pipeline:

Air pressure Pa,	The gas temperature Tg, °C	gas release time, c	gas density, kg/m^3	molar component of nitrogen
7080	4,5	1200	0,685	0,21

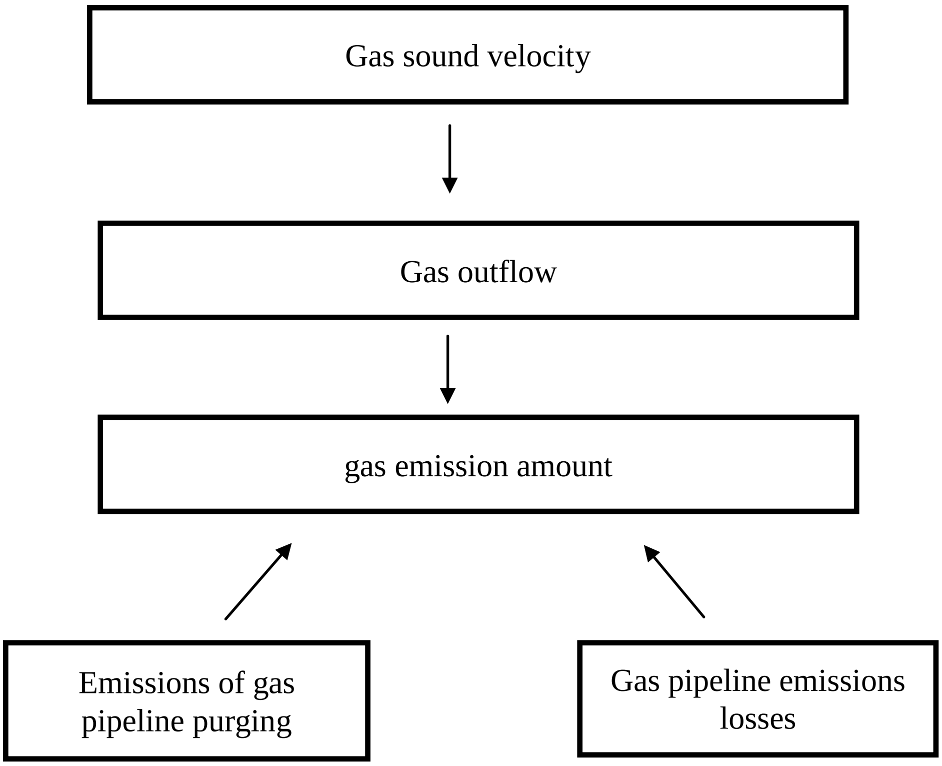

Figure.3. Calculating the amount of emergency gas emissions

Calculations are carried out according to the methodology of RH 159-39.4-079-01 "Methodology for determining gas consumption for the technological needs of consumers" We calculate the speed of sound in natural gas:

$$W_s = 18{,}591 \cdot (T_r \cdot k \cdot Z/\rho_0)^{0{,}5};$$

where; Tg – the gas temperature, K;

κ – the adiabatic index;

Z – gas compressibility factor;

ρ_0 – the absolute density of the gas, kg/m^3.

$W_{звук} = 18{,}591 \cdot (4{,}5 \cdot 1{,}428 \cdot 0{,}104/0{,}685)^{0{,}5}$= 18,350 m/s

The adiabatic indicator is computed by the formula:

$$K = 1{,}556 \cdot (1 + 0{,}074 \cdot x_n) - 3{,}9 \cdot 10^{-4} \cdot Tr \cdot (1 - 0{,}68 \cdot x_n) - 0{,}2 \cdot \rho_0 + \left(\frac{P_a}{T_g}\right)^{1{,}43} \cdot \left[384 \cdot (1 - x_n) \cdot \left(\frac{P_a}{T_g}\right)^{0{,}38} + 26{,}4 \cdot x_n\right];$$

where, x_n – the molar component of nitrogen;

Pa – absolute gas pressure, MPa. The total gas pressure in the Ferghana region is 0.001 MPa.

$$K = 1{,}556 \cdot (1 + 0{,}074 \cdot 0{,}21) - 3{,}9 \cdot 10^{-4} \cdot 4{,}5 \cdot (1 - 0{,}68 \cdot 0{,}21) - 0{,}2 \cdot 0{,}685 + \left(\frac{0{,}001}{273{,}15}\right)^{1{,}43} \cdot \left[384 \cdot (1 - 0{,}21) \cdot \left(\frac{0{,}001}{273{,}15}\right)^{0{,}38} + 26{,}4 \cdot 0{,}21\right] = 1{,}428$$

Calculating the gas compressibility coefficient:

$$Z = 1 - \big((10{,}2 \cdot P_a - 6) \cdot (0{,}00345 \cdot \Delta - 0{,}000446) + 0{,}015\big) \cdot \big(1{,}3 - 0{,}01444 \cdot (T_г - 283{,}2)\big);$$

where Δ – the relative densities of the gas.

$$\Delta = \frac{\rho_0}{1{,}2044};$$

$$\Delta = \frac{0{,}685}{1{,}2044} = 0{,}568$$

$$Z = 1 - \big((10{,}2 \cdot 0{,}001 - 6) \cdot (0{,}00345 \cdot 0{,}568 - 0{,}000446) + 0{,}015\big) \cdot \big(1{,}3 - 0{,}01444 \cdot (277{,}65 - 283{,}2)\big) = 0{,}104$$

Volume of natural gas emissions:

$$V_{выбр} = 110 \cdot S \cdot P_a \cdot \tau;$$

where S – the cross-sectional area of the gas outlet opening m^2;

τ – gas release time.

$$V_{emissions} = 110 \cdot 0{,}0003 \cdot 100 \cdot 1200 = 3960 \text{ m}^3$$

The cross - section area of the gas is calculated by the formula:

$S = \frac{\pi \cdot d^2}{4} = \frac{3{,}14 \cdot 20^2}{4} = 314$ мм = 0,0003 m

The amount of natural gas for purging a filled gas pipeline:

$$V_{\text{пр}} = 0{,}0029 \cdot k \cdot V_c \cdot \frac{(P_a + P_{\text{атм}})}{T_r};$$

where V_c – the volume of the cavity of the gas pipeline, m^3;

к – 1,25 the correction factor.

The volume of the gas line cavity:

$$V_c = L \cdot \pi \cdot r^2;$$

where L – distance between disconnecting devices, m.

In our case, the gas pipeline is taken of medium pressure:

$$V_m = 500 \cdot 3{,}14 \cdot 0{,}002 = 3{,}14 \text{ m}^3$$

In this case, we count the gas purge in the gas pipeline:

$V_{gp} = 0{,}0029 \cdot 1{,}25 \cdot 3{,}14 \cdot \frac{(100190+7080)}{277{,}65} = 4{,}40 \text{ m}^3$

Calculating the volume of natural gas loss:

$V_v = 3960 + 4{,}40 = 3964{,}4 \text{ m}^3$

Based on the calculations of the underground average press of polythene pipes, the following findings can be made:

1. The average pressure of the gas is 5733 Pa;
2. Can withstand pressure up to 8009,7 Pa;
3. Withstands pressure on the wall of the pipe up to 0,024 MPa;
4. In the case of an accident, emissions and losses amount to 3964,4 $м^3$

Used references:

1. Han Z Y, Weng W G 2011 Hazardous Materials 189 pp 509-518.
2. Khodjaeva S. I., Musaev M. N., Turaeva M., Developing of natural gas transportation of Central Asia and its geopolitical and geo-economic aspects // IOP Conference Series: Earth and Environmental Science, 2021 y.
3. Khodjaeva S. I., Musaev M. N., Akhmedov Sh.J. Analysis of the existing legal, regulatory and technical support for the prevention of environmental emergencies at gas pipeline facilities in Uzbekistan // IOP Conference Series: Earth and Environmental Science, 2021 y.
4. Khodjaeva S.I., Musaev M.N., Akhmedov Sh.J. Studying safety and risk management in the gas transmission system using GIS technology IOP Conference Series: Earth and Environmental Science, 2021 y.
5. Sharayts A.L. "Gas pipelines made of polymer materials" manual on design, construction and operation. M. 2007, p. 356.
6. SP 42-101-2003 General provisions on the design and construction of gas distribution systems made of metal and plastic pipes.