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ANALYSIS OF METHODS OF NATURAL GAS TECHNICAL LOSS DETERMINATION AND TECHNICAL LOSS NORMS IN GAS SUPPLY NETWORK

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ABSTRACT
In modern times, the role of energy resources is very large. One of the important energy resources is natural gas. The biggest advantage of using natural gas as a fuel is its high heat capacity and complete combustion without the formation of harmful substances. The process of natural gas distribution in the gas supply network is observed with gas loss. This is an objective, natural situation and creates a number of difficulties for natural gas enterprises. The article focuses on gas consumption in technological processes in the gas supply network, gas purges from pipelines during pipeline repair works, gas flushing out from the pipeline and determination of gas technological losses during the removal of air from the pipeline. Determination of gas losses caused by non-hermeticity of external gas pipelines and equipment, gas pressure regulation station (GPRS), cabinet-type gas control points (GCP), universal pressure regulator (UPR) and gas losses occurring during repairing of other technological equipment are discussed. Also, the determination of technical losses of natural gas at meters, sampling nodes, safety valves, gas distribution stations (GDS) (from gas losses during the management of shut-off valves, during purge of process instrumentation and automatics, when taking gas samples, during purges proses of safety valves, apparatus and pulse lines) is discussed. The article describes the principle of formation of technical losses in the gas supply network. Technical loss sources of natural gas in the process of gas supply, methods of calculating loss norms, the amount of small loss of which is determined separately for each specified loss source, are mentioned.

KEYWORDS:
Gas supply;
Natural gas;
Technical losses;
Pipeline; GPRS;
GCP; UPR;
Gas meters;
Safety valves;
Gas distribution station.

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The process of natural gas distribution in the gas supply network is observed with gas loss. This is an objective, natural situation. The loss rate needs to be calculated because the change in the structure of the gas distribution network, wear or renewal of equipment and other objective reasons change the technical losses of gas. The amount of technical loss of natural gas depends on the volume received by the distribution network and the technical condition of the equipment.

The rate of loss of natural gas is determined as a percentage of the total volume.

1. Gas loss during repair work on the gas pipeline

A gas pipeline is a complex of devices consisting of pipes, connecting parts and fittings for transferring gas over certain distances. When calculating the amount of gas loss due to repair work on gas pipelines, two cases should be taken into account [1, 2].

1.1 In order to carry out repair work, it is necessary to disconnect the repaired part of the gas pipeline (between the connecting fittings) from the gas distribution network, reduce the pressure to zero or minimum, and then purge it. The volume of gas loss resulting from this operation is calculated by the following formula:

$$Q_t = 0.00714 \cdot V \cdot \frac{P_{atm} + P_g}{273 + t_q} \qquad (1)$$

where V – the geometric volume of the discharged area, (between the connecting fittings) m^3; P_{atm} – atmospheric pressure, Pa; P_g – gas pressure in the pipeline, Pa; t_g – gas temperature in the pipeline, °C; 0.00714 is an empirical coefficient.

1.2 After repair work, the pipeline must be purge and filled to remove air from the linear part of the gas pipeline. At this time, the volume of gas loss is calculated by the following formula:

$$Q_p = 0.00357 \cdot V \cdot \frac{P_{atm} + P_g}{273 + t_g} \qquad (2)$$

where V is the geometric volume of the drained area, (between the connecting fittings) m^3; P_{atm} – atmospheric pressure, Pa; P_g – gas pressure in the pipeline, Pa;

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t_g – gas temperature in the pipeline, °C; 0.00357 is an empirical coefficient.

2. Calculation of gas loss caused by non-hermeticity of external gas pipelines and equipment [1-3]

Technical gas losses occur because of gas leakage into the soil, atmosphere or buildings due to the non-hermetic nature of external gas pipelines, fittings and equipment installed on them. An external gas pipeline is an underground, above-surface or surface gas pipeline laid outside the building, up to the structure of the external wall of the building. This gas loss (gas leaks) is inevitable because it is impossible to create absolute hermeticity of connecting fittings, gas equipment thread and flange joints. Thus, gas losses caused by non-hermeticity of external gas pipelines and equipment should be calculated.

The gas loss due to the non-hermeticity of the flange joints and thread is calculated by the following formula:

$$Q_{n.h} = \frac{G_{n.h}}{\rho} \quad (3)$$

$$Q_{n.h} = 0.31298 \cdot \eta \cdot P_{av} \cdot m \cdot V \cdot \sqrt{\frac{M}{T}} \quad (4)$$

where $G_{n.h}$ is the amount of gas released into the air, kg/year; ρ – gas density, kg/m^3; 0.31298 – empirical coefficient; η – reserve factor, (when $P_{av} \geq 2\times10^5$ Pa, $\eta=2$ is accepted; when 0.02×10^5 Pa$\leq P_{av} \leq 2\times10^5$ Pa, $\eta=1.5$ is accepted, when $P_{av} \leq 0.02\times10^5$ Pa, gas leakage is insignificant, $\eta=0$ can be accepted), P_{av} is the average pressure in pipeline, Pa; m – coefficient of non-hermeticity characterizing the relative pressure drop in the system per unit time, $1/st.m=m_1\cdot k$ ($k=250/d_c$ if the conventional diameter of the gas pipeline $d_c>250$ mm, $k=1$ if $d_c<250$ mm), (m_1 – determined depending on the operational period of the pipeline: up to 1 (one) year – m_1=0.001 - 0.002; from 1 year – up to 20 years - m_1=0.002; over 20 years - m_1=0.002 - 0.004), V – the volume of the gas pipeline, m^3; M – gas molecular weight, kg/kmol; T is the absolute temperature of the gas, K [2].

3. Gas loss at meters

In gas meters that are gas consumption control systems, losses in two directions are considered as technological losses [2, 4, 5].

3.1 Gas loss due to passport error of meters ($Q_{p.e}$, m^3/year) is calculated by the following formula:

$$Q_{p.e} = 0.011 \cdot \left(\frac{S_1}{\sqrt{n_1}} \cdot V_1 + \frac{S_2}{\sqrt{n_2}} \cdot V_2 + ... \frac{S_i}{\sqrt{n_i}} \cdot V_i \right) \quad (5)$$

where 0.011 is an empirical coefficient that takes into account possible errors in the registration of gas temperature and pressure indicators; n_1, n_2, n_i – the number of gas consumption measurements in the reporting period (month, year) is determined by multiplying the number of registrations of meter indicators by the number of meters of the same type in that period; S_1, S_2, S_i – the error of the counters, %, is accepted according to the passport indicators; V_1, V_2, V_i – gas volume measured with the same type of meters during the reporting period, m^3.

3.2 Calculation of gas loss due to disregard of temperature and pressure indicators in meters during gas consumption measurement

Gas distribution enterprises must purchase gas adapted to standard conditions from the supplier (t=20 °C, P=760 mmHg).

Real conditions in gas supply are different from standard conditions, which causes losses in gas distribution enterprises. Adaptation of the gas passing through the meter to the standard conditions is calculated by the following formula:

$$V_{st} = V_1 \cdot \frac{293.15 \cdot (P_m + P_a)}{760 \cdot (273.15 + t_m)} \quad (6)$$

where V_{st} – gas volume adapted to standard conditions; V_1 – measured (metered) volume of gas, m^3; P_m – real (excess) pressure inside the meter or in the gas pipeline, mm diameter; P_a – atmospheric pressure, mm Hg.; t_m is the real temperature inside the meter or in the gas pipeline, °C.

Gas loss (Q_{st}, m^3) due to the fact that the temperature and pressure indicators in the meters are not taken into account during the measurement of gas consumption is calculated by the following formula:

$$Q_{st} = V_{st} - V_1 \quad (7)$$

4. Gas loss during adjustment of QPRS, GCP, UPR and other technological equipment [2, 4]

The gas loss ($Q_{a.d}$, m^3) during the adjustment and debugging of QPRS, GCP, UPR and other technological equipment is calculated by the following formula:

$$Q_{a.d} = 9.24 \cdot d^2 \cdot \tau \cdot \frac{P_{atm} + P_g}{T_g} \cdot \sqrt{\frac{P_q}{\rho}} \quad (8)$$

where d is the inner diameter of the purge plug, m; τ – adjustment and debugging time, st; P_g – gas pressure in the device, Pa; P_{atm} – atmospheric pressure, Pa; T_g – gas temperature in the device, K; ρ is the gas density, kg/m^3.

5. Gas loss at sampling points

Technological losses occur at sampling points in the gas supply network, blowout of the sampled line, blowout of the sampled container, and when gas is

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taken into the container [2, 5].

Gas loss during taking a sample (Q_s, m^3) is calculated as follows.

$$Q_s = Q_L + Q_p + Q_{t.c} \quad (9)$$

where Q_L – gas consumption for purge of sampled line, m^3; Q_p – gas consumption for purge the sampled container, m^3; $Q_{t.c}$ is the volume of gas taken into the container, m^3.

5.1 Gas consumption for blowing the sampled line (Q_L, m^3) is calculated by the following formula:

$$Q_L = K \cdot F \cdot P \cdot \tau \quad (10)$$

where K is a coefficient that depends on the gas flow mode; F – the cross-sectional area of the drain pipe, (or, in the case of a valve, the drain valve, taking into account the percentage of opening), m^2; P – absolute gas pressure in front of the inflatable tube, MPa; τ – inflation time, (according to ГОСТ 18917-82 τ=60-120 s.).

The coefficient depending on the nature of gas flow is defined as follows:

- K=3018.4 m/(MPa·s) in the critical gas flow mode;
- K=1121.7 m/(MPa·s) in the gas pre-critical flow regime.

5.2 Gas consumption for blowing the sampled container (Q_c, m^3) is calculated by the following formula:

$$Q_c = C \cdot \tau_c \quad (11)$$

where C is the gas velocity during container inflation (C=0.0020-0.003 m^3/min according to ГОСТ 18917-82); τ_c is the duration of container inflation (according to ГОСТ 18917-82 τ_c=10-15 min.).

5.3 The volume of gas taken into the container ($G_{c.t}$, m^3) is calculated by the following formula:

$$Q_{c.t} = 2983 \cdot V_c \cdot \frac{P_c}{T_c \cdot Z} \quad (12)$$

where V_c is the volume of the container, m^3; P_c – pressure in the container, MPa; T_c – temperature in the container, K; Z is the compression ratio of natural gas.

6. Gas loss in safety valves

Safety valves present in the general system have technological losses during start-up and when checking the safety valves' functionality [2, 4, 5].

6.1 The gas loss ($Q_{s.v}$, m^3) that occurs when the protective valves are activated depends on the type of valve, its diameter, the pressure to the valve and is calculated by the following formula: [4]

$$Q_{s.v} = 63 \cdot P \cdot \tau \cdot d \quad (13)$$

where 63 is an empirical coefficient; P – gas pressure to the valve, kgg/cm^2; d – valve diameter, cm; τ is the check time of valve actuation, (0.0006 d, 1-2 s).

6.2 Gas loss during the check of the safety valves

The total gas loss (Q_g, m^3) during the periodic serviceability check of a safety valve is determined by the following formula:

$$Q_c = 37.3 \cdot 103 \cdot F \cdot \alpha \cdot P_w \cdot \sqrt{\frac{Z}{T_w}} \cdot (\tau_v \cdot n) \quad (14)$$

where F cross-sectional area of the valve, m^2; α – consumption coefficient of the valve (passport data); P_w – working pressure in the valve, MPa; Z – gas compression ratio; T_w – working temperature in valve, K; τ_v – operating time of valves, s; n is the number of inspections of safety valves during the year [2, 4].

7. Gas loss in gas distribution stations

Gas distribution stations (GDS) are installed on separations from main gas pipelines to supply natural gas to domestic and utility-industrial facilities, city gas networks in the form of purified, dried, odorized state and volume measured in cubic meters. GDS, having several outputs according to their purpose, perform direct regulation of pressure and gas consumption based on technological mode requirements. In GDS, the main losses are the losses that occur during the operation of the pneumatic transmissions of the safety valves and ball valves, and during the purge of the sampling nodes and the connecting lines of the process instrumentation and automation (PI and A) devices.

7.1 The volume of gas taken for sampling is considered as gas loss and is determined according to clause 5 [1, 2, 4].

7.2 Gas loss in safety valves should be calculated in the form mentioned in clause 6.

7.3 Determination of gas loss in the operation of pneumatic transmissions of ball cocks [3-5].

The volume of gas loss ($Q_{b.c}$, m^3) in the operation of pneumatic transmissions of ball cocks is determined according to the following formula:

$$Q_{b.c} = q_g \cdot n \cdot 10^{-3} + q_c \cdot \tau \cdot 10^{-3} \quad (15)$$

here q_g is the volume of gas released into the atmosphere during the start of the pneumatic transmission, m^3 (determined according to table 1); n – the number of times the pneumatic transmission of the cocks is activated during the reporting period; q_c – gas consumption in the operation of the ball valve, m^3/day (passport information); τ is the operating time of the faucets during the reporting period, day.

7.4 Determination of gas loss during purge of connecting lines of process instrumentation and automatics (PI and A) units [2, 4, 6].

The gas loss (Q_p, m^3) during the blowing of impulse lines of PI and A devices is determined according to the following formula:

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Table 1

Gas loss in the operation of pneumatic transmissions of ball cocks

The diameter of the ball cock, mm	Gas consumption during the start of the pneumatic cock (1 time), m^3
1	2
50	0.030
80	0.070
100	0.160
150	0.500
200	0.700
300	1.000
400	1.600
500	1.800
700	4.500
1000	5.000
1200	10.500
1400	15.500

$$Q_p = 10.2 \cdot A_i \cdot F_i \cdot P_i \cdot \left(1/\sqrt{T_i}\right) \cdot \tau_i \cdot b_i \cdot n_i \qquad (16)$$

here A_i is the coefficient depending on the state of gaseous hydrocarbons, according to table 2; F_i – the cross-sectional area of the valve depending on the degree of opening of the valve (φ) is taken according to table 3; P_i – absolute pressure in front of the drain valve, MPa; T_i – working temperature of the gas in the device, K; τ_i – duration of one purge, min.; b_i – the number of pulse lines of device number i; n_i – the number of purges in the device during the reporting period; 10.2 is an empirical coefficient, $m \cdot K^{0.5}$ /MPa·min.

The cross-sectional area of the purge place of the needle valve (D – 6, 15, 20 mm) at a certain degree of opening φ

The gas supply network of «Azerigas» PU is a production complex that transports and delivers natural gas to consumers.

The gas supply system consists of gas pipelines, gas-regulating points (GRP), gas-regulating cabinets (GRC), and gas regulating devices (GRD). All elements of the gas supply system create safe and reliable conditions for the consumer.

The gas supply system is two-stage. Depending on the pressure of the gas transported in the gas supply system of cities, regions and residential areas, the first level is medium pressure gas pipelines (working pressure from 0.05 to 3 atm). The second stage is low-pressure gas pipelines (working pressure up to 0.05 atm). Medium and low pressure gas pipelines are connected by QPRS, GCP, UPR.

The main element of the gas supply system is the gas pipeline. Thus, 70-80 % of the capital investments are spent on the construction and construction of the gas pipeline. Medium-pressure gas pipelines transmit gas through gas control points to low-pressure gas pipelines and also to industrial and domestic enterprises.

Depending on the location, surface and underground, internal and external gas pipelines are in operation.

Newly laid and renovated underground pipelines are mainly polyethylene pipes.

GDP and GDU are intended for lowering and maintaining pressure in the gas supply system. Stationary and cabinet-type GDPs are installed in the system, the main working parts are UPR-type regulators. As part of the technological equipment of the GDP, the safety valve (SV) is installed. SV prevents gas transmission to consumers in case of increase or decrease of gas pressure.

While analyzing the activities of «Azerigas» PU, the sources of technological loss of gas in the gas supply network were identified and shown in the following figure 1.

In comparison with the existing gas supply system in 2020, additional sources of losses have arisen due to the introduction of new gas stations to «Azerigas» PU. These were also included in the report when calculating the technical losses of gas in 2023 and were

Table 2

Dependence of the coefficient «A» on the molecular mass of the gas

The molecular mass of the gas	4	5	16	17	18	19	20	25	30	44
«A»	9348	8202	4370	4200	4100	3966	3859	3391	3068	2550

Table 3

The cross-sectional area of the purge place of the needle valve (D – 6, 15, 20 mm) at a certain degree of opening φ

φ*	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
$F \cdot 10^5$, m^2	0.14	0.21	0.28	0.35	0.42	0.48	0.55	0.62	0.68

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calculated separately for each regional gas exploration department (RGED).

According to the calculations made on the basis of the actual technological data of the last 3 years in the gas supply network, the technological loss rate of natural gas for «Azerigas» PU was set at 2,836 percent of the total gas received. Figure 2 shows the percentage of sources in the general system.

As you can see from the picture, meters are the sources that cause the biggest losses. As mentioned earlier, gas losses occur in the meters in two directions due to the passport error and due to the consideration of temperature and pressure indicators. Based on the calculations, it was found that the losses caused by the passport error in the meters make up 0.076 percent of the total gas. The largest share falls on the gas losses caused by adjusting the gas passing through the meter to standard conditions and is 1.959 percent.

In addition, the gas loss in this direction differs according to the type of meters. During the research, gas consumption losses were calculated in 4 types available in the gas supply system, mechanical with thermocompensator for the population, mechanical with thermocompensator for the non-population and mechanical for the population, mechanical for the non-population. Calculation results are shown in percentage in figure 3.

Figure 4 shows the forecast indicators of technical loss norms of gas calculated for individual RGED as percentages.

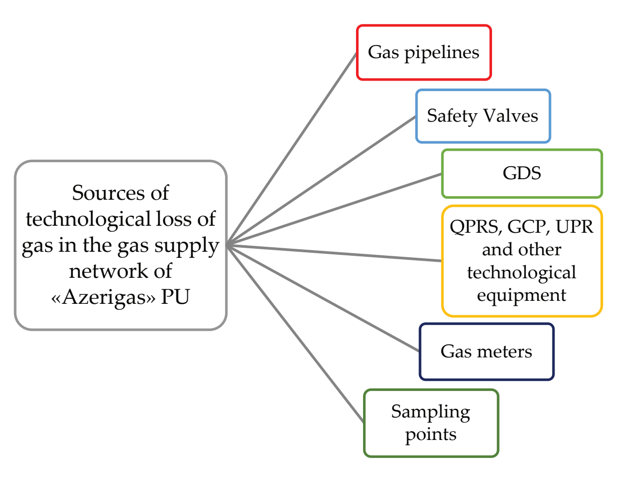

Fig. 1. Sources of technological loss of gas in the gas supply network of «Azerigas» PU

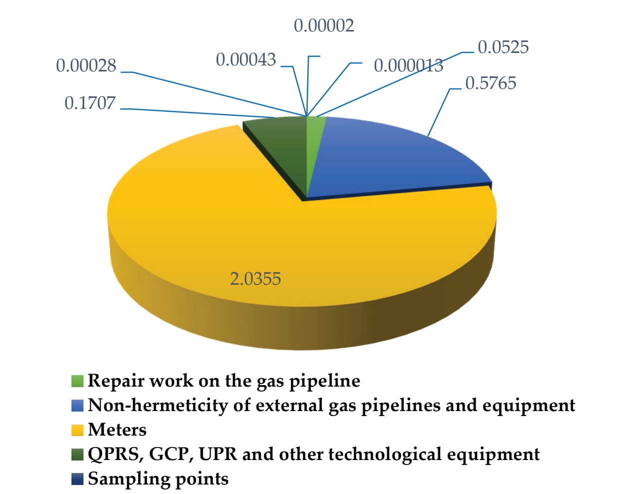

Fig. 2. Technical loss norms of natural gas according to loss sources for «Azerigas» PU

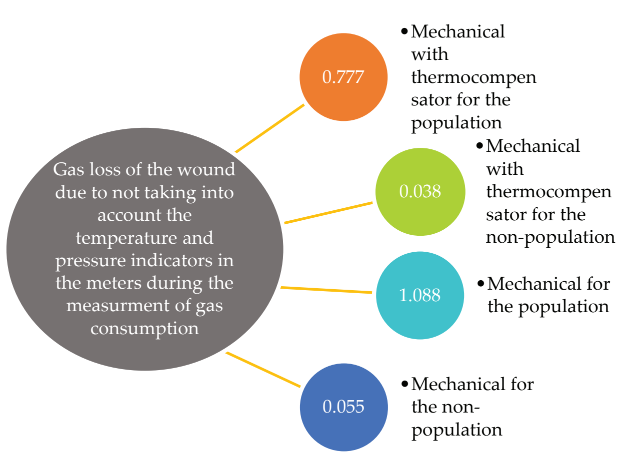

Fig. 3. Percentage of losses during gas consumption measurement at meters

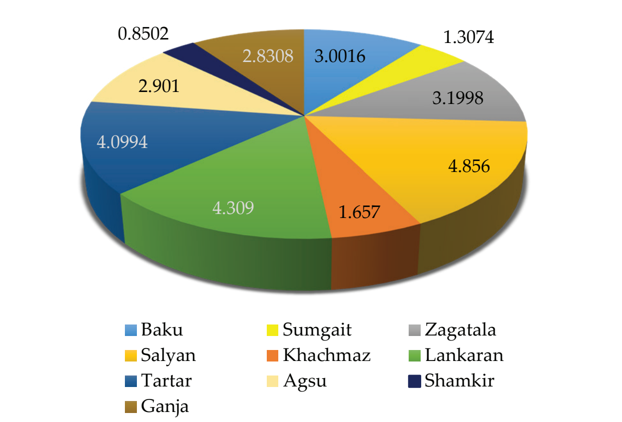

Fig. 4. The amount of forecast indicators of technical loss norms of gas according to RGED in percentage

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The results of the investigations and reports are shown in figure 1, 2. As can be seen from the picture, the most important directions in the total volume of technological losses are meters and losses caused by non-hermetic pipes.

The technical loss rate of natural gas for the gas supply network of «Azerigas» PU is set at 2.836%. Due to the fact that the temperature and pressure indicators in the meters are not taken into account during the measurement of the «hidden» gas consumption that is not released into the atmosphere related to the gas meters, the gas loss caused by the passport error of the meters is 2.0355%. The «real» gas loss during operation is 0.8004%. It should be noted that the biggest «real» gas loss is caused by the leakiness of the pipeline and is 0.5765%.

Conclusion

1. During the investigation, the technical loss norms of natural gas determined separately for each designated source of loss in the gas supply network of «Azerigas» PU for Baku, Sumgait and 8 RGED. The principle of the formation of technical losses in the gas supply network, the determination of the sources of technical losses of natural gas in the gas supply process and the methods of calculating the loss norms were considered.
2. Based on the conducted research and report results, it can be said that in order to reduce the losses in the existing system, it is necessary to increase the hermeticity of the gas supply system by using modern equipment, fittings and sealing materials.
3. Purge of gas pipelines and other objects of the gas supply system without releasing gas into the atmosphere. It is important to control the hermeticity of the elements of the gas supply system and improve diagnostic techniques, document and analyze all cases of natural gas loss, reduce the repair time of the main equipment of the gas supply network, and modernize the automated systems and complexes of gas accounting.
4. Technical loss norms of natural gas should be calculated for the planned period based on the actual indicators, and these norms will create a basis for determining the sources of excess costs and applying economical work mode.

References

1. Farzaneh-Gord, M., Reza Rahbari, H. (2018). Response of natural gas distribution pipeline networks to ambient temperature variation (unsteady simulation). *Journal of Natural Gas Science and Engineering*, 52, 94–105.

2. Salikov, A. R. (2015). Imbalance in gas distribution networks. Gas of Russia, 4, 36-41.

3. Farzaneh-Gord, M., Rahbari, H. R. (2016). Unsteady natural gas flow within pipeline network, an analytical approach. *Journal of Natural Gas Science and Engineering*, 28, 397–409.

4. Belousov, A. E., Ovchinnikov, E. S. (2022). Mathematical modeling of the operation of an expander-generator pressure regulator in non-stationary conditions of small gas pressure reduction stations. *Mathematics*, 10, 393.

5. Fetisov, V., Shalygin, A. V., Modestova, S. A., et al. (2023). Development of a Numerical method for calculating a gas supply system during a period of change in thermal loads. *Energies*, 16, 60.

6. Eparu, C. N., Neacsa, A., Stoica, D. B. (2023). Gas losses in the distribution networks: An interdisciplinary analysis. *Energies*, 16, 196.