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Research of pressure influence in the gas supply system on the energy consuption level of gas devices

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Abstract

There are investigated the influence of operating pressures in the gas supply system on the level of such energy indicators as efficiency, gas flow and gas overrun by gas equipment in residential buildings. There is established a relationship between the values of operating pressures in the gas supply system and the gas consumption level of household appliances. The causes of insufficient pressure in the gas networks of settlements are analyzed in the article. There is also developed an algorithm for calculating the change in the efficiency of gas appliances depending on the operational parameters of the gas network. It has been found that the most efficient operation of gas appliances is observed at an overpressure at the inlet of gas appliances of about 1200 Pa.

To ensure the required quality of natural gas combustion among consumers and minimize gas consumption there are justified the following measures in the article: coordinating a domestic regulatory framework for assessing the quality of natural gas with international norms and standards; improving the preparation of gas coming from local wells before supplying it to gas distribution networks; auditing low pressure gas pipelines and reconstructing areas affected by corrosion; ensuring standard gas pressure in the network for the normal operation of domestic gas appliances; stating quality indicators of natural gas combustion by gas sales organizations.

Keywords: *efficiency factor, gas devices, gas flow rate, gas supply.*

In recent years, the problem of gas overruns in the gas supply system has reached the scale of the whole country. Experts and the society, which is not completely informed, began to give their versions and explanations for increasing gas consumption, especially in the residential sector. The situation is complicated even further by a significant increase in the cost of gas, which together creates a clear conflict between suppliers and consumers. At the first glance, it is obvious that the problem is the inadequate quality of natural gas. Hence, there is low calorific value and significant overconsumption. However, the reason for this situation is not the quality of the gas, which is overwhelmingly satisfactory. In fact, the cause of gas overconsumption is inefficient burning in consumer burners, caused by a significant pressure decrease in gas appliances and, as a result, their operation in the low efficiency zone. Therefore, an important and extremely urgent task is to study the influence of operating pressures in the gas supply system on the level of gas consumption.

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Stable normative gas pressure for consumers makes it possible to ensure the highest efficiency of gas equipment, a constant or close to it thermal power of gas appliances, for which the efficiency and performance of the equipment are optimal and close to the certified values. It is especially important to ensure constant pressure for household gas appliances that are not equipped with individual gas pressure regulators [1, 2].

Methods of calculating gas pipelines and practical recommendations for them are given in the works of N.L. Staskevych, G.N. Severynets, D.Ya. Vygdorchyk in the mid-80s and early 90s of the twentieth century [3].

The heat of combustion of fuel also has an important effect on the volume of thermal power; it varies depending on the composition of combustible gas, which takes into account standard pressure in accordance with state building standards [4], and does not take into account the effect of pressure changes. The calorific value for gas used as fuel for industrial and domestic consumers is established by the gas quality certificate, which must be obtained by the gas consumer and meet the requirements of regulatory documents [1, 2].

The throughput study in [5] is carried out on a model of a low-pressure gas network, the configuration of which is close to real conditions. The calculation is performed for various options of the excess gas pressure magnitude at the outlet of gas distribution points (GDP). A change step value of the inlet pressure is 200 Pa. As a result, the value of the gas network throughput is obtained depending on the excess gas pressure value at the GDP outlet and the dependence is as follows

$$P_{out} = 1782 + 0.332Q + 2.740 \cdot 10^{-4} Q^2, \quad (1)$$

where P_{out} is the excess gas pressure at the GDP outlet of a low-pressure ring gas network, Pa; Q is the volume of gas consumption by the network, m^3/h.

This dependence allows us to determine the minimum excess gas pressure at the GDP outlet, where there are ensured permissible pressure losses in the network and the required gas flow rate.

As noted earlier, the influence of operating pressures is important for the energy efficiency of gas equipment. The theoretical basis for this statement was formed by the works of A.G. Kolienko, A.V. Shelimanov, V.A. Kolienko and also the works of Yu.V. Ivanov, who was involved in the basics of calculations and design of gas burners, taking into account the effect of pressure on gas combustion [6].

Using the research results [6], it is possible to assess the influence of individual operational factors on the thermal capacity of the N burner. The factors of its influence, provided that the burner is of constant design, have the following operational characteristics and quality parameters of natural gas:

calorific value of natural gas under normal conditions Q_{nc};

natural gas density ρ_{gnc};

gas pressure in front of the burner P_g, Pa, which in our case will change.

An assessment of these factors by the amount of thermal power (kW) can be carried out in the following dependency analysis

$$N = \frac{B \cdot Q_{nc}}{3600}. \quad (2)$$

The flow rate of dry natural gas *B*, which is supplied to the burner under normal conditions, is determined by the dependence

$$B = 3600 \varphi_c f \sqrt{\frac{2P_g}{\rho_g} \cdot \frac{P_g + P_{bar} - P_{wv}}{P_{bar}^{nc}} \cdot \frac{T_{nc}}{T_g}}, \quad (3)$$

where *f* is the area of the fire holes of the burner or gas nozzle (for injection burners), m^2. When flammable gases are supplied to the burners that meet the requirements of interchangeability, the area of the nozzle or fire holes remains unchanged; φ_c is the coefficient depending on the shape and manufacturing quality of the nozzle or the firing holes of the burners, φ_c = *idem*; R_g is the gas pressure in front of the burner; R_{wv} is the pressure of water vapor, which is contained in gas; ρ_g is the density of natural gas, kg/m^3; R_{bar} is the barometric pressure; T_g is the gas temperature, K.

This dependence takes into account all the necessary parameters, the research of which was also carried out by other outstanding scientists of the oil and gas industry [5, 6].

The pressure value depends on the parameters of the gas network, gas control installations, uneven gas consumption, hydraulic operation of distribution gas pipelines and pressure drop of gas ΔP in a gas network.

According to the DBN V.2.5-20–2001 requirements [4] the pressure drop from GDP to consumers of low pressure should not exceed 1.8 kPa, of which 1.2 kPa falls on distribution networks. The choice of pressure differential in inter-workshop and intra-workshop gas pipelines of industrial enterprises is generally chosen arbitrarily.

This work is related to gas appliances, and the most common gas appliance is a gas stove, the most common are gas stoves with an oven. V.N. Pelypenko and A.A. Ivanov have established, as a result of experiments, that injection burners are quite sensitive to pressure drops [7, 8]. A maximum efficiency of gas appliances is achieved due to the nominal gas pressure in front of the burner for the model chosen.

The nominal values of a gas stove efficiency is 59 % according to the State Standard GOST 2204–93, for a direct flow water heater, the efficiency should be at least 82–84 % according to GOST R 51847–2009, and for gas boilers – not less than 87–88 % according to GOST 3948–2000.

A study of natural gas quality guidelines, both domestic and foreign [9, 10], indicate a generalized indicator of gas quality – the Wobbe number, which is used in most European countries.

Examinations of gas distribution systems show that the influence of the quality of fuel gas and hydraulic modes of gas distribution pipelines on the efficiency of gas use in gas-burning equipment is unconditional [5].

The deviation of gas pressure, as well as the value of thermal power, for consumers from the nominal passport values leads to the following consequences:

operation of fuel-consuming equipment (FCE) with thermal overloads or insufficient heat production, which affects the effectiveness of the main technological process, reduces the overhaul period of fuel-consuming equipment operation;

decrease in gas use efficiency, increase in gas overhead, decrease in fuel-consuming equipment efficiency. It is well known that the deviation of the thermal power of industrial FCE towards decrease from the nominal by 10 % leads to a loss of efficiency by 0.2–0.5 % and in the direction of increase by 0.8–1.0 %. Due to this fact, most foreign manufacturers of gas burners equip them with individual gas pressure stabilizers;

environmental degradation of fuel combustion products [5].

Experimental studies of modern gas stoves burners indicate a significant decrease in their thermal efficiency even when the heat output of the burner deviates from the nominal values by 10–15 %, both downward and upward. So, with an increase in the gas pressure in a line in front of the gas stove from the nominal value of 1270 Pa to 3000 Pa, the efficiency decreases from 45 to 29 %, and at a pressure of 3500 Pa, the efficiency is already about 20 %. A decrease in the efficiency of stove burners is accompanied by deterioration in the environmental performance of their work – when the fuel is burned, there is formed an increase of dangerous carbon monoxide and other products of incomplete combustion.

The power of the burners of gas treatment equipment, or the thermal power of the burners N in kilowatts, of domestic gas stoves in accordance with [11] is calculated by the formula as follows

$$N = \frac{V_0 \, Q_{nc}}{3600\, t} \,, \qquad (4)$$

where V_0 is the volume of dry gas reduced to normal conditions, m^3; t is the time during which the volume of gas consumed, hrs, is measured ($t \geq 0.1$ h).

Another criterion of calorific value and the most reliable indicator of gas properties for its combustion in household gas appliances is the Wobbe number W (MJ/m^3) [12], which is calculated by the formula as follows

$$W = \frac{Q_{nc}}{\sqrt{\bar{\rho}_g}} \,, \qquad (5)$$

where $\bar{\rho}_g$ is a relative density of natural gas.

S.S. Hou and C.H. Chou, J.F. Stubington, G. Reashel, T. Murphy, R. Junus, P.J. Ashman, G.D. Sergeamt [12–15] studied the effect of pressure and three other main parameters to increase the efficiency of gas appliances and burners. In particular, their works describe high-pressure gas burners KB-5, which are widely used in Thailand. They achieved an increase in thermal efficiency of 7 % compared to analog ones. For their work, scientists have studied the effect of liquefied petroleum gases.

The level of gas consumption is growing annually in the world, therefore ensuring the highest efficiency significantly affects energy costs. S.S. Hou and C.H. Chou [13] note that gas burners have advantages over alternative sources due to their easy installation and relatively lower energy and material costs. The main goal of research and the superiority over gas burners, which use gas, is to obtain the maximum possible amount of thermal energy.

The characteristic of the burner head affects the thermal efficiency and the calorific value of the burner. The study of low-pressure gas burners and their transfer to high pressure for improving thermal efficiency were made by J.F. Stubington et al. [14]. Ashman P.J. et al. [15] used a fuel burner to determine the charge intensity and found a decreasing thermal efficiency with increasing high pressure load. The authors pay attention to adjusting the degree and number of internal and external ports for an overall improvement in thermal efficiency.

The reason for the lack of pressure in gas networks is complex. On the one hand, this situation is caused by the lack of resources for innovation and modernization of pipelines and equipment through the disproportionate structure of the gas supply tariff, which does not even cover the current expenses of gas distribution companies. Often, new subscribers have to be connected to existing networks without the necessary modernization measures – replacement of gas pipelines, commissioning of additional GDP. In this case, the working gas pressure of remote subscribers may be lower than the normative one. On the other hand, chronic non-payments for gas consumed lead to a decrease in the volumes of its purchase and supply by transport companies. Permanent non-payments or their delays cause a reduction in limits on the purchase of blue fuel. And insufficient volumes of gas transportation lead to a pressure decrease in distribution gas pipelines.

So, an analysis of domestic and foreign scientific papers on energy efficiency of gas supply systems has demonstrated the absence of a comprehensive scientific and methodological approach to taking into account all the factors affecting the operation of gas equipment and the level of gas consumption. The lack of a methodology for taking into account the operational parameters of gas networks for the efficiency of domestic gas-consuming equipment is particularly negative.

An extensive network of gas distribution pipelines provides gas to more than 11 million households and 184 thousand state and private enterprises and institutions. Unfortunately, the high cost of energy, the shortage of foreign currency for its purchase and chronic non-payments for gas already used lead to a decrease in the volume of natural gas sales in the domestic market of Ukraine. The decrease in the volume of transported gas is carried out, inter alia, by reducing the operating pressure in the network. The actual gas pressure at the exit point of the GDP, instead of the standard value of 3000 Pa, can be 2500 Pa in the summer, and in winter it can drop to 2000 Pa. The development of this methodology aims to establish the relationship between the operating pressure and the amount of gas consumed.

The gas supply system is designed with the condition that gas pressure at the exit point of a GDP is 3000 Pa, and the pressure loss does not exceed 1200 Pa up to the most distant consumer, that is, gas pressure of the last consumer at the entrance to the house should be 1800 Pa. Allowable pressure loss in household gas pipelines should not exceed 600 Pa, that is, gas pressure at the inlet to a gas device should be approximately 1200 Pa.

Injection gas burners, used in most gas appliances, are quite sensitive to changes in gas pressure [11]. With its excessive increase there occurs the initial moment of flame detachment from the fire hole. The flame height increases, which leads to a collision of the flame with the cold part of the vessel or heat exchanger, which heats the gas. As a result of this there are produced products of incomplete combustion of gas, such as formaldehyde, benzapyrene, benzene, carbon monoxide (CO), nitric oxide (NO_x), which are harmful to human life. The most toxic is carbon monoxide, the maximum permissible concentration (MPC) of which is 2 mg/m^3 in residential buildings according to [12]. According to these data, the CO content in the air of kitchens of typical gasified apartments exceeds the MPC by 10–50 times, reaching a value of 100 mg/m^3.

To summarize the above, we can conclude that fluctuations and decreases in pressure do not only affect the efficiency and gas flow, but also reduce the safety of a person's life, because according to the results of

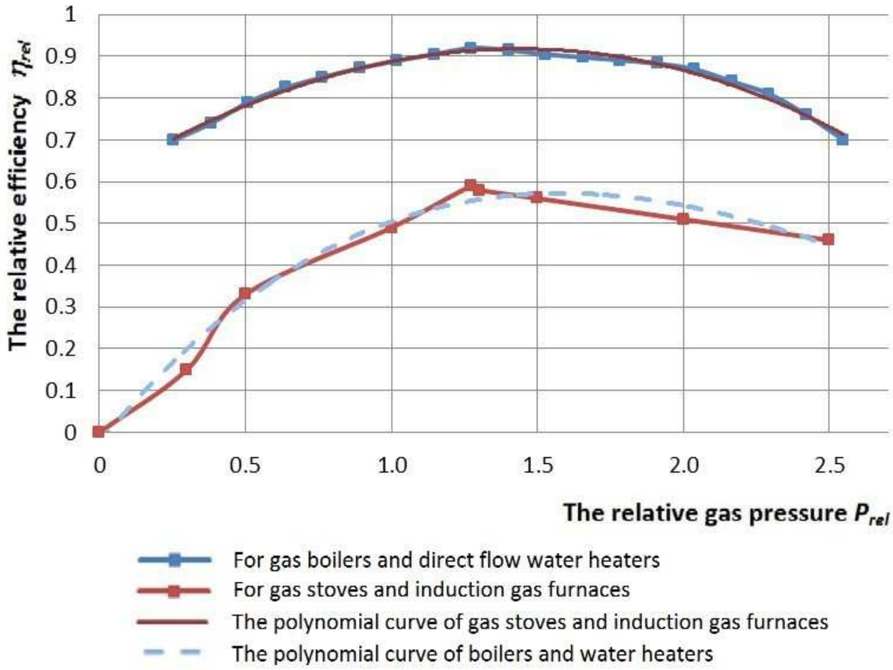

Figure 1 – The dependence of the relative efficiency of gas appliances on gas pressure

studies, the concentration of harmful substances can increase with increasing or decreasing gas pressure in front of the burner in the room, including carbon dioxide in 2.5–3 times. This can be explained by the fact that with an increase in the gas flow rate, which is directly affected by the decrease in pressure, the heating time increases, accordingly, the cooling time of the heat receiver increases, which worsens the conditions for the oxidation of carbon monoxide to dioxide, and the concentration of nitric oxide also increases. Minimum concentrations of harmful substances are observed at a nominal gas pressure (P_{nom}).

According to [7], pressure fluctuations in line in front of gas appliances are allowed within ± (0.10–0.15) of P_{nom}, although, in modern real operating conditions, deviations significantly exceed the recommended indicators. The maximum efficiency of household gas appliances and the most complete combustion of gas is achieved at a constant nominal pressure for each specific model. Structurally there are distinguished devices designed for operation at a nominal pressure of natural gas – from 1274 to 2000 Pa. The constancy of this pressure provides the greatest durability of the device, that is, with a decrease in gas pressure less than the nominal one; there occur dangerous thermal stresses and long-term overheating in some structural elements, which leads to burnout of heat-exchange surfaces.

To construct the dependence of the efficiency of gas burners of household gas appliances on the pressure value, there was used the method of regression analysis by the experimental data from published sources [7, 8].

To simplify the processing of data of various types of devices (a gas stove, a water heater, a boiler) with significantly different absolute values of efficiency and nominal gas pressure, as well as the possibility of obtaining the dependence $\eta = f(P)$ for all types of devices, the relative parameters were used and

$$\eta_{rel} = \frac{\eta_i}{\eta_{nom}} , \quad (6)$$

$$P_{rel} = \frac{P_i}{P_{nom}} , \quad (7)$$

where η_i, P_i are intermediate values of efficiency and gas pressure in line in front of the device; η_{nom}, P_{nom} are nominal values of efficiency and gas pressure in line in front of a device.

Figure 1 shows the dependencies for various types of domestic gas equipment: a gas stove, gas direct flow water heaters and domestic gas boilers.

A decrease in the efficiency of the burner with a decrease in the gas pressure below the nominal value is explained by a decrease in the volume of the torch, and, as a consequence, a decrease in heat transfer. At the same time, the coefficient of air excess and losses to the environment increase. With increasing pressure, there is an increase in heat loss with combustion products that do not have time to give thermal energy to the heat exchanger. In the course of researches, the highest value of efficiency is achieved at a gas pressure equal to the nominal one, that is, at $P_i / P_{nom} = 1$.

Two approximating dependences are obtained in the form of polynomials: the first one – for direct flow water boilers and gas boilers, the second one – for gas furnaces and stoves

$$\eta_{rel1} = 0.6043 + 0.4239 P_{rel} - 0.1348 P_{rel}^2 - 0.0058 P_{rel}^3 , \quad (8)$$

$$\eta_{rel2} = 0.7765 P_{rel} - 0.2998 P_{rel}^2 - 0.0242 P_{rel}^3 . \quad (9)$$

Given the nominal values, one can calculate the dependence $\eta = f(P)$ in absolute terms for all of the above types of gas appliances equipped with an injection burners.

The obtained dependence makes it possible to clarify in the future the permissible differential pressure of gas for a more accurate hydraulic calculation, or to show how much the efficiency of gas appliances decreases due to non-compliance with pressures. By correcting this dependence, to find the efficiency of a gas device with a given pressure, we substitute expressions (8) and (9) into formulas (6) and (7). As a result, we obtain

$$\frac{\eta_i}{\eta_{nom}} = 0.6043 + 0.4239\frac{P_i}{P_{nom}} - 0.1348\left(\frac{P_i}{P_{nom}}\right)^2 - -0.0058\left(\frac{P_i}{P_{nom}}\right)^3; \quad (10)$$

$$\frac{\eta_i}{\eta_{nom}} = 0.7765\frac{P_i}{P_{nom}} - 0.2998\left(\frac{P_i}{P_{nom}}\right)^2 + +0.0242\left(\frac{P_i}{P_{nom}}\right)^3. \quad (11)$$

Therefore,

$$\eta_i = \left(0.6043 + 0.4239\frac{P_i}{P_{nom}} - 0.1348\left(\frac{P_i}{P_{nom}}\right)^2 - -0.0058\left(\frac{P_i}{P_{nom}}\right)^3\right)\cdot\eta_{nom}; \quad (12)$$

$$\eta_i = \left(0.7765\frac{P_i}{P_{nom}} - 0.2998\left(\frac{P_i}{P_{nom}}\right)^2 + +0.0242\left(\frac{P_i}{P_{nom}}\right)^3\right)\cdot\eta_{nom}. \quad (13)$$

The nominal values of the gas stove efficiency are 59 % according to the State Standard GOST 2204–93, for a direct flow water heater, the efficiency should be at least 82–84 % and for gas boilers at least 87–88 % according to GOST 3948–2000.

Thermal power N_i (kW) of household gas equipment is determined by:

$$N_i = \frac{Q_p^н}{3600}, \quad (14)$$

where $Q_p^н$ is the net calorific value, kJ/(kg·K).

Then the gas flow rate of domestic gas equipment can be defined as the ratio of thermal power to the net calorific value, and in order to adapt to the actual operating conditions by showing real gas flow rates, this dependence is determined in accordance with the State building standards [15]:

$$Q_d^h = \frac{N_i \cdot 3600}{Q_p^н \cdot \eta_i}, \quad (15)$$

where Q_d^h is the gas flow rate of a domestic gas appliance, m^3/h; η_i is the efficiency of domestic gas appliance.

Having performed the calculation for the nominal pressure values, when the efficiency is the highest one, and using the obtained approximate dependence, we derive the dependence of gas flow on pressure for conventional gas appliances, having equated dependences (13) and (11), and substituting the value of the net calorific value of natural gas for a settlement, we obtain

$$Q_d^h = 3600\, N_i\, \eta_i \left\{Q_p^н\left(0.6043 + 0.4239\frac{P_i}{P_{nom}} - -0.1348\left(\frac{P_i}{P_{nom}}\right)^2 - 0.0058\left(\frac{P_i}{P_{nom}}\right)^3\right)\right\}^{-1}; \quad (16)$$

$$Q_d^h = 3600\, N_i\, \eta_i \left\{Q_p^н\left(0.7765\frac{P_i}{P_{nom}} - -0.2998\left(\frac{P_i}{P_{nom}}\right)^2 + 0.0242\left(\frac{P_i}{P_{nom}}\right)^3\right)\right\}^{-1}. \quad (17)$$

The obtained dependence enables us to evaluate the influence of the operating pressure in a gas network on the gas flow rate by means of domestic appliances.

Given the need for multivariate calculations of energy parameters of gas appliances according to the proposed methodology and the need to display graphical dependencies, computer-aided tools were used, namely, Visual Basic application software for Microsoft Excel.

The graphical dependence of the efficiency of household gas appliances on the inlet gas pressure is shown in Figure 2. On each curve, a maximum can be seen, which corresponds to the nominal operating pressure of the gas equipment. In the case of devices operating at a pressure different from the nominal one, their efficiency is less than the maximum one. In this case, the heat transfer of gas equipment is insufficient as long as the working pressure is removed from the nominal one. Figure 3 shows a graphical relationship between gas flow and pressure. There is also a minimum gas flow rate at a nominal overpressure.

Figure 4 shows a graphical dependence of gas overrun by devices due to the deviation of the working inlet gas pressure from the nominal one at the input to a residential building. The most excessive gas overrun is observed at an extremely low inlet pressure of 800 Pa. The operation of gas appliances at this pressure is not only economically viable, but also extremely dangerous due to the unstable operation of burners and the likelihood of a flame burst or its periodic attenuation with the subsequent formation of an explosive gas-air mixture.

In order to test the proposed methodology and developed software, there was calculated gas consumption by consumers in a rural village with a population of 4000 inhabitants. The calculation was carried out in a wide range of changes in the operating gas pressure at the input to a residential building. The purpose of testing was to determine the total possible gas overrun caused by the deviation of the operating pressure in the network from the nominal parameters. In the case of a significant decrease in gas pressure at the outlet of a GDP to 2000 Pa, given the pressure loss in a gas network, an excess gas pressure can be 800 Pa at the input to a residential building. At such an inlet pressure,

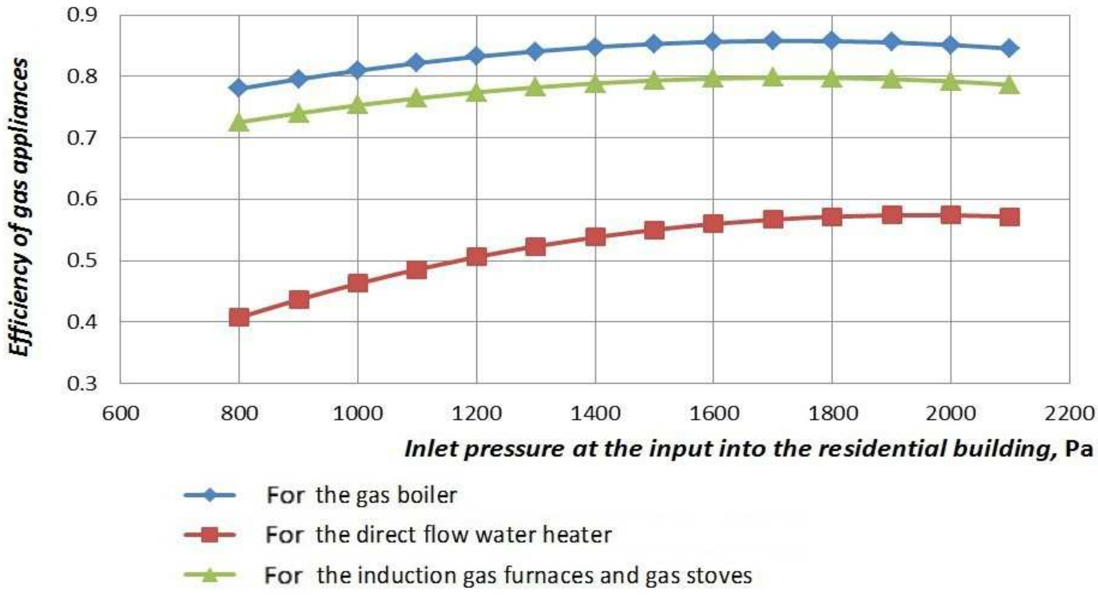

Figure 2 – The dependence of gas appliances efficiency from the input pressure

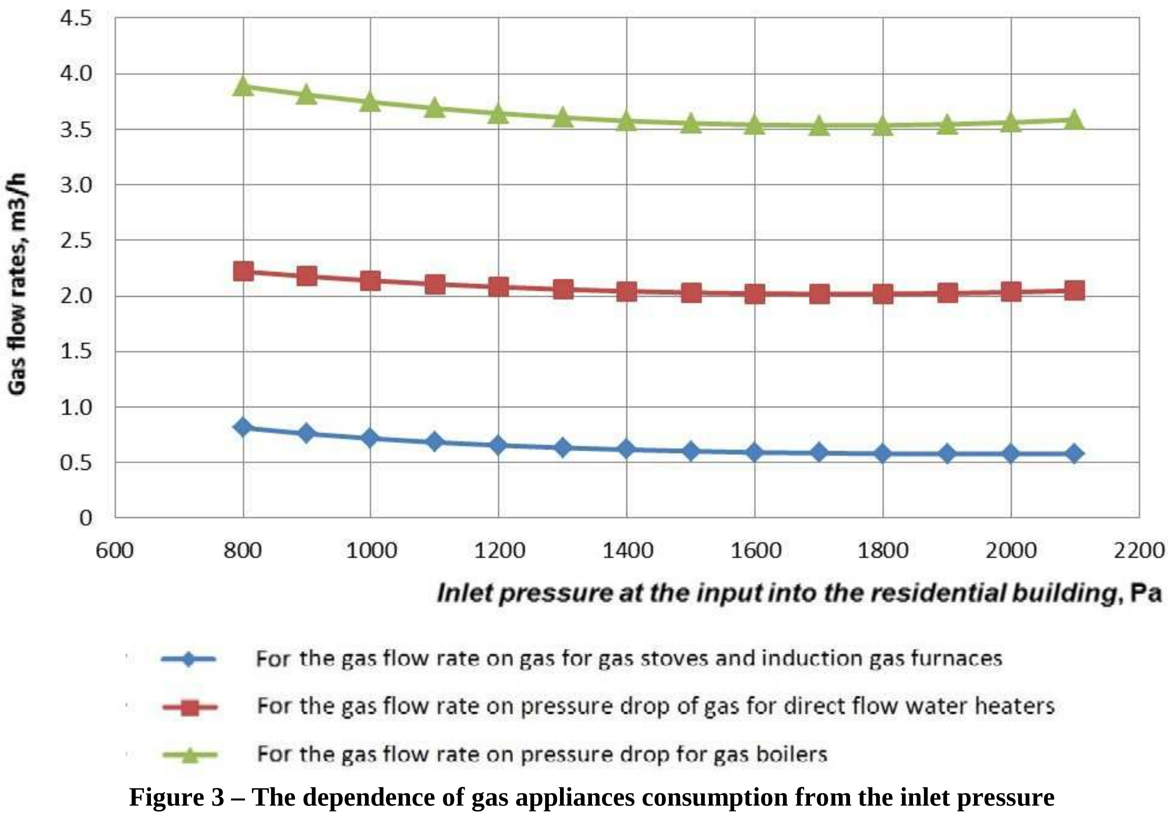

Figure 3 – The dependence of gas appliances consumption from the inlet pressure

based on the obtained graphical dependences and calculation data according to the developed method, the efficiency of gas appliances is reduced to 20 %, and the overconsumption of gas consumed is from 0.2 to 0.4 m^3/h for one device of each type. Given the amount of gas overconsumption by appliances when turned on simultaneously, it is 0.67 m^3/h. Such a volume of gas is burned per hour by a gas stove at a nominal pressure, that is, while devices are operating at the same time, the consumer overpays for gas consumption of one more stove. On the scale of an entire settlement, the overconsumption of gas per hour can be several hundred cubic meters. Calculation results are shown in Figure 5 in the form of a graphical dependence of the total gas overconsumption by the settlement on the inlet gas pressure into a house.

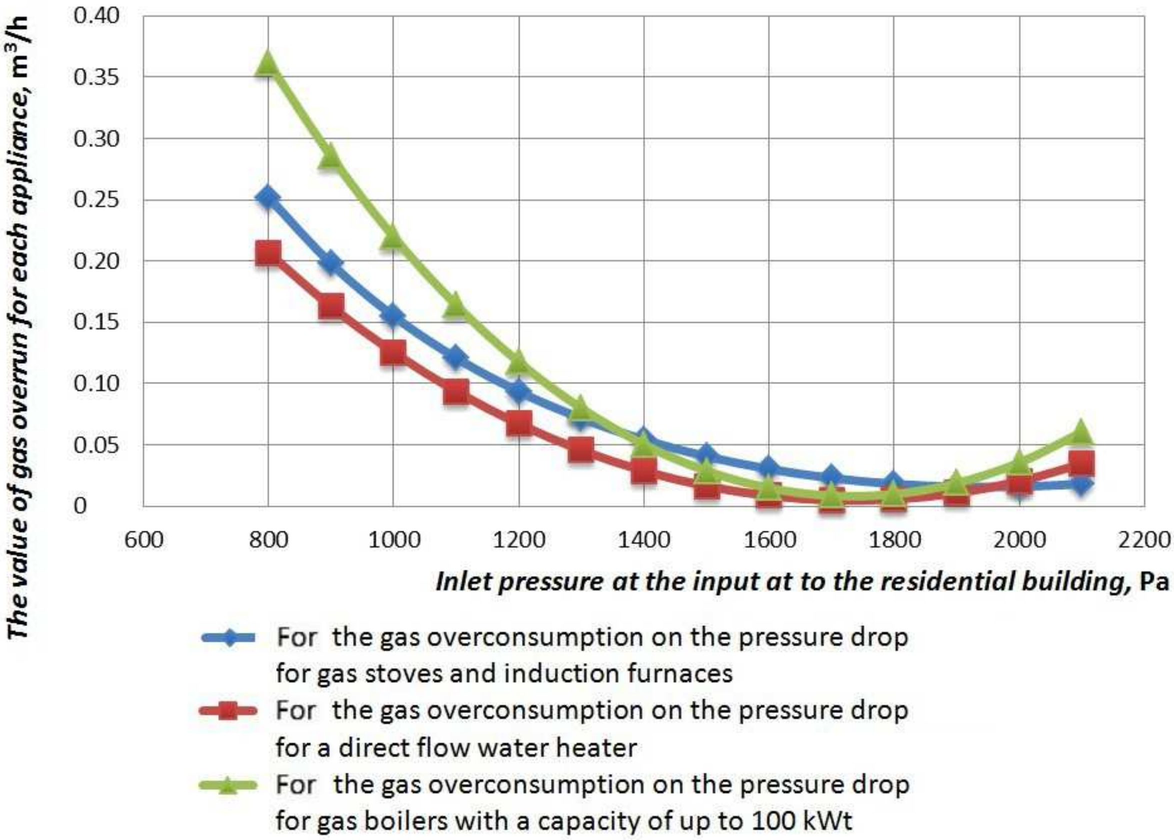

Figure 4 – Dependence of gas devices overconsumption on the inlet pressure

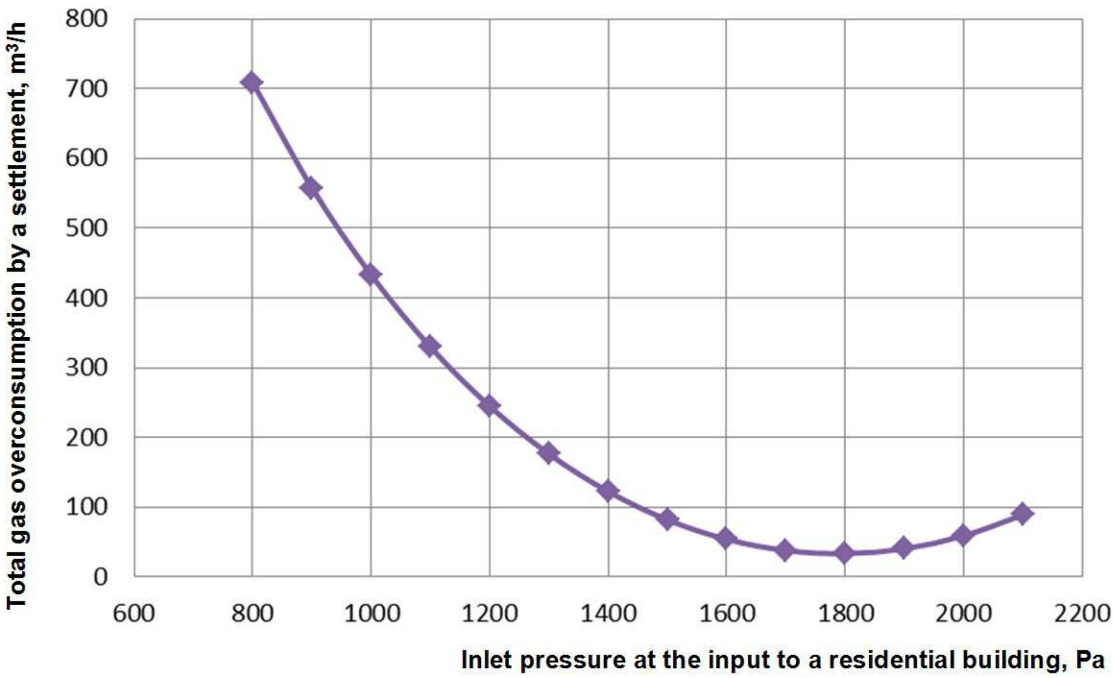

Figure 5 – Dependence of the total hourly gas appliance overconsumption by a settlement on the inlet pressure

Conclusions

It is established that the most efficient operation of gas appliances is observed at a nominal pressure in the network and at the inlet to appliances. The minimum level of energy consumption by household gas appliances occurs in case of a pressure excess of 1800 Pa at the input to a house and an excess pressure of about 1200 Pa for gas appliances. A significant underestimation of the operating pressure leads to a significant overconsumption of gas by consumers whose metering devices are not equipped with correctors for pressure and temperature.

To ensure the proper quality of household natural gas combustion and minimize gas consumption, it is necessary to implement the following measures:

coordinating the domestic regulatory framework for assessing the quality of natural gas with international norms and standards, taking into account, first of all, such characteristics as the calorific value, the Wobbe number, the dew point, nitrogen and hydrogen sulfide content;

improving the preparation of gas coming from local wells in front of supplying it to gas distribution networks;

auditing low pressure gas pipelines and reconstructing corroded sections;

ensuring standard gas pressure in the network for the normal operation of household gas appliances;

stating quality indicators of natural gas combustion for consumers by means of media by gas sales organizations.

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Дослідження впливу тиску в системі газопостачання на рівень енергоспоживання газових приладів

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Досліджено вплив режимних тисків у системі газопостачання на рівень таких енергопоказників, як коефіцієнт корисної дії (ККД), витрату та перевитрату газу газового обладнання житлових будинків. Встановлено взаємозв'язок між значеннями режимних тисків у системі газопостачання та рівнем газоспоживання побутових приладів. Проаналізовано причини виникнення недостатнього тиску в газових мережах населених пунктів. Розроблено алгоритм розрахунку зміни ККД газових приладів залежно від режимних параметрів роботи газової мережі. Встановлено, що найбільш ефективна робота газових приладів спостерігається за надлишкового тиску на вході в газові прилади приблизно 1200 Па.

Обґрунтовано заходи для забезпечення необхідної якості горіння природного газу у споживачів та мінімізації рівня газоспоживання: узгодження вітчизняної нормативної бази з питань оцінювання якості природного газу із міжнародними нормами та стандартами; покращання підготовки газу, що надходить з місцевих свердловин, перед подачею його до газових розподільчих мереж; ревізія газопроводів низького тиску та реконструювання уражених корозією ділянок; забезпечення нормативного тиску газу в мережі для нормальної роботи газових приладів населення; декларування газозбутовими організаціями показників якості горіння природного газу.

Ключові слова: *витрата газу, газові прилади, коефіцієнт корисної дії, системи газопостачання.*