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Analysis Regarding the Influence of the Atmospheric Pressure on Natural Gas Consumption

Cristian Eparu*, Mihai Albulescu*, Ligia Medrea**, Virgil Metea**

* Universitatea Petrol-Gaze din Ploieşti, Bd. Bucureşti, 39, Ploieşti
e-mail: iepy79@yahoo.com

** E-on Gaz România, Str. Justiţiei, 12, Târgu Mureş

Abstract

This paper presents a major problem of nowadays society, i.e. the influence of the atmospheric pressure on gas consumption. A model for one household gas consumer has been realized, and, after verifying the results, the model has been extended for a gas distribution network and an analysis has been performed.

Key words: *consumption, gas flow, pressure*.

The calculation that determines the daily, weekly or yearly gas allocation presupposes the value of the constant atmospheric pressure equal to the value of normal pressure p_N = 1.01325 Pa. Due to the fact that the atmospheric pressure decreases with the height increase, one can take into account a local value of the atmospheric pressure adjusted with the height, a value by which 11 mbar are being subtracted for each 100 m H altitude out of the normal pressure value. Thus, the normal local pressure can be calculated using the formula:

$$p_{Local} = p_N - \Delta p_H = p_N - 0.011H \quad (1)$$

The real atmospheric pressure varies and it can be bigger or smaller than the values used in the calculation. This paper considers a numerical analysis regarding the influence of the real atmospheric pressure on gas allotment, thus determining the level of errors which can be made if neglecting this factor. We would like to mention that at present the influence of the pressure variation on gas allotment is not being taken into account when calculating gas allotment.

The Mechanism through which the Pressure Influences Gas Consumption

From a technological point of view, most of the combustion processes in industrial or household installations are being performed in depressurized heating chambers placed at atmospheric pressure. This thing is being reflected in the way in which the gas burners are being built. Figure 1 shows the scheme of a household burner type B, where one can easily notice a detent of the natural gas from the pressure in the pipe to the pressure in the stove burning point, which represents the atmospheric pressure.

As a conclusion, the gas flow that passes through the burner is directly proportionate with the difference between the gas pressure in the pipe and the atmospheric pressure in most of the combustion installations. The tap or valve adjusting element modifies the flow section, but it does not influence the values of the pressures in the gas pipe or the burning point, the latter being equal to the atmospheric pressure.

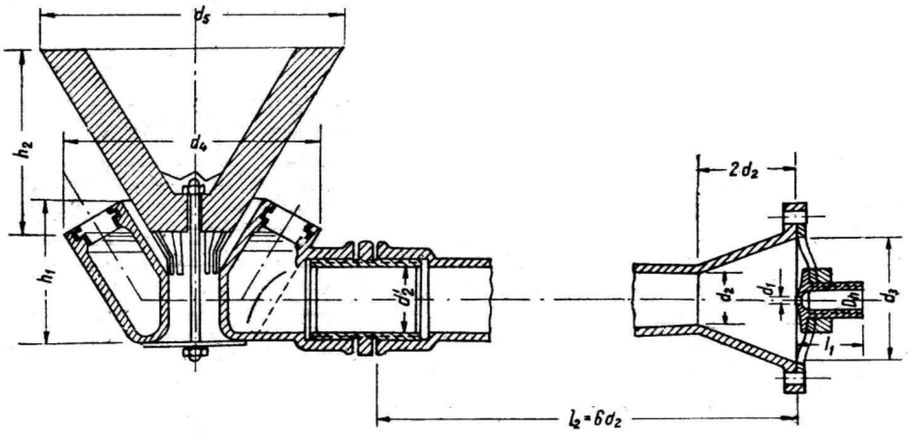

Fig. 1. Household burner type B

If one maintains in a constant position the gas flow adjusting element, so that the flow section remains unchanged, the gas flow will be constant. If the gas pressure before the burner is controlled to a constant value, the only measure that influences the gas flow that crosses through the pressure controller is the atmospheric pressure value.

Gas Flow Simulation in Distribution

In order to study the influence of the atmospheric pressure on natural gas consumption a model for one gas consumer was realized in the first phase, model that can simulate the gas flow from the distribution pipe to the burner.

The model thus defined for one consumer was extended for analysis on a tree distribution network made up of more consumers and subsequently on a curled network that includes the consumers above.

The models were realized using the software AFT ARROW 4.0 owned with the corresponding licenses by the Hydraulics, Thermotechnics and Reservoir Engineering Department.

The model for one consumer

The model for one consumer was realized by using proper objects available in the menu of AFT Arrow software. This is realized according to figure 2.

This model is made up of a three-way pipe through which the link with the distribution network is achieved (junction J4 in the figure 2). The pressure before the burner is being adjusted with a pressure controller / reducer. The object in the software that simulates this function is the adjustable valve, which depends on pressure, junction J5 in figure 2. According to the properties of the object, the exit pressure can be prescribed.

It was taken into account that the pressure at which the pressure controller / reducer is being adjusted is $p_g = 40$ mbar and that this adjustment was made at a normal atmospheric pressure of $p_{atm} = 1013$ mbar, therefore the prescribed pressure is $p_p = p_{atm} + p_g = 1013 + 40 = 1053$ mbar.

The gas consumption is limited by the adjusting element or by the tap. We considered that the adjusting element does not modify its position during the analysis. The fixed section orifice was chosen from the object bar for the simulation of the adjusting element (junction J6, figure 2). According to the properties of this element, one can define the diameter or the area through which gas flows, the pressure behind the nozzle, in this case the atmospheric pressure and the temperature in the same location, i.e. atmospheric temperature.

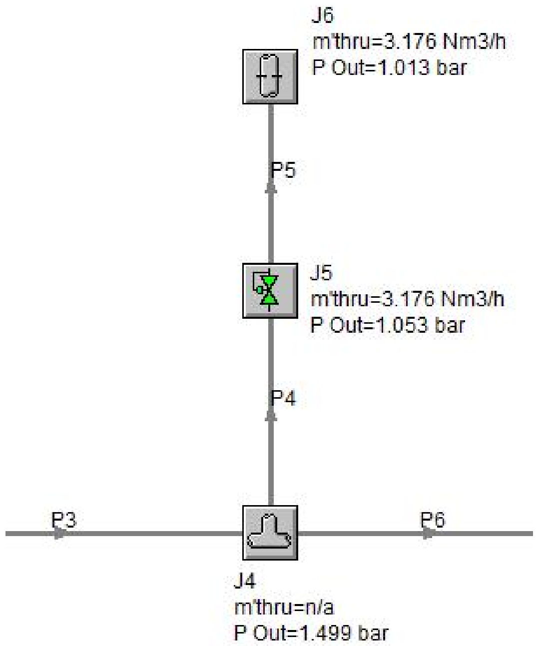

Fig. 2. Model for one consumer

The nozzle diameter was chosen so that it achieves a numerical medium gas flow equal to that of the consumer.

The model for a distribution network

A similar model to the one above was defined for each consumer. The differentiation of the consumers was realized according to the consumed gas flows, which determined in the model the definition of nozzle sections specific to each client. The lengths of the distribution networks and their constructive elements were defined by using the properties of the pipe object, such as the type and the material of the pipe, the diameter, roughness and length, figure 3.

The hypotheses in which the distribution models were realized are the following:

- The flow rates consumed by the users are constant for the numerical expert period, and their values result from the difference of gas pressure in the network, the pressure controller / reducer, the atmospheric pressure and the nozzle section.
- The experiments were made for two situations, during summer when the gas temperature in the network was 15°C and during winter, when a medium temperature of -5°C was considered.
- Each numerical experiment was developed for one value of the atmospheric pressure. The 1.013 bar normal atmospheric pressure was being considered and we analyzed the situation in which the pressure has lower values, in this case the values 0.990 and 1.000 bar were chosen, situations which are commonly met in reality and a higher value of the atmospheric pressure of 1.020 bar.

- For all the analyzed situations, the gas pressure in the distribution network with a value of 0.5bar (1.5 bara), the adjustment of the controlling devices for the 40 mbar and the nozzles diameters were kept constant.

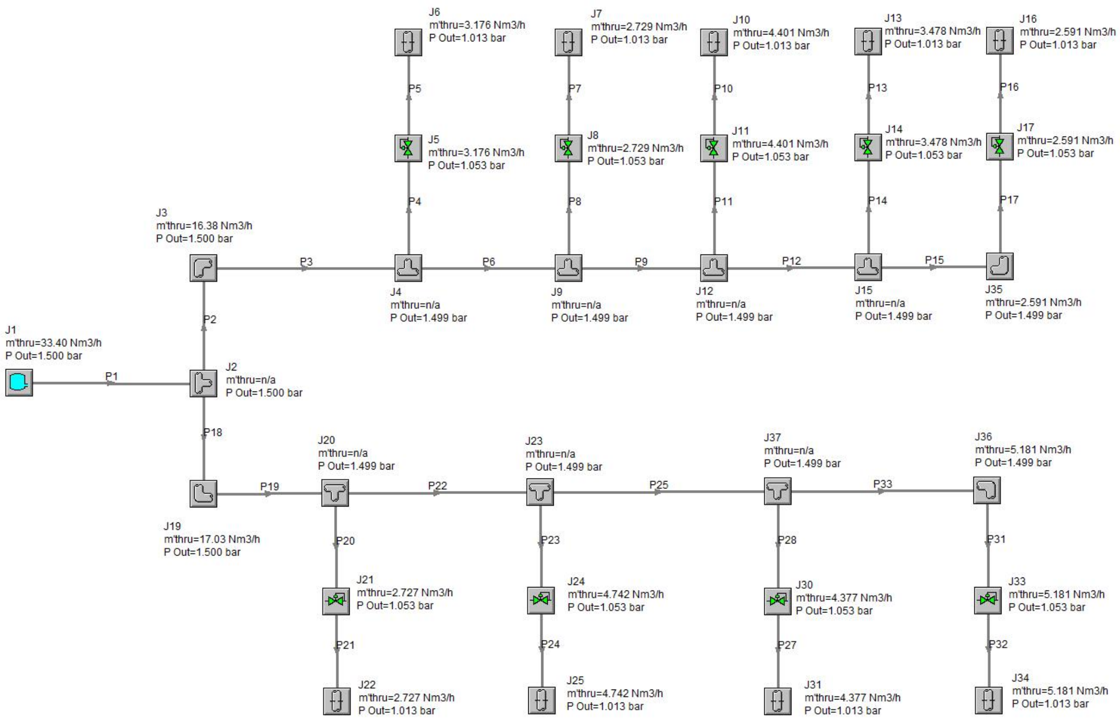

Fig. 3. Model for a distribution network

The Results Obtained Using the Model of a Distribution Network

Figure 4 shows the gas flow at the entry in the network, depending on the atmospheric pressure variation in the case of the summer season, when the temperature is considered 15°C. As it had been expected, the gas flow in the network increases with the decrease of the atmospheric pressure.

In order to better observe this influence, the flow was normalized to the normal pressure of 1.013 bar, hence resulting the percent variation of the gas flow (figure 5). The presentation of the percent difference of the variation of the flow considered as reference flow, the flow for the normal pressure value (figure 6), is more revealing.

As the graphic analysis shows, especially figure 6, the flow for which the percent difference is null is represented by the normal pressure flow, because this value was chosen as reference value. The percent differences to this value are significant for small pressure variations. Thus, a pressure decrease of 0.013bar (from 1.013 to 1.000) determines a flow increase of 15% for pressure values of 0.995 which appear frequently. In practice the flow exceeds 20%. When the atmospheric pressure is bigger than the normal pressure, the gas flows decrease.

In order to compare the flows from different consumers, these were normalized using as reference flow the normal pressure flow, and if we note with $\overline{Q}_N$ the normalized value of the flow for consumer *i*, this can be defined as follows:

$$Q_N = \frac{Q_{i,P}}{Q_{i,PN}} \tag{2}$$

where:

$Q_{i,P}$ – the flow at any value of the atmospheric pressure for consumer i

$Q_{i,PN}$ – the reference flow for the normal pressure value for consumer i

The percent difference for consumer i is given by the formula:

$$\overline{\Delta Q}_N = 100\frac{Q_{i,P} - Q_{i,PN}}{Q_{i,PN}} \text{ [\%]} \tag{3}$$

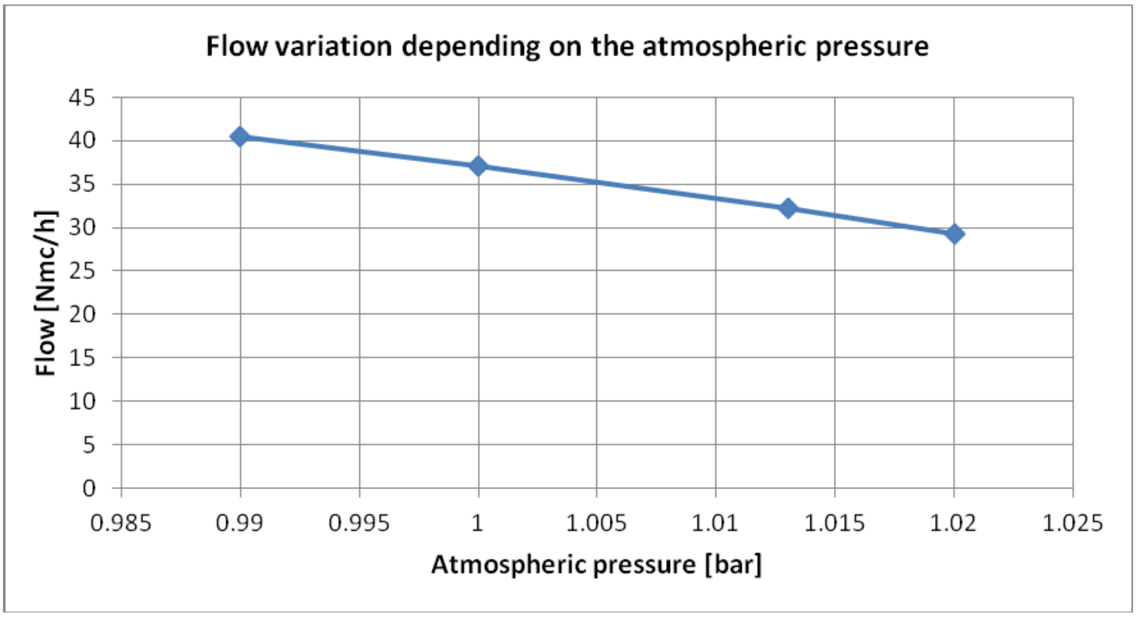

Fig. 4. Gas flow variation depending on the atmospheric pressure

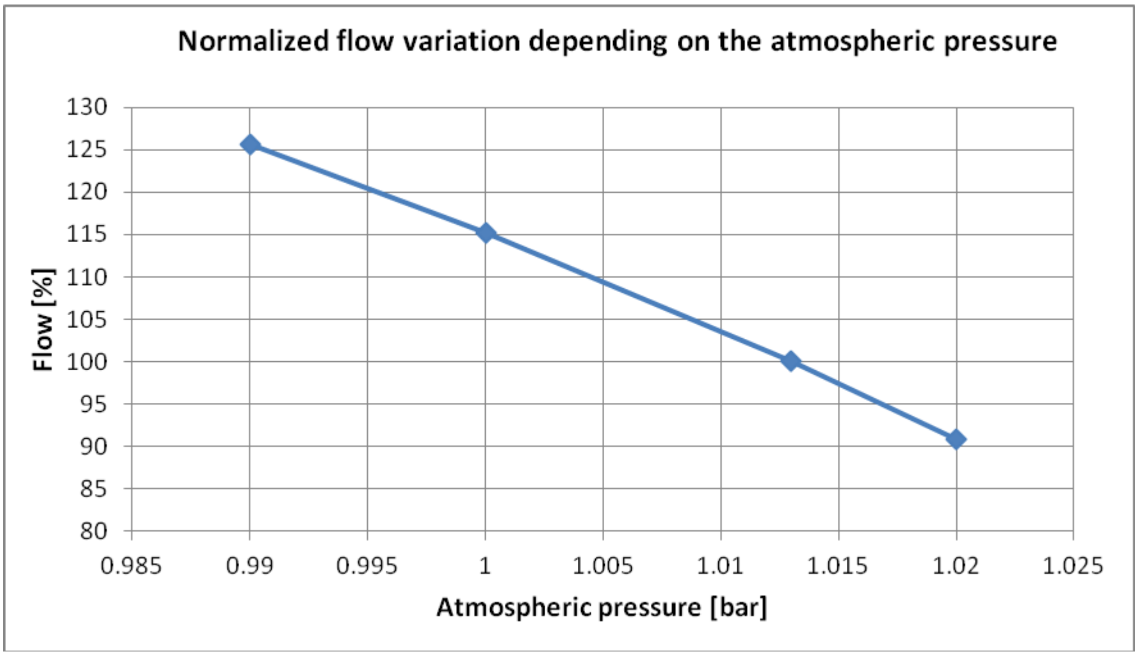

Fig. 5. Normalized gas flow variation depending on the atmospheric pressure

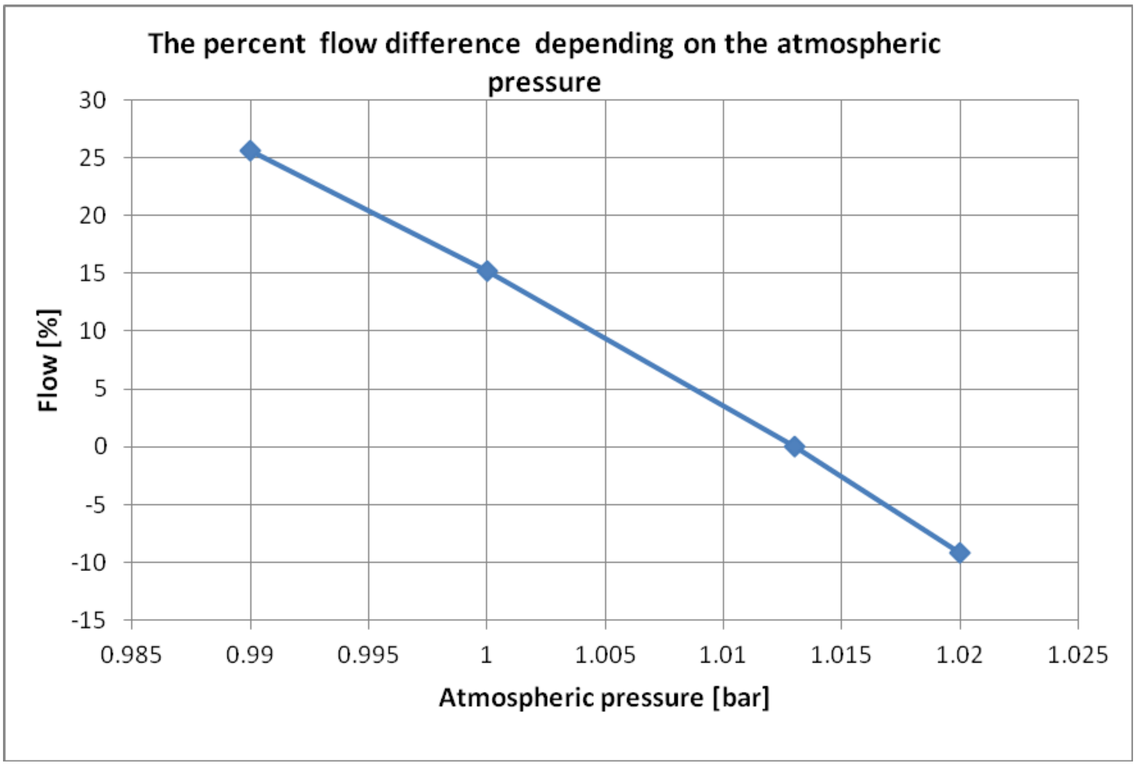

Fig. 6. Normalized percent gas flow difference depending on the atmospheric pressure

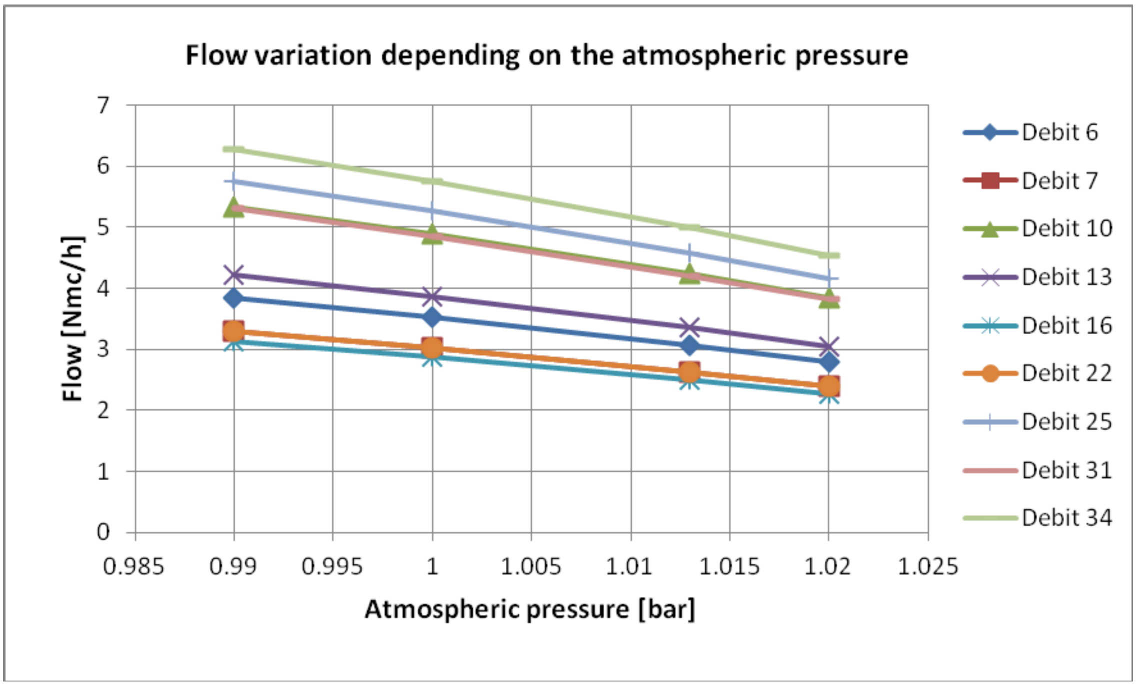

Fig. 7. Gas flow variation depending on the atmospheric pressure

The normalized values presented in figures 8 and 9 show the fact that all consumers are influenced similarly and that the normalized curves overlap almost perfectly.

A similar behavior of the variation between flow and pressure for the cold season is also noticeable. The only remark that we can add to the analysis for the warm season is that the absolute value of the flows has modified.

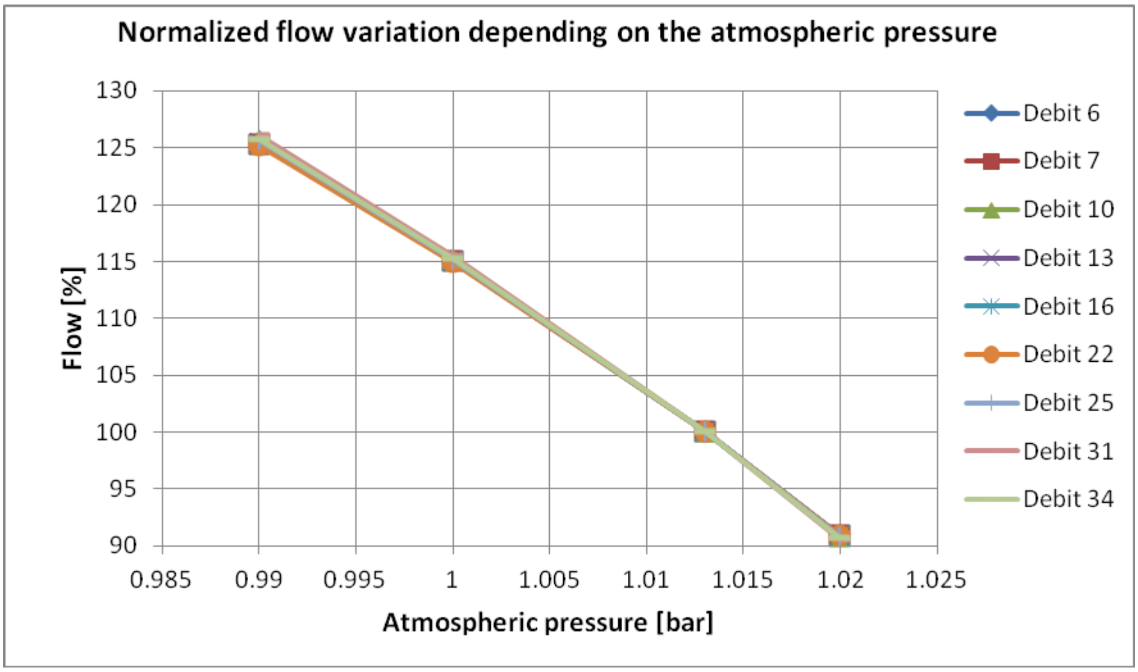

Fig. 8. Normalized gas flow variation depending on the atmospheric pressure

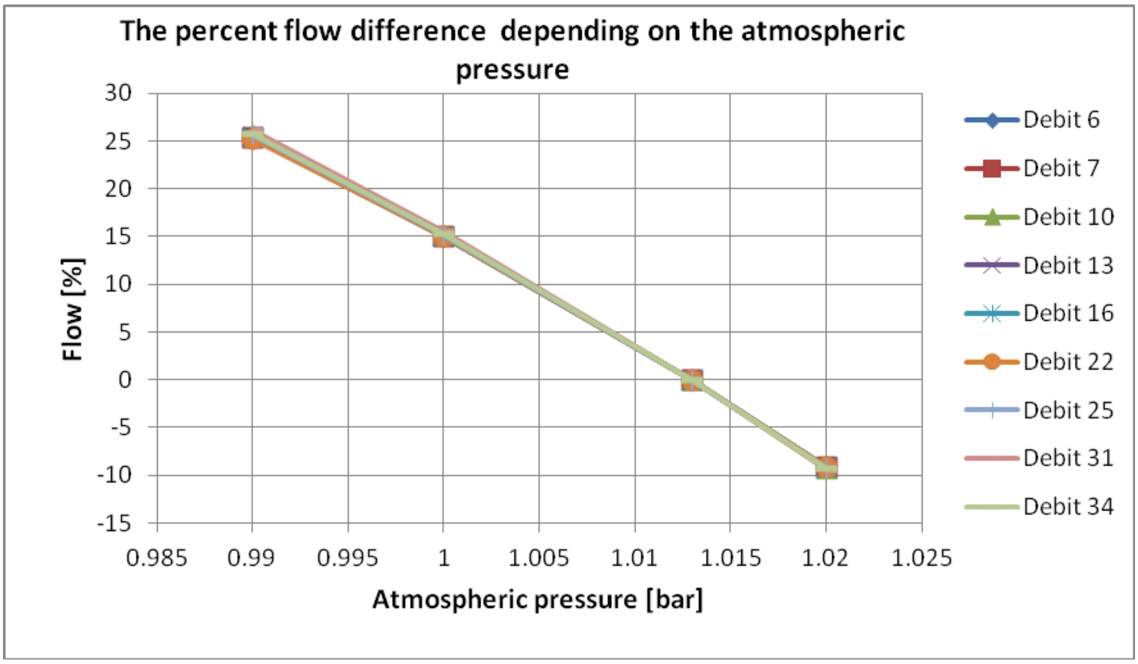

Fig. 9. The percent flow difference depending on the atmospheric pressure

Figure 10 shows a comparison of the flow absolute values between the summer and winter systems, made for the same network, with the same nozzle geometry and for the same pressure differences. In these conditions one can easily notice that the flow values distributed in winter are noticeably higher than the ones distributed in summer. Since this comparison is made for mass flow expressed in Nm^3/h, this situation can be explained by the gas density differences which appeared due to different temperatures.

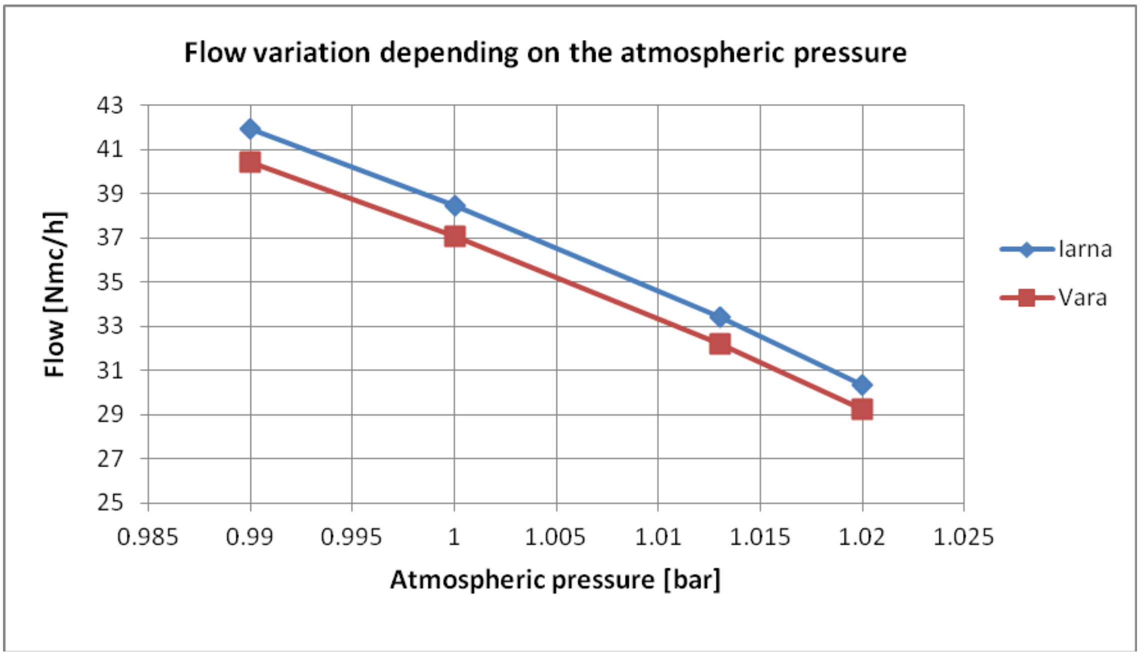

Fig. 10. Comparison of summer and winter flows depending on the atmospheric pressure

Conclusions

According to the Network Code methodology, the gas allotment destined to consumer consumption in the next periods is being calculated according to the clients' needs and according to the atmospheric temperature variation.

The analysis presented in this paper emphasizes the influence of the atmospheric pressure on natural gas consumption, a factor which can be taken into consideration when calculating gas allotments.

In most of the burning points where the burning of the fuels takes place, the burning process is performed at atmospheric pressure. The gas flow that enters the burning point is proportionate with the difference between the pressure in the network pipe and the atmospheric pressure.

The modeling of gas flows in atmospheric burning points has been achieved in minute details using performing software. Taking the atmospheric pressure as variable, the analyzed variables are within the limits measured in the laboratory. The influence of this parameter on natural gas consumption was determined by computation.

The results show that, once the pressure decreases, the consumed natural gas flows increase and vice versa, when the atmospheric pressure increases over the normal value, the flows decrease. This influence is due to the technology used in gas junctions.

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Analiza influenței presiunii atmosferice asupra consumului de gaze naturale

Rezumat

Lucrarea abordează o problemă de strictă actualitateă şi anume influența presiunii atmosferice asupra consumului de gaze. S-a realizat un model pentru un consumator casnic şi, după verificarea rezultatelor, s-a extins modelul pentru o rețea de distribuție şi s-a făcut analiza.