RESEARCH TO DETERMINE THE DEPENDENCE BETWEEN THE ENVIRONMENTAL TEMPERATURE AND THE TEMPERATURE OF NATURAL GAS USED FOR THE DOMESTIC SECTOR AS A CONSUMPTION FACTOR

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ABSTRACT. In this report we present a current issue related to the recalculation of the volume of natural gas used in the domestic sector and the dependence on the weather conditions of the coefficients involved in these corrections. Several methods of data processing were used, including: regression analysis and artificial neural networks ANN. The gas distribution companies in the course of the operation of the gas distribution networks solve this problem, related to the accuracy of reporting the consumed quantity of gas, depending on its priorities and expert capacity. To this end, colleagues from Sofia Gas have conducted a study and observed differences in readings of the reported amount of gas per user, in which the consumption was measured with a gasmeter without temperature correction and with a temperature correction gasmeter. On this basis, by additionally mounted temperature sensors and volume correctors of the Gas Center experts, we have conducted an experiment to specify the impact of environmental parameters on a model for adjusting the volume of gas. On the basis of the data used for the heating periods in 2016/2017, the report presents a mathematical model, which defines a function describing the gas temperature dependence on the daily air temperatures. Using Artificial Neural Networks (ANN), relationships between air temperature and soil temperature are determined for different gas flows. A software application has been developed to predict the temperature of the soil depending on the climate zone and average air temperature. The results of solving this problem and the possibility to forecast are the opportunities to improve the effective management of the Gas Distribution Networks.

Keywords: natural gas, applications for natural gas consumption, flow measurement, correction factors for natural gas consumption

ИЗСЛЕДВАНЕ ЗА ОПРЕДЕЛЯНЕ НА ЗАВИСИМОСТ МЕЖДУ ТЕМПЕРАТУРАТА НА ОКОЛНАТА СРЕДА И ТЕМПЕРАТУРАТА НА ПРИРОДНИЯ ГАЗ ИЗПОЛЗВАН ЗА БИТОВИЯ СЕКТОР, КАТО ФАКТОР ЗА ПРЕДВИЖДАНЕ НА ПОТРЕБЛЕНИЕТО

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РЕЗЮМЕ. В настоящия доклад представяме актуален проблем, свързан с преизчисляване на обема на използвания природен газ в битовия сектор и зависимостта на коефициентите участващи в тези корекции от метеорологичните условия. Използвани са няколко метода за обработка на данните, между които: регресионен анализ и изкуствени невронни мрежи ANN. Газоразпределителните дружества в процеса на експлоатацията на газоразпределителните мрежи решават този проблем, свързан с коректността в отчитането на потребеното количество газ, в зависимост от своите приоритети и експертен капацитет. В тази насока към момента колеги от Софиягаз АД са провели изследване и наблюдавали разлики в показанията на отчетеното количество газ за един потребител, при който е измерено потреблението с разходомер без температурна корекция и с разходомер с температурна корекция. На тази база, чрез допълнително монтирани датчици за температура и коректори за обем сме реализирали експеримент с цел уточняване на влиянието на параметрите на околната среда за извеждаме на модел на коригиране на обема на газа. На основата на използвани данни за отоплителните периоди през 2014/2015 година в доклада е представен математически модел, чрез който е определена функция описваща зависимост на температурата на газа от дневните температури на въздуха. Чрез използвани Изкуствени Невронни Мрежи (ANN) са определени връзки между температурата на въздуха и температурата на почвата при различни дебити на газа. Използвано е софтуерно приложение за предсказване на температурата на почвата в зависимост от климатичната зона и средната температура на въздуха. Резултатите от решаването на този проблем е и предоставените възможности за прогнозиране са възможностите за подобряване на ефективното управление на Газоразпределителните мрежи.

Ключови думи: природен газ, заявки за потребление на природен газ, измерване на дебит, коригиращи фактори при потреблението на природен газ

Introduction

The purpose of this report is to systematize and present information on the result of a study to establish a relationship between the volume and temperature of the natural gas used in the domestic sector and the relationship of these parameters to the ambient temperature as a key factor in predicting the consumption of natural gas.

Natural gas, like all gases, is a highly compressible fluid and its volume depends on and varies according to the pressure and temperature at which it is measured. In the gas practice basic conditions are defined, characterized by a fixed temperature and pressure conditions under which to trade with natural gas. For basic comparison conditions, when measuring physical quantities such as volume, reference and measurement conditions are used, which are published in BDS EN 13443 and are 20 ° C (293.15 K) and 1 atmosphere (101 325 Pa).

Correct determination and metrologically accurate measurement of the volume of compressible fluids, as well as the natural gas used in households, is related to the ability to obtain accurate gas pressure and temperature data in the so-called working conditions. This data must be consistent with the exact moment at which the flowmeter reads the volume of the gas passing through it.

The consumption of natural gas in household consumers is measured by flowmeters without built-in temperature or pressure correction. The technology for determining gas consumption in this case is related to adjusting the monthly reporting volume in accordance with the average temperature (T) and atmospheric pressure (P), and not so much with a compressibility factor (Z) which is acceptable to the extent that the correction coefficient of over-compression (Kz) at atmospheric pressure is with a value determined by BDS EN ISO 12213-2 (http://www.bgc.bg/zfactor/AGA8-92DC_clear.php?).

In accordance with the state-of-the-art technology in the measurement, the temperature and pressure correction can also be performed on-site by using temperature and pressure sensors that are mounted in place called "Smart" flow meters that are integrated into the Commercial Metering Tool (CMT) and are capable of a one-way or a two-way commands and data transfer. As long as this type of flow meters is not yet widely used, correction factors are used to recalculate the volume of gas, mainly related to the need to recalculate the volume of gas from temperatures close to 0° C (for the heating season) to 20 ° C (КЕВР, Показатели за качеството..., 2004).

Most EU countries have solved this problem by selecting 0° C for base conditions and thus minimizing the error of lack of temperature correction in the winter months, Table 1 (BDS EN 13686:, 1998).

In real terms, for companies supplying gas to consumers, most of the commercial metering devices (CMDs) are from batches that do not have the ability to recalculate the volume of gas at a standard temperature (20 °C). In these cases, the use of a technique to give an idea of the actual temperature of the gas used (Филков, 2010) is important for the accuracy of reporting and gaining confidence from gas users.

This study ends with several conclusions and suggestions that, in our opinion, would minimize the possibility of technical discrepancies between the actual amount of household gas used and that reported by the flow meter.

Table 1
Basic temperature conditions at which natural gas is traded in countries around the world

#	Country	Conditions	
		temperature, ^0C	pressure, Pa
1	Austria	0	101 325
2	Belgium	0	101 325
3	Bulgaria	20	101 325
4	UK	15	101 325
5	Germany	0	101 325
6	Denmark	0	101 325
7	India	0	101 325
8	Spain	0	101 325
9	Italy	0	101 325
10	Hungary	0	101 325
11	France	0	101 325
12	Holland	0	101 325
13	Sweden	0	101 325
14	Japan	0	101 325
15	China	20	101 325

Scope of the problem

The reached length of the urban distribution network in the developed gas supply regions is more than 1590 km and continues to increase. In these networks-260000 potential of consumptions (Николов, 2007), the distances that natural gas passes from the point of reading its physical parameters into the points of entry to the populated areas, the automatic gas regulator stations (AGRC), to the points for measuring and reporting natural gas to consumers, are significantt. The measurement of these input parameters can not be related to the physical state of the gas in the places where the consumed amount of household gas is taken into account. In addition, the use of temperature correction (temperature-correcting and volume-correcting) commercial metering devices (CMDs), as discussed above, is not wide-spread.

At the same time, precise information about temperature and absolute gas pressure is essential for the accuracy in accounting for and invoicing the actual amount of gas consumed.

To solve the problem described, a survey was conducted and three control samples were collected to gather data about:
• Average monthly air temperature for the surveyed region;
• The hourly consumption of gas for three types of objects surveyed;
• The air temperature in the vicinity of the flow meter location;
• Soil temperature in the studied region.

Processing of the task

Experiments include the sequential installation of two flow meters that measure the volume of gas simultaneously. The flow meter (1) is of the GMT G 2.5 type, with no gas temperature readout, and the second flowmeter (2) is the Galus 2100 TCE type, which recalculates the gas volume according to its temperature. In the monthly reports on flowmeters 1 and 2 there is a difference between the registered gas volumes due to the use of the temperature correction in the flowmeter 2 automatically performed by the CMD. From the ratio of the reported quantity of gas from the two flow meters, applied to a specific period (month), it is also possible to establish the value of the correction coefficient for the studied region under the conditions specific to it. With the obtained coefficient, the readings of the flowmeters in the region are corrected for each reported period.

The sequentially located flow meters are a very good basis for continuing the experiment. However, they do not provide sufficient data which, by processing as information, allows us to conclude how the temperature of the gas is influenced by the ambient temperature and what the dependence of gas consumption on this temperature is. To achieve these goals, the experiment has been extended and has passed the next scheduled stage.

In order to establish the actual gas parameters (temperature and pressure) recorded at the sale to the customer, an experimental set up with two electronic temperature and pressure correctors connected to existing diaphragm volumetric flowmeters was built. The flow chart is shown in Figure 1. The temperature of the gas and the impulses from the counter of the flow meter are input at the inlet of the corrector 1. At the output of the same corrector, the same pulses are output synchronously, entering the input of the corrector 2. In this way, the corrector 2 simulates the same expense as the pulses are synchronized over time. At the same time, the temperature input of the corrector 2 is fed by the ambient temperature signal. Both pressures of the pressure inlet are supplied with atmospheric pressure. For the purpose of the experiment, the two correctors are synchronized over time and report the data in their memory every hour. Flowmeters are approved under MID, Measuring Instruments Directive.

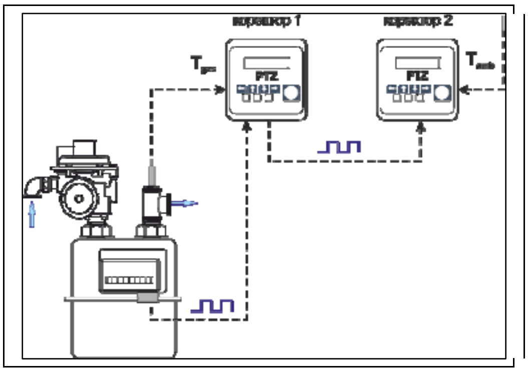

Fig 1. Connecting scheme

To find differences and analogies for different types of clients, this scheme has been transferred to 3 sites with the following features:

Object 1: Multi-family house. Research in the period: January-February 2016; High monthly consumption of natural gas; Flow meter located in a cabinet outside the building near the ground;

Object 2: Apartment in a residential building. Research in the period: March 2016; Low monthly consumption of natural gas; Flow meter located on floor 4 of the building;

Object 3: Office space. Research period: December 2015; Flow meter located outside the building at a height of one meter from the ground elevation; Average monthly consumption per customer type.

Essential laws and anomalies in the survey

Considering the daily consumption data and comparing them with the changes in the temperatures of the gas and the air by hours for all three sites, the results are in the direction of:

- In terms of household gas consumption in settlements, the temperature of the gas is strongly influenced by the air temperature, regardless of where the flow meter is located: inside or outside the building (Figs. 2, a, b, c);
- The temperature of the gas follows the temperature of the air tightly, exceeding it by one degree;
- In the case of consumption close to the maximum, realized at minimum temperatures, the gas temperature falls by half to one degree below the air temperature due to the throttle effect obtained in the regulator at the flow meter inlet;
- For all objects, 60 to 70% of gas consumption accumulates during a period when minimum temperatures are measured.

The three studies clearly outline the characteristic dependence of the two measured temperatures. Accordingly, at lower air temperatures the gas temperature is lower and the gas consumption is increased. This difference is in some cases up to 30% and the reason for this is the higher energy consumption associated with compensating for heat loss at low ambient temperatures.

In Figure 2,a in red there is a line describing the change of the gas temperature, and in blue is the line of the change of the air temperature. The measurement period is limited to the broken green line, after which the set up is transferred to another object.

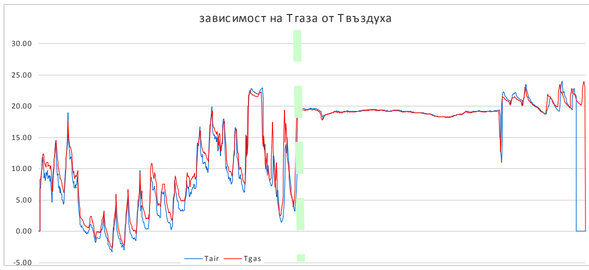

Fig. 2,a. Temperature of Gas and Air.

In the following case are presented the results obtained from the temperature measurement in the residential building set up (relatively constant) and the results of the measurement of the hour temperature of the gas and the hourly gas consumption.

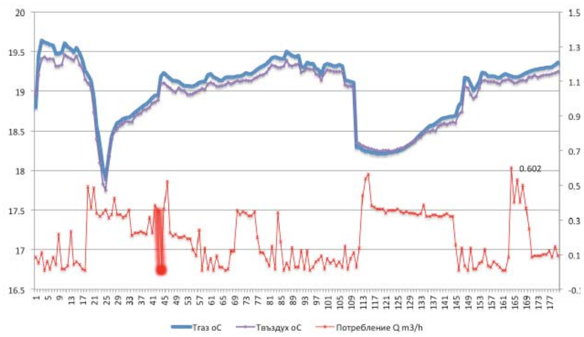

Fig. 2,b The result of metering

In this case, the dependence that is obtained when the temperature and the amount of gas used in the household are reduced. In the surveyed period, about 65% of the consumption was recorded at the minimum set temperatures.

The third study has a clearly expressed sine wave of the temperatures obtained during the light and dark of the day. Regardless of the typical increase of the air temperature during the day, the gas temperature without delay changes in parallel with the air temperature. In this case, there is an increased consumption at minimum temperatures (Fig. 2 c). Figure 2c clearly shows the relationship between air temperature (blue line) and gas temperature (red line).

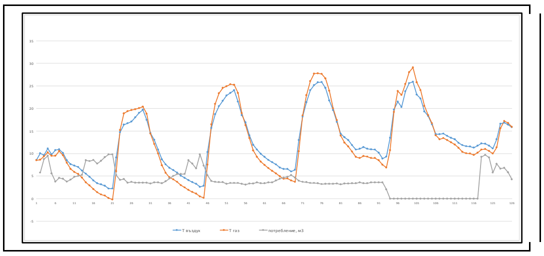

Fig. 2 c. Temperature in object „C"

At lower temperatures, the consumption is higher and due to the throttle effect, there is a decrease in the temperature of the gas below the air temperature by another degree, a degree and a half.

Impact of soil temperature

Regarding the influence of the temperature of the soil on the gas temperature, we can say that it is essential and determinant in the gas transmission system and does not affect the temperature of the gas from the gas distribution networks. Of relevance to this topic are the following observations.

The 24-hour temperature fluctuations in the snow cover penetrate into small depths (20-30 cm) and as a result, on a monthly basis, they remain relatively constant. The average diurnal temperature of the soil in the depth decreases during the summer and grows in the winter, in the transition seasons (spring and autumn) there is a much more complex distribution of this temperature with depth. The vertical distribution of the soil temperature has a significant effect on the surface layer. In the summer, when the direct sunlight is the main factor in the warming of the soil, the soil under grassy areas at all depths is colder than in the streets and pavements.

In winter, when the predominant role plays the radiation, the soil under the vegetation is warmer than the bare terrain, but in winter the snow cover plays a major role in the formation of the thermal regime of the soil. Snow reflects strongly the solar radiation and at the same time radiates almost as a black body a long wavelength radiation. For this reason, the radiation balance on the surface of the snow, as a rule, is negative. Under the influence of radiation heat loss the surface of the snow is heavily cooled. At the same time, the snow has a small thermal conductivity, increasing with its density.

As a result of the small heat conduction, the temperature inside the snow layer sharply increases with the depth. As a result, the surface temperature of the soil under the snow is always higher than the temperature of the non-snow-covered parts and may affect the ambient temperature of the gas panel in which the flow meter is located.

In addition, the criterion for the thermal properties of the soil is its thermal conductivity. Soil is a bad heat conductor and its average thermal conductivity is 26 times lower than that of water. That is why if the soil is dry the heat transfer is slow. This explains the heating rate on wetter and drier soils. Slow heating of moist soils is due not only to evaporation but also to faster heat transfer to deeper layers. Accordingly, their slow cooling during the night is due to the compensation of heat from the deeper layers.

As a result, we can conclude that the change in the surface layer of the soil may affect the ambient temperature, but since in Bulgaria the CMDs are located in panels and are not outdoors, the main factor influencing the temperature of the gas remains the temperature of the air. These results can also be seen through the SCADA system of the gas company.

Possibility for gas demand prediction

From hourly consumption for the period and gas temperatures, analyzes were made to determine a function describing dependencies between the two parameters.

After a series of samples, it was found that a function of type (1) best describes the daily gas consumption according to the average daily temperature. This function is (Бояджиев , 2012):

$$Y = -1E{-}04x^3 + 0.0047x^2 - 0.0772x + 0.6197 \qquad (1)$$

Investigating the results of the analysis, it was assumed that the functions obtained through data using air temperature gave more accurate estimates.

It can certainly be assumed in the specific case of this study that the ambient temperature (in this case the air) is most correlated with the gas temperature. This conclusion requires that the air temperature be used when determining the correction coefficient for calculating the volume of gas under standard conditions (1 atm. and 20°C).

Conclusions

The survey and research covered a period of 4 months and was realized with the logistic support of colleagues from the gas distribution company of Overgas Network AD.

Investigating the results of the analysis, it was assumed that the functions obtained through data using air temperature gave closer results to those with the gas temperature. It can certainly be assumed in the specific case of this study that the ambient temperature (in this case the air) is most correlated with the gas temperature. This conclusion makes it necessary to use the air temperature when determining the correction coefficient for calculating the volume of gas under standard conditions (1 atmosphere and 20°C).

Most of the gas consumption is realized in the periods when the air temperature is close to the minimum registered value. This observation determines the need to adjust the volume to give a greater weight to the average minimum temperature to form a correction factor when needed.

In the case of correction coefficients for temperature set on the basis of average monthly temperatures possible technical losses on the volume of natural gas for thin client (100 m3 / monthly consumption) could reach 2.8% relative value, while for large domestic customers (300 m3 / month) - a relative error in the order of 2.4%.

The possible SOLUTION is in two directions: The first option does not require capital costs but requires a change in the regulatory environment and consensus in the gas community.

We propose the basic conditions for trade in natural gas to be changed to 0^0 C. Such is the good practice studied in developed gas countries like Germany, France, Spain, the Netherlands, Italy and others.

The second option will give the most objective results with respect to the reported gas quantity both for the seller and the customers and is related to the replacement of flowmeters with those capable of performing at least temperature correction of the measured volume of gas.

We consider this correction to be key in measuring accuracy. The other pressure adjustment is also important, but the pressure at the flow meter input is a controllable quantity and the process itself is under the control of network operators.

Only in this option it is not necessary to apply a medium-weighted coefficient to all users, which will inevitably place a particular group in a more favorable situation and will be less favorable as an approach to other consumer groups.

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