

Theoretical Considerations and Experimental Measurements Concerning the Defining of Correction Coefficients in Case of Measuring Natural Gas Volumes for Household Consumers

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This paper proposes the insertion of correction coefficients for the volumes of natural gas measured with mechanical gas meters. These coefficients are based on the annual average values of the atmospheric pressure and temperature, also taking into account the altitude of the measuring point, as they were experimentally established in the laboratories of the Petrol – Gaze University in Ploiesti.

Keywords: mechanical meters, correction coefficients, natural gas

Gas distribution companies take over the natural gas from the domestic gas producers or the international market and then distribute it to the consumers. The natural gas volumes are always administrated in the normal state. The conversion of a gas volume from a certain state to the normal state is called as correction and is done using the formula

$$V_c = V \frac{Z_N}{Z} \frac{p}{p_N} \frac{T_N}{T}, \quad (1)$$

in which Z is the compressibility factor,

p – pressure, T – temperature,

Z_N – compressibility factor at the normal state ($Z_N = 1$),

p_N – normal state pressure ($p_N = 0.101325$ MPa),

T_N – normal state temperature ($T_N = 273.15$ K).

The gas taking over is realized by means of gas meters equipped with correction devices, so that all the amounts of gas are expressed in normal-state conditions. The gas is distributed both to the main industrial consumers, which usually have gas meters equipped with correction devices, and to the little household consumers, using, in more than 80% of the cases, mechanical meters which are not equipped with correction devices. In these conditions, differences between the gas volumes taken over by the distribution companies and the gas volumes distributed to the household consumers appears. As mounting gas meters with correction devices for all the household gas consumers is a long and expensive process, methods are seek to regulate the calculation of the corrected gas volumes distributed using mechanical gas meters.

This work proposes the defining of several correction coefficients for the gas volumes distributed through mechanical meters. The experimental results presented here are part of a research work performed by the Hydraulics, Thermodynamics and Reservoir Engineering Department of the Petrol – Gaze University in Ploiesti, for E-ON Gaz Romania, and are published with the permission of E-ON Gaz Romania.

Analysis of the factors affecting gas volumes correction

Correcting natural gas volumes involves the use of an analytical method which converts the gas amounts measured in various pressure and temperature conditions into normal-state volumes, for that they can be

administrated. The relationship (1) shows that the factors that influence the correction are gas temperature and pressure.

Experiments on gas temperature at the measuring point

The mechanical gas meters used to measure gas volumes for the household consumers are not equipped with temperature measuring devices. Consequently, we tried to experimentally establish the difference between gas temperature and atmospheric temperature in the measuring point. For doing this, a Regulating-Measuring Point (RMP) was equipped with several temperature transducers, in the range (-35...100) °C. The transducers used have an accuracy of 0.2 °C in the range (-5...70) °C and of 0.5 °C in the remaining interval. The transducers were placed as follows:

- T1 at the gas entrance in the niche;
- T2 in the soil, at the gas pipe burying depth;
- T3 between the adjuster and the gas meter;
- T4 after the gas meter.

The positions of the sensors can be seen in figure 1.

At the temperature sensors installed in the niche and in the soil, an absolute pressure transducer for the measurement of atmospheric pressure and a temperature transducer for the determination of atmospheric temperature were added. The data acquisition system is designed to work automatically 24 h per day. Data acquisition is performed each minute, and after 24 h a file including the data gathered is created.

The signals from the transducers are taken over by means of signal adapters with both local display and a data transmission through RS485 device, which sends the signals to a converter for serial communication RS232 equipped with an IP address, so that the data can be accessed on the Internet and the Intranet.

The measurements made between June and July 2007, for an average gas flow rate of 2.5 Nm³/h, showed that gas temperature at the RMP outlet, measured with the transducer T4, is very close to the atmospheric temperature. This fact indicates that, in the AMP, an intense heat transfer between the atmospheric air, the equipment in the niche, the pressure adjuster and the gas meter on one hand and the natural gas volume being measured and sent to the consumer on the other hand occurs.

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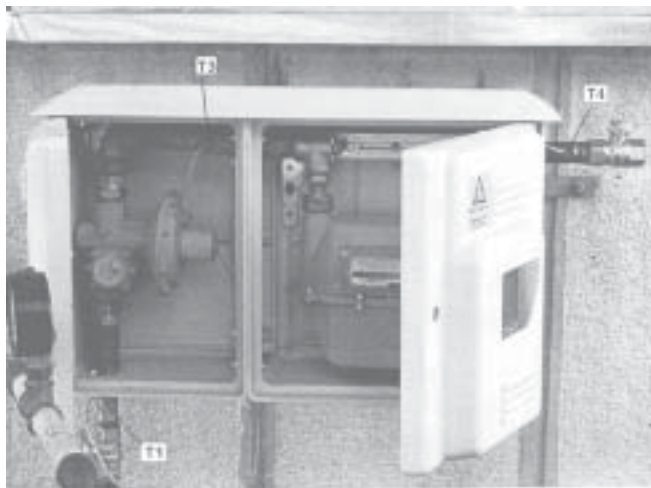


Fig. 1.

The measurements were performed in steady-state flow conditions. Actually, gas consumption is intermittent, according to consumer's needs, and consequently the temperature of the natural gas in the RMP is practically equal to the atmospheric temperature. As an example, in figures 2, 3 and 4, several daily temperature records

obtained with the device previously described are shown.

It can be seen that the temperatures recorded in various locations inside the niche closely follow the atmospheric temperature. The only temperature which remains practically constant is the one recorded in the soil, at the gas pipe burying depth. The temperature maxima which can be observed on the plots in figures 3 and 4, corresponding to the hour interval 17...19, are due to the sun exposure of the niche. During the sunny days, the niche is exposed to the sun just in this interval. It can be also noticed a significant temperature increase in the vicinity of the niche and in the gas flowing through the RMP, as a consequence of the solar radiation.

We can conclude that the temperature of the natural gas, even if it is delivered through buried pipelines, becomes practically equal to the atmospheric temperature in the Regulating-Measuring Point (RMP).

Experiments on atmospheric pressure variation

The relative (gauge) pressure of the natural gas delivered through the gas distribution systems is very low, ranging between 25 mbar and 50 mbar. Equation (1) indicates that, for establishing the correction coefficient, the absolute pressure of the natural gas is used, which represents the

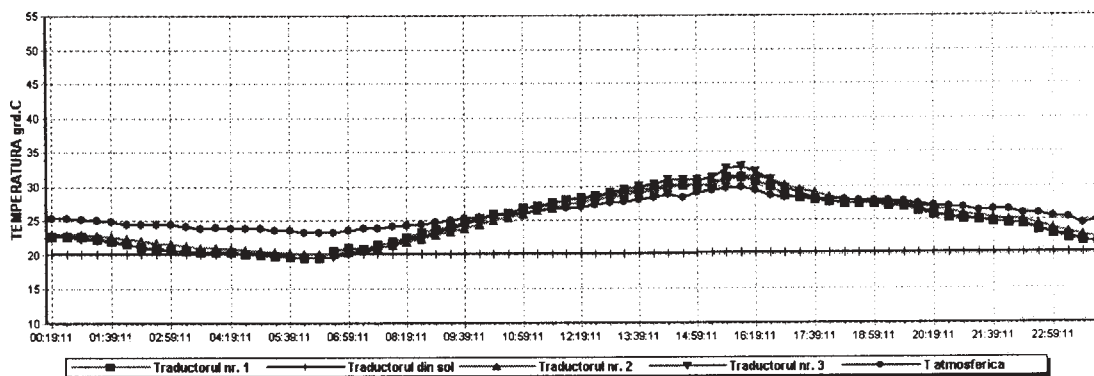


Fig. 2.

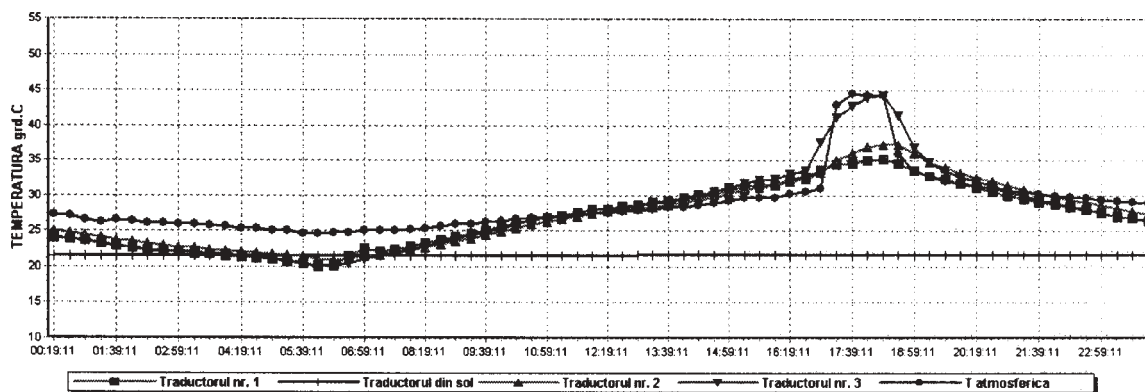


Fig. 3.

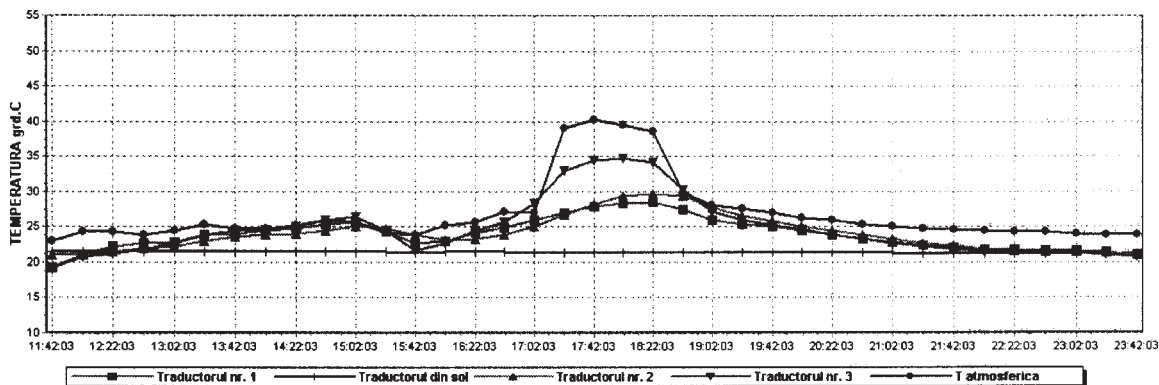


Fig. 4.

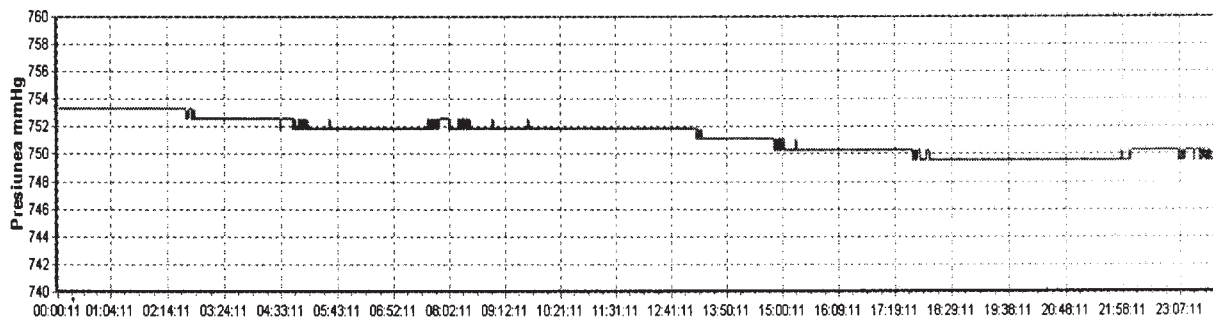


Fig. 5

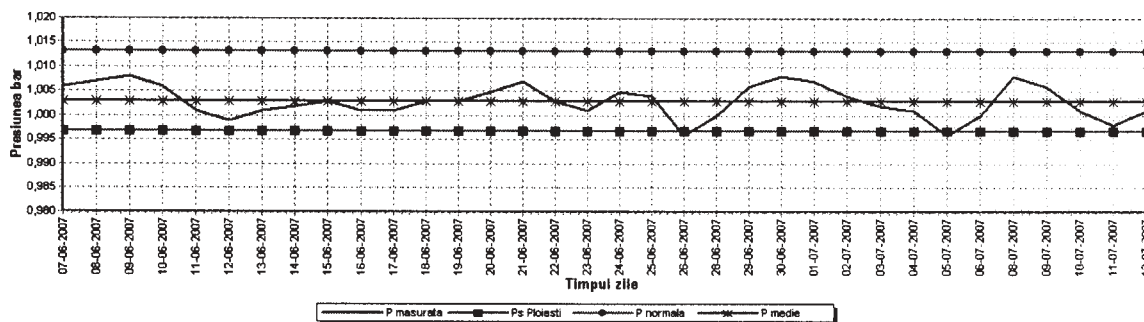


Fig. 6

sum of the atmospheric pressure and the gas relative pressure. The influence of the atmospheric pressure on the natural gas absolute pressure is significant, because of the low value of gas relative pressure. The variation of the atmospheric pressure is due to two factors; the first one (as the altitude increases, the atmospheric pressure decreases with a step of 11 mbar for each 100 m - value accepted by the National Administration of Meteorology) is predictable, and the second one (the atmospheric pressure is influenced by the movements of air masses) is at random.

The measuring system previously described was used to determine the local variation of the atmospheric pressure. The results are plotted in figure 5, which shows a daily pressure variation and figure 6 shows the natural gas variation measured on a longer time interval. In figure 6, several marks were drawn: the normal-state atmospheric pressure (1,013.25 mbar), the theoretical value of the atmospheric pressure in Ploiesti, the city where the measurements were realized and which has an average altitude of 150 m (996.75 mbar), as well as the average value of the measured pressures (1,002.94 mbar).

The variation of the atmospheric pressure during the time interval considered for drawing the plot in figure 6 develops in a range bigger than the theoretical pressure value calculated for the city in which the measurements are performed. If the atmospheric pressure is recorded during a longer time interval, which includes several seasons, the average value obtained will be very close to the theoretical value calculated as a function of the altitude.

Defining the correction coefficients

When using temperature-correction gas meters, the correction of gas volumes according to the ambient temperature is done in real time, together with their metering. Since the gas meter is not equipped with a pressure gauge, the absolute pressure of the gas flowing through the meter is approximated by the sum of the normal atmospheric pressure and the gas relative pressure.

The mechanical flow meters, used on a large scale for the household gas consumers, can measure neither the pressure nor the temperature necessary to correct the volumes of gas consumed. Consequently, correction

coefficients based on average values of the natural gas parameters established during long time intervals (preferably, one year) have to be established.

According to equation (1), the following correction coefficients are defined:

K_T - thermal correction coefficient, as

$$K_T = \frac{T_N}{T}, \quad (2)$$

K_Z - compressibility correction coefficient, as

$$K_Z = \frac{Z_N}{Z}, \quad (3)$$

and K_p - pressure correction coefficient, as

$$K_p = \frac{P}{P_N}. \quad (4)$$

Considering the pressure variation with the altitude, the pressure correction coefficient can be expressed as

$$K_p = \frac{P}{P_N} = \frac{P_N + \Delta p_G - \Delta p_H}{P_N}, \quad (5)$$

where Δp_G is the gas relative pressure in the pipeline, and Δp_H - the pressure variation due to the altitude. If the value of 11 mbar at each 100 m for the pressure variation with altitude is accepted, the relationship (5) becomes

$$K_p = 1 + \frac{\Delta p_G - 0,11H}{1,013,25}, \quad (6)$$

with Δp_G expressed in mbar, and H - altitude of the measuring point, in meters.

The notations previously introduced can be used to define a global correction coefficient as

$$K_c = K_Z K_T K_p. \quad (7)$$

In order to evaluate the correction coefficients we used the following assumptions:

- for the temperature correction coefficient, the gas temperature in the RMP was supposed to be equal to the atmospheric air temperature, so that, for the calculations, the monthly averaged temperatures obtained from the National Administration of Meteorology were used;

- for the pressure correction coefficient, equation (6) was accepted;

- for the compressibility correction coefficient, a constant value equal to 0.9977 was used, because of the low value of gas relative pressure in the distribution networks, which determines the compressibility coefficient

Table 1

District	H_{med} m	P_{atm} mbar	T_{med} °C	T_{med} K	P_{gaz} mbar	K_T	K_p	K_z	K_c	ε_m %
Alba	246	986,19	9,37	282,52	37,92	0,96682	1,01071	0,9977	0,97493	-2,57
Arad	116	1000,49	9,92	283,07	30,00	0,96497	1,01701	0,9977	0,97913	-2,13
Bacău	184	993,01	9,30	282,45	30,00	0,96707	1,00963	0,9977	0,97414	-2,65
Baia Mare	216	989,49	9,33	282,48	35,00	0,96696	1,01109	0,9977	0,97544	-2,51
Bihor	136	998,29	9,89	283,04	30,00	0,96505	1,01484	0,9977	0,97712	-2,34
Bistrița	366	972,99	8,28	281,43	40,00	0,97057	0,99974	0,9977	0,96809	-3,29
Botoșani	161	995,54	9,22	282,37	30,00	0,96736	1,01213	0,9977	0,97684	-2,37
Caraș Severin	279	982,56	9,70	282,85	40,00	0,96571	1,00919	0,9977	0,97234	-2,84
Cluj	410	968,15	8,39	281,54	30,00	0,97019	0,98510	0,9977	0,95354	-4,87
Harghita	661	940,54	5,38	278,53	35,00	0,98067	0,96278	0,9977	0,94200	-6,15
Hunedoara	240	986,85	9,40	282,55	39,17	0,96673	1,01260	0,9977	0,97666	-2,38
Iași	102	1002,03	9,88	283,03	30,00	0,96511	1,01853	0,9977	0,98074	-1,96
Mureș	308	979,37	8,61	281,76	35,00	0,96945	1,00111	0,9977	0,96829	-3,27
Neamț	314	978,71	8,73	281,88	30,00	0,96902	0,99552	0,9977	0,96246	-3,90
Satu Mare	123	999,72	9,28	282,43	35,00	0,96713	1,02119	0,9977	0,98535	-1,48
Sibiu	443	964,52	8,38	281,53	35,00	0,97025	0,98645	0,9977	0,95490	-4,72
Suceava	350	974,75	8,04	281,19	30,00	0,97140	0,99161	0,9977	0,96104	-4,05
Timiș	86	1003,79	10,42	283,57	40,00	0,96327	1,03014	0,9977	0,99002	-1,00
Vaslui	116	1000,49	9,68	282,83	30,00	0,96576	1,01701	0,9977	0,97994	-2,04
Zalău	295	980,80	9,60	282,75	35,00	0,96605	1,00252	0,9977	0,96625	-3,49
Annual average value for the analyzed districts:						0,967977	1,00544	0,9977	0,970961	-3,005

to be close to the unity.

For 20 districts, the values of the individual correction coefficients and of the global correction coefficient were calculated. To evaluate, as percents, the effect of the correction on gas volumes, the relative error committed if non-applying the correction, defined as

$$\varepsilon_m = \frac{V - V_C}{V_C} \cdot 100 \%$$

was also calculated. The results are listed in table 1.

Conclusions

The measuring of natural gas consumed by the household users is associated with errors, due to the lack of correction. The mechanical gas meters cannot measure gas parameters (temperature and pressure) and atmospheric temperature, which leads to a difference between the gas volumes delivered through these meters and the gas volume balance of the distribution company, the last being done only with corrected gas volumes. For diminishing these differences, we introduce the correction coefficients based on average values of the atmospheric parameters. The example in table 1 presents the values of the correction coefficients calculated using the method previously described.

By analyzing the results, one can observe that the value of the global correction coefficient varies according to the local conditions specific to each zone. The defining of a zonal correction coefficient for the gas volumes measured mechanically is a difficult task. Moreover, for elaborating a regulating act, specialists seek for a global, national-scale, solution. The results shown in this paper can constitute the basis for the deriving of a global correction coefficient applicable to the gas volumes distributed to household gas consumers all over the country and stated in a regulatory document.

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