

Considerations on the Errors Associated to the Measuring of the Amounts of Natural Gas Delivered to Household Consumers

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This work deals with the evaluation of the error level occurring at the measuring of natural gas volumes supplied to the household users. The main factors that influence the measuring errors are one by one analyzed, and then a methodology for estimating measuring error level is introduced. The results are experimentally confirmed by the data obtained from the regulate-measuring points equipped with temperature-correction devices.

Keywords: measuring error, natural gas, temperature correction

The natural gas distribution companies operate, according to the regulations in force, only with volumes of gas expressed in standard-state conditions. The numerical procedure for converting the gas volumes delivered at a pressure p and a temperature T into standard-state volumes ($p_s = 0,101325$ MPa, $T_s = 288,15$ K) is called as correction and the gas volumes accordingly calculated are named corrected volumes. The correction is performed with the formula

$$V_c = V \frac{Z_s \cdot p \cdot T_s}{Z \cdot p_s \cdot T}, \quad (1)$$

in which V is the measured volume, p - the delivered gas absolute pressure, T - the delivered gas temperature, Z - the compressibility factor at pressure p and temperature T , and Z_s - the compressibility factor at the standard state, which is considered as equal to unity.

The gas distributors receive the natural gas from their purveyors - in Romania, the main purveyors being Transgaz and Petrom - and then they send the gas to the consumers. The volumes of gas received in the RMSs (Regulating-Measuring Stations) are corrected at the standard state. For more than 80% of the small consumers (mainly, the household ones), the gas volume measurement is realized using mechanical meters which cannot apply corrections. Consequently, there are differences between the corrected gas volumes received through the RMSs and the gas volumes measured at the consumers with mechanical gas meters.

The consumer receives a gas volume V which comes from a corrected gas volume V_c took over the RMS. Between the two gas volumes a difference appears. If the gas volumes delivered to consumers are corrected to the standard state, then the balance should be set and the volumes received through the RMSs should be equal to the corrected volumes delivered. For applying the correction to a gas volume, its absolute pressure and temperature have to be measured, and the meter has to be equipped with an electronic device able to numerically convert these signals, to correct the gas volume measured during a short time interval, and then to store the resulting data for at least one month, which represents the invoicing period.

In fact, the gas meters used now are mostly mechanical devices. New electronic gas meters, equipped with temperature correction devices, which can apply corrections to the gas volumes delivered during small time steps and then store these data for time periods ranging

between one and three months appeared on the market and begun to be installed to the gas consumers during the last few years.

Taking into account that the weight of the gas meters with correction devices is smaller than 20%, this paper introduces an attempt to establish the error level induced by the use of mechanical gas meters. We will calculate the error due to the lack of correction using the formula

$$\varepsilon = \frac{V - V_c}{V_c} \cdot 100. \quad (2)$$

Analysis of the factors which determine gas flow rate differences

On the basis of the gas analysis bulletins at the inlet of the RMSs, the values of the compressibility factor at a relative pressure of 50 mbar and various temperatures in the range -20 °C ... $+40$ °C were calculated. These pressure and temperature values were chosen because they are close to those encountered when gas is delivered to the consumers.

For calculating the compressibility factor, specialized software, elaborated by the Hydraulics, Thermodynamics and Reservoir Engineering Department team, was used. The software allows the determining of the compressibility factor as a function of the gas mixture composition, using the following five correlations: *Hall-Yarborough*, *Dranchuck-Abu Kassem*, *Dranchuck Purvis Robinson*, *Papay* and *Istomin*. These are the best correlations mentioned in the literature and they get the most accurate results.

In table 1, the values for the analysis bulletin concerning the gas taken from Caransebes RMS are presented. The values of the compressibility factor Z are denoted as follows: Z_1 - *Hall-Yarborough* correlation; Z_2 - *Dranchuck-Abu Kassem* correlation; Z_3 - *Dranchuck Purvis Robinson* correlation; Z_4 - *Papay* correlation, and Z_5 - *Istomin* correlation.

The result concerning the influence of the compressibility factor, plotted in Figure 1, show that, for the gas delivery pressure and various temperatures, the relative error is less than 0.17%, which is insignificant for the gas volume correction.

The experiments realized by the Hydraulics, Thermodynamics and Reservoir Engineering Department indicated that, during the gas flow through the regulating-

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Table 1
COMPRESSIBILITY FACTOR VERSUS TEMPERATURE, AT THE PRESSURE $p = 0.101325$ MPa

$T, ^\circ\text{C}$	Z_1	Z_2	Z_3	Z_4	Z_5
-20	0.9965	0.9949	0.9966	0.9937	0.9957
-15	0.9967	0.9951	0.9968	0.9938	0.9959
-10	0.9969	0.9953	0.9970	0.9939	0.9962
-5	0.9971	0.9955	0.9972	0.9940	0.9964
0	0.9972	0.9956	0.9973	0.9941	0.9966
5	0.9974	0.9958	0.9975	0.9942	0.9968
10	0.9975	0.9959	0.9976	0.9943	0.9970
15	0.9977	0.9960	0.9977	0.9944	0.9973
20	0.9978	0.9962	0.9979	0.9945	0.9974
25	0.9979	0.9963	0.9980	0.9946	0.9976
30	0.9981	0.9964	0.9981	0.9947	0.9978
35	0.9982	0.9965	0.9982	0.9948	0.9980
40	0.9983	0.9966	0.9983	0.9949	0.9981

measuring point mounted at the gas consumer (which consists in a niche containing the regulator and the gas meter), an intense heat transfer occurs between the gas, the apparatuses and the atmospheric air, so that the natural gas temperature in the measuring point becomes practically equal to the atmospheric temperature.

An important problem for the correction is the interval in which the volume of gas delivered is recorded. If the gas meter used is a mechanical device, the interval between two readings is, usually, of 30 days. This large time interval makes the calculation of the correction factor a difficult task, because the temperature varies widely during this interval. That is why the error due to the lack of correction has to be estimated. Both when using temperature-correction gas meters and when numerically simulating for estimating the correction factor, the corrected volume is calculated as

$$V_c = \sum_{i=1}^N \Delta V_{c_i}, \quad (3)$$

$$\Delta V_c = \Delta V \frac{p_s + \Delta p_G}{p_s} \frac{T_s}{t + 273}. \quad (4)$$

For short time steps (20 s in the case of temperature-correction gas meters or 1 minute for the numerical simulations) the elementary gas volume consumed DV is calculated, then the corrected value of this volume is determined with equation (4), considering that the temperature t is constant, and finally the elementary volumes are summed with relationship (3).

An important aspect is the dynamics of the gas volumes consumed by the subscribers, which has a random variation. For establishing the influence of the temperature and the consumption dynamics, a gas volume of 16 m^3 consumed during one day, at various hour intervals, was chosen. The temperature distribution for this example corresponds to a month in winter. The difference between the corrected and the uncorrected gas volumes and the daily or monthly average error were calculated.

The plot in the top of figure 2 shows the temperature variation during a winter day, and the plot in the bottom is the uniform distribution of a 16 m^3 gas volume along the 24 hours interval. The gas volumes consumed each hour were corrected and the total corrected volume was compared to the consumed volume, the relative error being of -5.98% . Then, a new value of the corrected volume was established, using the average temperature, and a value of 17 Nm^3 was found, which is comparable to the 16.98 Nm^3 previously calculated.

Figures 3 and 4 present the same 16 m^3 daily gas volume consumption, for the same temperature distribution, but for different dynamics. One can see that the errors are now changed. This fact is due to the consumption dynamics combined to the temperature evolution. The correction is applied only when the gas volume delivered is different from zero, so the correction factor corresponds to various temperatures and the error values reflect this change.

In figure 5, the daily gas consumption of 16 m^3 with the hourly distribution from figure 4 was considered, but the simulation interval was extended to 30 days, using an actual temperature variation, obtained from the archive of a

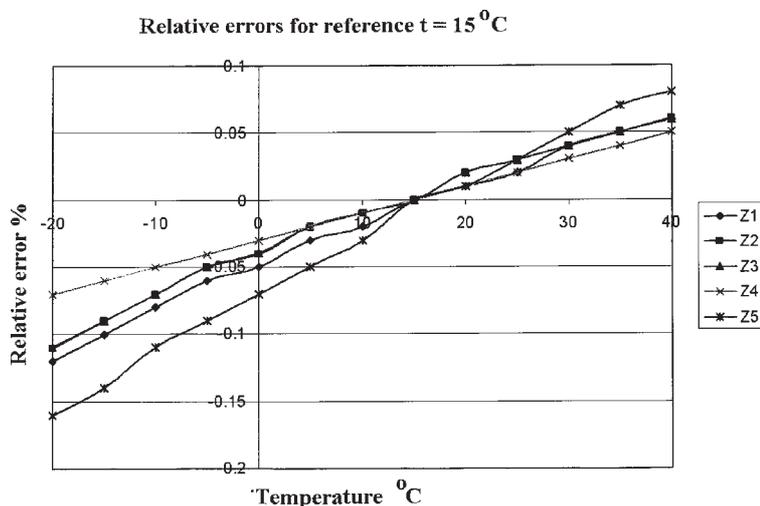


Fig. 1. Variation of the Z factor as a function of temperature

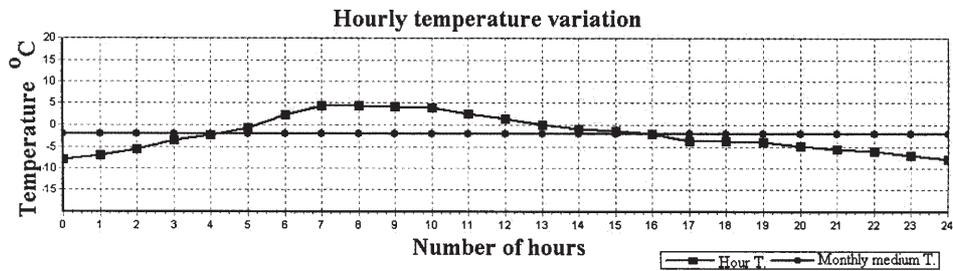


Fig. 2. Delivered volume: 16m^3 ; corrected volume: 16.98Nm^3 ; error: -5.98%

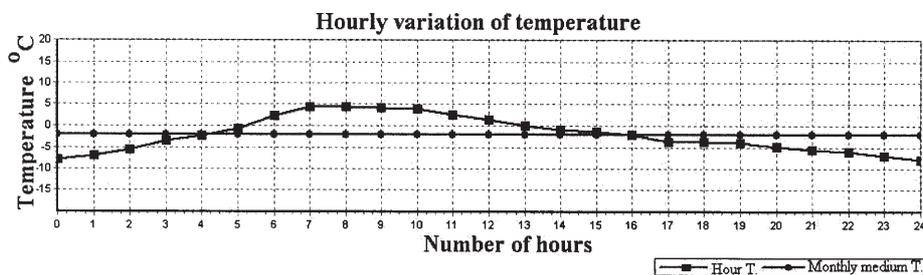
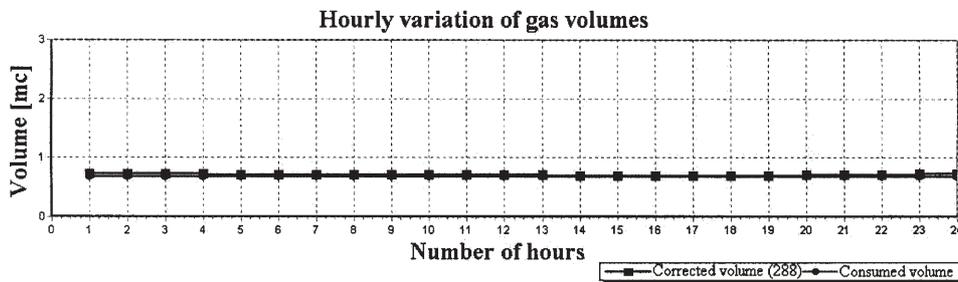


Fig. 3. Delivered volume: 16m^3 ; corrected volume: 17.47Nm^3 ; error: -6.63%

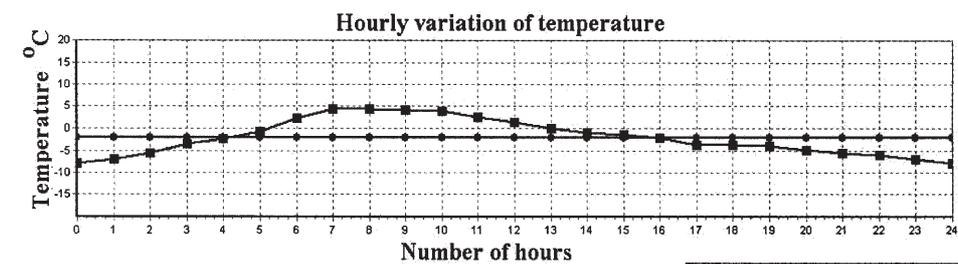
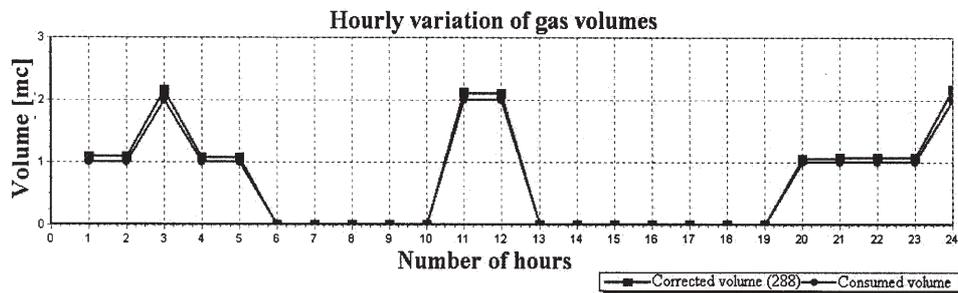
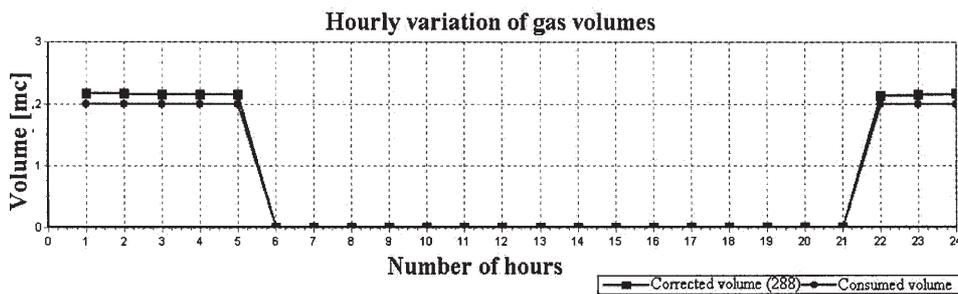


Fig. 4. Delivered volume: 16m^3 ; corrected volume: 17.25Nm^3 ; error: -7.26%



temperature-correction gas meter. For figure 6, the daily consumption scheme is identical to the one in figure 4.

The simulation shows that the error tends to grow when the time interval increases.

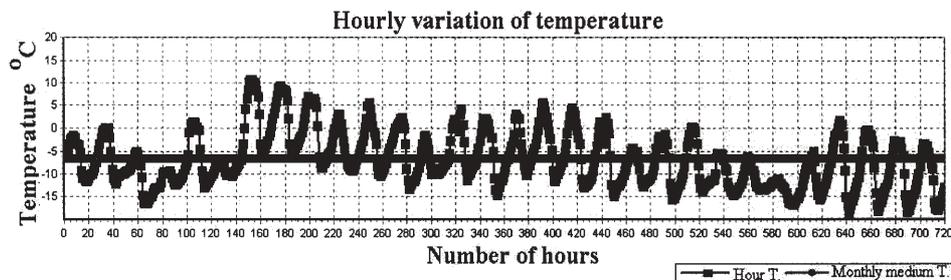


Fig. 5. Delivered volume: 480m³; corrected volume: 512.16 Nm³; error: -7.90%

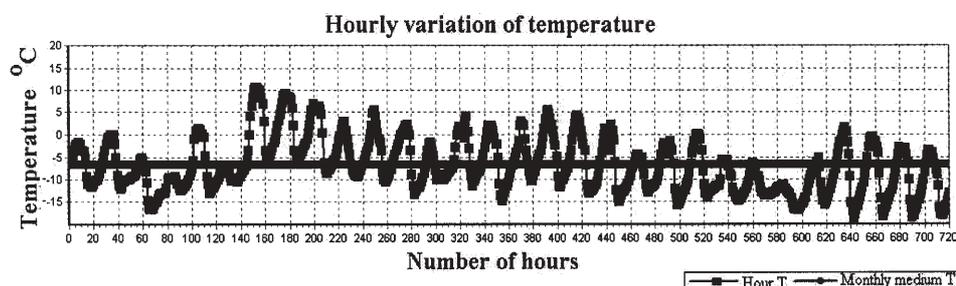
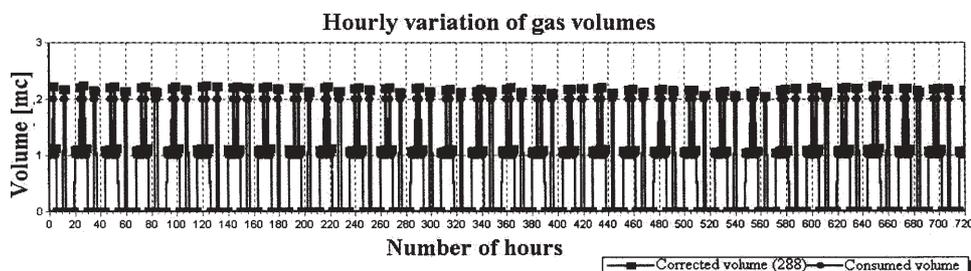


Fig. 6. Delivered volume: 480m³; corrected volume: 512.16 Nm³; error: -8.623%

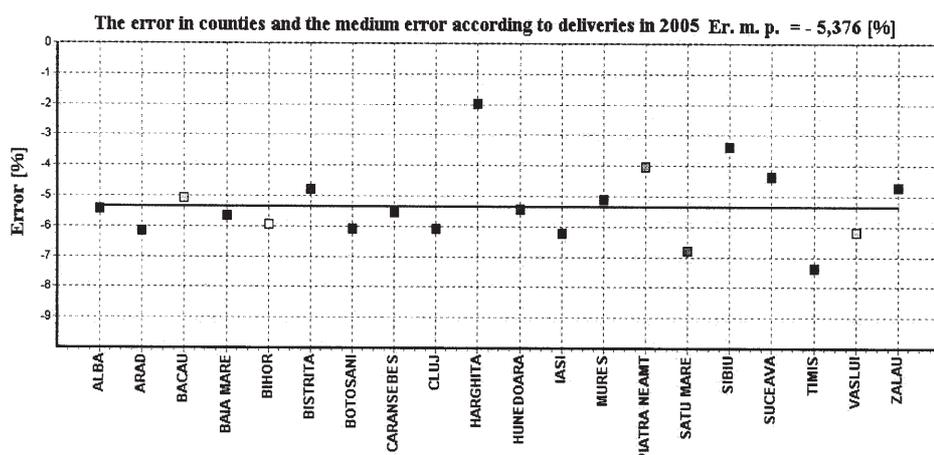
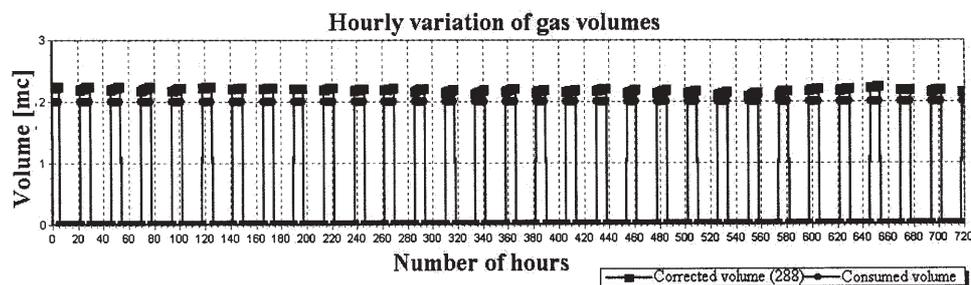


Fig. 7. The weighted average error as a function of the volumes delivered by the gas distribution sectors during the year 2005; the weighted average value of the error for the whole system is - 5.37%

The analysis of the data offered by E-ON Gaz România for the year 2005 and the numerical simulation results led to an average value of the measuring error due to the use of mechanical gas meters equal to 5.376%, according to figure 7; 3% of this error is caused by the atmospheric temperature variation, and the rest is due to the dynamics of the gas consumption.

Verification of the estimation level

For verifying the methodology used to estimate the errors as well as the error level found, we used the data gathered from the archives of the correction gas meters, which were put at our disposal by E-ON Gaz România. The data collected from two of these archives are plotted in figures 8 and 9. The records of the gas volumes measured with mechanical meters and of the corrected gas volumes are both included.

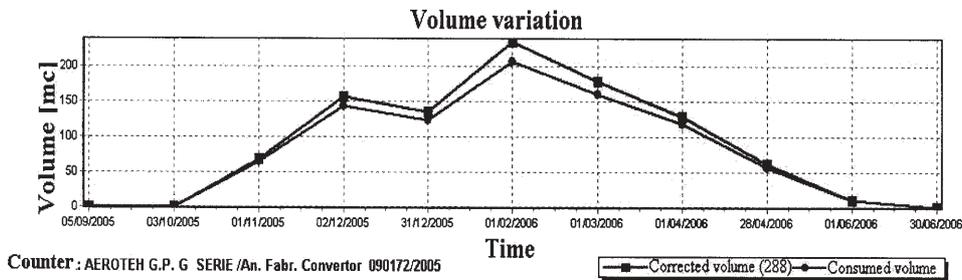


Fig. 8. The average value of the error for the corresponding time interval is - 8.59%

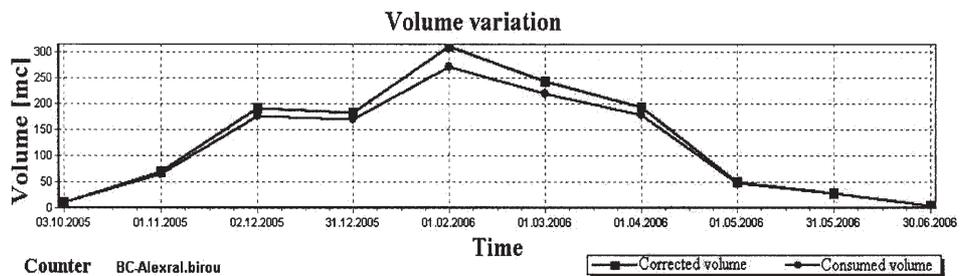
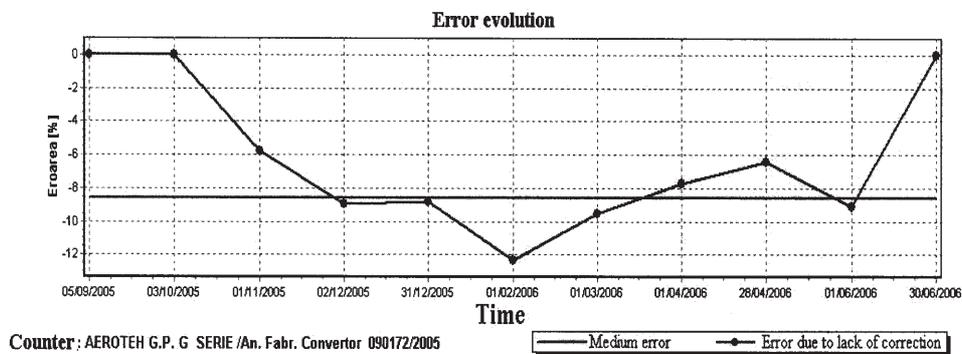


Fig. 9. The average value of the error for the corresponding time interval is - 7.21%

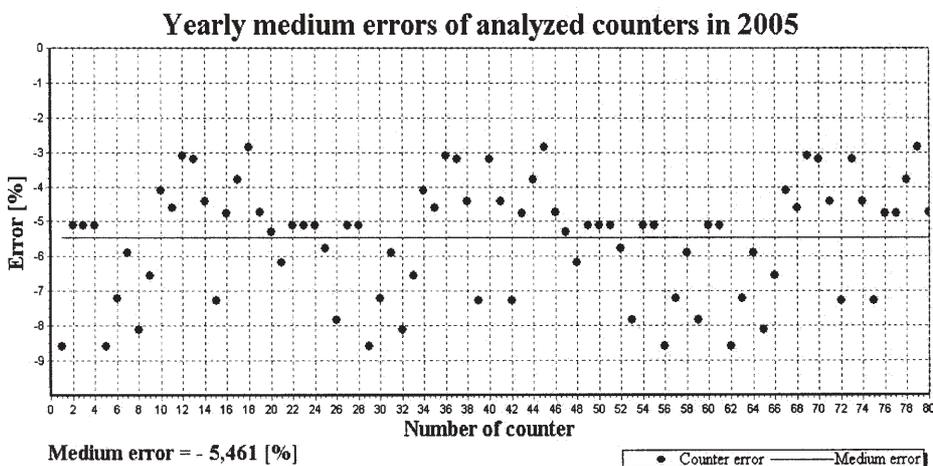
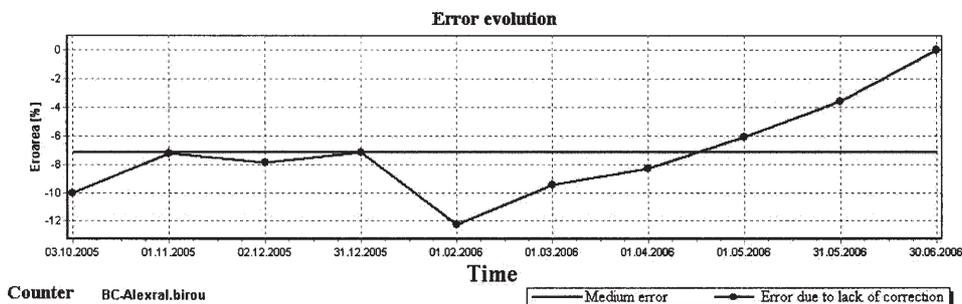


Fig. 10. The average value of the error for the year 2005 as calculated from the data measured by the correction gas meters (-5.46%)

Taking into account that the sampling interval is 20 seconds, these records include both the influences of the

temperature variation and the consumption evolution. The two examples indicate an increase in the error value during

the cold months of the year.

The analysis of the data obtained from the correction gas meters yielded an average value of the error for the year 2005. The results are partially presented in figure 10.

The values of the error estimated for the year 2005 and calculated from correction gas meters are very close; this fact validates the procedure proposed in this work.

Conclusions

The data presented in this paper own to and are published with the permission of E-ON Gaz România. These data were gathered during a research program developed by a team from the Hydraulics, Thermodynamics and Reservoir Engineering Department in the Petroleum - Gas University Ploiesti for E-ON Gaz România, as part of a research contract.

The gas distribution sectors in Romania are equipped, in 80% of the cases, with mechanical gas meters. A future solution, which implies high costs, is to replace the mechanical gas meters by temperature-correction gas meters. The use of mechanical meters implies to invoice, for the household consumers, the uncorrected gas

volumes. Since all the amount of gas received by a gas distribution sector is expressed as a corrected volume, the volumetric and financial balances are not set. The previous considerations indicate the usefulness of a rigorous methodology of estimating the errors associated to the use of mechanical gas meters for the household consumers, as a basis for the decisions of the National Regulatory Authority in the Natural Gas Domain.

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