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Inefficient Charging for Delivered Gas by Local Gas Distributors

In this region, especially in Serbia, common belief is that local distributors of gas used by households don't charge for gas properly. It is suspected that there are two sources for improper ways of gas charging. Local distributors charge for delivered gas only, according to flow rat but not according to gas quality. It is usual that local distributors deliver gas of different quality than one signed in contract. In this work will be considered only one of aspects inefficient charging for delivered gas by local gas distributors, which is connected to variable atmospheric pressure. There is doubt, that local distributors make mistakes during accounting for delivered gas to costumers in regard atmospheric pressure. At the beginning of every investigation, problem has to be located and recognized. Authors are going to collect as much as possible available data, to elaborate and analyze data by scientific methods and to represent conclusions. So, the aim of this work is to diagnose current state and to approve or disapprove above mentioned suspicions. In our region this theme is very interesting, both because of energy efficiency and air pollution control. In this way both consumer and distributor will know, how mush energy they have really spent.

1. Introduction

Gas distributors charge for standard qubic meter of delivered gas. Standard cubic meter is gas volume (II gas group, subgroup L, according to JUS H.F1.001) of a cubic meter on the standard conditions:

- atmospheric pressure on see level p_{Sa} = 1,01325 bar;
- temperature 15^{0}C, t_s = 288,15 K;
- lower heat power H_{Sd} = 33.338,35 KJ/m^3.

Standard cubic meter actually presents mass flow. There is difference between standard conditions and delivered ones. Delivered conditions have differences in temperature, pressure and gas quality than that in standard ones. Therefore, it is necessary reduce delivered to standard conditions. Common way of reducing delivered to standard conditions is by means of correction factor:

$$f = \frac{(p_a + p_m)}{p_{Sa}} \frac{(T_S)}{(273.15 + t)} \frac{H_d}{H_{Sd}}, \qquad (1)$$

where are:

p_a [bar] - atmospheric pressure on local altitude,

$p_m = 0.022$ [bar - gauge pressure ,

$p_{Sa} = 1{,}01325$ [bar - atmospheric pressure on see level,

t [°C - measured mean temperature,

H_d [kJ/m^3 - measured lower heat power,

H_{Sd} [kJ/m^3 - lower heat power on standard condition.

In this work will be considered only one of aspects inefficient charging for delivered gas by local gas distributors, which is connected to variable atmospheric pressure. So, hypothesis of this work is doubt, that local distributors make mistakes during accounting for delivered gas to costumers in regard atmospheric pressure.

2. Analysis of problem

In this work authors were only interested in the part of correction factor, which deal with reducing absolute (measured) pressure to standard atmospheric pressure.

$$f_1 = \frac{p}{p_{Sa}} = \frac{p_a + p_m}{p_{Sa}}, \qquad (2)$$

As just shown above, absolute pressure consists of atmospheric and gauge pressure. Both of them vary during the time and distinguish than standard atmospheric pressure. Household gas meter with blow pipe is the most incorporated type of gas flow rate meter both in Serbia and region. All of them are equipped with pressure regulator, but they haven't got pressure compensation, which would be vary expensive solution for household gas meter.

The problem with gauge pressure is only partly solved by pressure regulator, which decreases gauge pressure from gas network to $p_m = 18 \quad 25$ mbar (allowed pressure in household gas installation). Regulated value of gauge pressure is usually adjusted at $p_m = 22$ mbar, which can't be considered as constant value, because it depends on accuracy of regulator and consumers consumption. For type of household gas meter with blow-pipe G4 , adjusted value of regulated gauge pressure p_m varies from 19 to 24 mbar.

Local gas distributors for monthly account of delivered gas to customer use gauge pressure $p_m = 22$ mbar, without correction with seen deviation of 20 %. Of course, this is a roughly estimated deviation, which can be only included by more detailed statistical analysis.

Change of local atmospheric pressure for 10 mbar induces error in measuring of flow rate for roughly 1%, but in literature, we can usually find that delivered gas a little depends on atmospheric pressure, because atmospheric pressure insignificance changes in a area.

$$\frac{p_{Sa} - p_a}{p_{Sa}} \cdot 100\% = \frac{1013,25 - 1003,25}{1003,25} = 0,987\% \quad 1\%$$

This way of meaning is connected to local gas distributors, which believe that atmospheric pressure is slowly and only changed by altitude. Therefore, most of them for monthly accounting of delivered gas use atmospheric pressure at local altitude.

3. Experimental/theoretical investigation of gas volume dependence on atmospheric pressure

3.1 Example of incorrect accounting local atmospheric pressure

The typical example of incorrect accounting of atmospheric pressure by local gas distributors was registered in DP "Energetika", Kikinda. For accounting delivered gas to consumers, they use atmospheric pressure at altitude of Kikinda $p_a = 1,013$ bar. This atmospheric pressure is roughly equal atmospheric pressure on standard conditions $p_a \approx p_{Sa} \quad 1.01325$ bar. In this way, importance of atmospheric pressure is minimized.

Kikinda is placed on the north of Serbia, in plain at altitude 81 m, where many other towns have the same or vary similar altitudes. So, this mean of accounting local atmospheric pressure is commonly use in this region, as well as in the whole country.

3.2 Local character of atmospheric pressure

Atmospheric pressure is constant value in horizontal plane stilly air, but generally it depends on air height. This dependence comes from:

- with growth of altitude, air column (which vertical weights) becomes shorter.
- due to gravitation, which pulls the weightier particles of air toward the Earth,

air density becomes smaller with growth of altitude, as well as atmospheric pressure.

Atmospheric pressure doesn't change equally with growth of altitude, it decreases faster in lower layers then in higher ones. This happens due to decreasing air density with altitude. Besides, this decreasing of atmospheric pressure depends on temperature of air column as well as quality of air. Therefore, we can't only use altitude for calculating of atmospheric pressure, the temperature and quality of air (which are related to local conditions) must be included.

Babinea's equation uses for practical calculating of atmospheric pressure

$$p_{1a} + p_{2a} \quad 16000\ (1 \quad \alpha\, t)\ \frac{p_{1a} - p_{2a}}{h}, \qquad (3)$$

Mean temperature

$$t = \frac{t_1 + t_2}{2}, \qquad (4)$$

where are:

p_{1a}, p_{2a} [Pa] atmospheric pressures which correspondent altitudes h_1 and h_2;

p_{Sa} [Pa] standard atmospheric pressure;

h [m] difference altitudes h_1 and h_2;

t [K] mean temperature;

t_1, t_2 [K] temperatures which correspondent altitudes h_1 and h_2;

α [-] volumetric dilatation coefficient $\alpha = \frac{1}{273}$.

As you could see, quality of gas doesn't exist in mentioned equation, which influence decreasing atmospheric pressure with altitude. Therefore, mentioned equation can be only used for altitudes from 1500 to 2000 m. There is similar Laplase's equation which partly includes influence quality of air, via modification of volumetric dilatation coefficient $\alpha = 0{,}004$.

$$p_{1a} + p_{2a} \quad 64 = \left(250 \cdot t\right) \frac{p_{1a} - p_{2a}}{h} + , \qquad (5)$$

Doubtlessly, atmospheric pressure has really local character, and can't be only estimated by diagrams.

3.3 Variable nature of atmospheric pressure

Daily changes of atmospheric pressure distinguish than daily changes of any other metrological element (radiation, temperature etc.). Other metrological elements have only one maximum and minimum value during the day, while atmospheric pressure has two maximal and two minimal values during the day.

Atmospheric pressure grows up from the morning until 9-10 h and decreases after that until 15-16 h; atmospheric pressure grows up after that until 21-22 h and decreases again until 3-4 h, when it grows up again. Thence, atmospheric pressure has two maximal values during the day at 9-10 h and 21-22 h, and two minimal values during the day at 15-16 h and 3-4 h. This way of atmospheric pressure changing is upset only by cyclone and anticyclone.

Annual changes of atmospheric pressure depend on temperature of air. Opposite to daily changes, these changes are less variable during the year in Equator area, where temperature has minimum variation. When you go away from Equator, temperature as well as atmospheric pressure vary more and more.

Annual amplitude of atmospheric pressure above ocean is less than above land. Besides, changes of atmospheric pressure are vice versa above ocean than above land. For example, atmospheric pressure has in the inside of continent maximum in the winter and minimum in the summer, while above ocean is vice versa. It is interesting that in the West Europe in the winter continental conditions prevail, while in the summer ocean conditions prevail.

3.4 Proposal for better accounting of local atmospheric pressure

In the Table 1. are given data of Republic Hydrometeorological Service of Serbia for average daily, monthly and annul atmospheric pressures. Indeed, we can see that atmospheric pressure is variable, which changes per day and per month. For example, during the March atmospheric pressure varies from 996.8 to 1016.2 mbar, while during the year it varies from 999.5 to 1012.6 mbar. So, accounting with atmospheric pressure $p_a = 1013$ mbar, which is obtain by altitude of Kikinda is unacceptable.

In the Figure 1. we can see accuracy of atmospheric pressure accounting. Account atmospheric pressure is practically constant, while local atmospheric pressure is variable, which varies during the year. Difference between curves of account and local atmospheric pressure is account error, which is of course paid by customers.

Authors consider that in the near future, variable and local nature of atmospheric pressure must be included into accounting of delivered gas. Great potential of Republic Hydrometeorogical Service should be used in solving this problem. Republic of Serbia established very good network of metrological stations, Figure 2., which efficiently covers all local gas distributors in Republic of Serbia. Therefore, all gas distributors should be use monthly average atmospheric pressure data of local meteorological stations, and in that way decrease error due to existing gas accounting. Model of accounting average local atmospheric pressure, which was presented in the Table 1., should be established as a rule. Data of monthly atmospheric pressure is very suitable, because of monthly changes of atmospheric pressure and monthly accounting of atmospheric pressure by local gas distributors. Every month, local gas distributors should take data from local meteorogical stations, and in that way decrease calculation error and engage all available local meteorological stations.

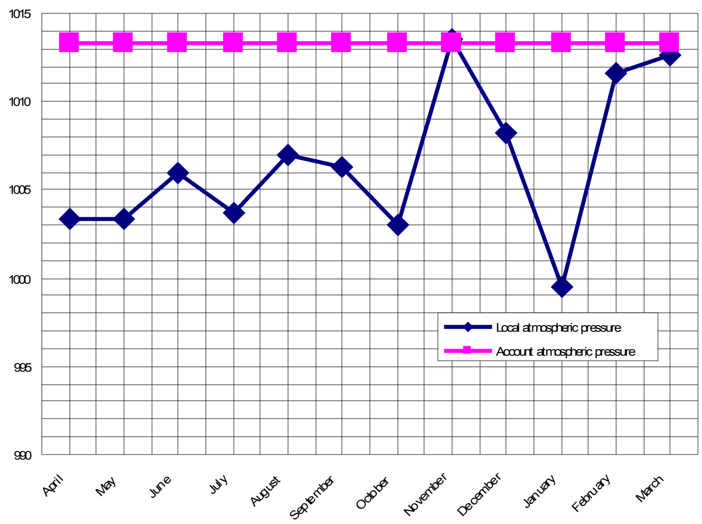

Figure 1. Difference between local and account atmospheric pressure

Table 1.I. Local atmospheric pressure in Kikinda during period of a year (2004/2005)

	April	May	June	July	August	Sept.
1	1005.6	998.8	1006	1005.9	1004.7	1009.6
2	1010.5	1000.8	1004	1004.5	1002.8	1011.4
3	1014.3	1000.9	1004.5	1008.4	1001.5	1014.4
4	1013.1	994.5	1006.5	1010.7	1001.5	1014.4
5	1005.6	988.8	1003.6	1008.5	1002.1	1014.6
6	1000	986	1004.5	1006.6	1003.2	1017.1
7	995.4	992.5	1009.5	1009	1004.3	1017.1
8	1004.8	996.9	1011	1005.9	1002.9	1011.8
9	1003	997.8	1009.7	1002	1002.9	1017.6
10	999.6	999.6	1011	1001.7	1004.4	1019.4
11	1003.7	1004.4	1006.8	1001.1	1004.5	1016.6
12	1006.7	1003.1	1006.4	1000	1002.1	1009.4
13	999.6	995.8	1008.2	999.4	999.7	1009
14	1007	1005.7	1012.4	1005.3	1002.8	1009.4
15	1017.6	1011.4	1007.3	1006.1	1007	1006
16	1011.6	1006.3	1001.5	1008.6	1008.1	1010.1
17	999.2	1010.2	1004.2	1010.6	1007	1015.5
18	993.4	1013	998.2	1010.1	1006.6	1014.5
19	992.6	1010.2	998	1008.2	1004.8	1010.1
20	997.6	1007.9	996.1	1006.8	999.9	1009.3
21	1005.5	1003.7	1004.3	1006.6	999.4	1004.5
22	1004.4	1002.4	1009.8	1007.1	1007.2	1006.1
23	1002.7	1007.6	996.1	1006.8	999.9	1009.3
24	1003.8	1011	1002.7	1003.9	1010.3	998.8
25	1007.7	1011.7	1004.9	1001.5	1004.7	1001
26	1008.2	1010.3	1012.2	999.4	996.7	1006.2
27	1006.7	1008.7	1011.8	1000.4	1002.6	1009
28	1005.3	1008.9	1010.1	1003.3	1007	1011.8
29	1001.3	1010.5	1011.1	1004.6	1007.8	1008.8
30	998.1	1010.1	1010.7	1006.6	1006.7	1010.3
31		1007.2		1005.9		
Average values of local atmospheric pressure per months						
	1003	1003	1006	1004	1007	1006,2

Average year value of local atmospheric pressure p_a=1006.49

Annotation: local atmospheric pressure p_a [mbar]

Table 1.II. Local atmospheric pressure in Kikinda during period of a year (2004/2005)

	October	Nov.	Dec.	January	Feb.	March
1	1012.9	1009.1	1008.4	1014.8	1001.9	1007.2
2	1012.8	1010.1	1005.3	1010.4	1009.5	1005.2
3	1014.1	1015.6	1009.6	1015.8	1013.5	1006.6
4	1015.7	1017.1	1019.8	1014.4	1020.1	1000.2
5	1014.8	1012.9	1020.5	1016.8	1021.8	992.4
6	1013.4	1008.5	1017.4	1016.3	1025.8	997.9
7	1010.3	1004.5	1022.7	1024.1	1028.9	1004.3
8	1007.7	997.2	1022	1017.9	1030	1004.8
9	1004	999.9	1023.4	1019.3	1029	1007
10	1002.9	1001.9	1021.2	1022.5	1026.5	1013.8
11	1011.1	1007.5	1023.1	1019.5	1016.9	1008.4
12	1019.4	1010.8	1022.5	1019.1	1005.4	995.1
13	1018.8	1001.2	1023.4	1015.8	989	1003.7
14	1010.9	1001.4	1024.7	1015.7	988.9	1010.9
15	1003.3	1005.5	1022.1	1016.7	986.5	1015
16	1005.8	993.7	998.2	1000.9	1002.7	1008.1
17	998.1	1013.9	1001	1021.4	1001.9	1016.2
18	1006.3	1005.7	991.4	1005.5	1006	1011.6
19	1005.8	993.7	998.2	1000.9	1002.7	1008.1
20	1005.9	1005.8	1007.5	1003.7	1004	1016
21	1006.1	1012.1	1015	991.3	997.2	1013.1
22	1012.4	1014.9	1014.7	998.4	995.7	1013.9
23	1005.9	1005.8	1007.5	1003.7	1000.4	1016
24	1010.9	1014	1004	1000.5	1003.2	1012.7
25	1007.7	1020.4	1002.6	997.8	1002.7	1009
26	1003.8	1017.3	997.6	990	999.5	1004.5
27	1001.3	1013.5	1001	998.8	991.3	999.1
28	1002	1013	1006	1004.4	1005.2	996.8
29	1001.1	1008.2	1004.7	1004.9		1005.6
30	1001.3	1009.4	1018.3	1013.6		1006.5
31				1009		1011.8
Average values of local atmospheric pressure per months						
	1003	1013,5	1008,2	999,5	1011,6	1012,6

Figure 2. Network of meteorological stations established on the territory of Serbia.

4. Conclusion

This work proved next facts:

- existing accounting of local atmospheric pressure is incorrect;
- atmospheric pressure definitely not only depends on altitude, but it has local character;
- atmospheric pressure has variable nature;
- it is necessary make accounting local atmospheric pressure modification.

Authors of this work offered better way of accounting atmospheric pressure, which includes mentioned facts and makes less mistakes. In near future this way of accounting atmospheric pressure should be accept as a rule.

Authors of this paper are planning to develop turbine meter, for measuring volume flow rate of gas, for households. This meter will be able to take into account temperature compensation and will be equipped for measuring of gas quality. Above all, this equipment will better register changes of absolute pressure, so it is only need to choose mentioned way of pressure account. In this way, measuring will be more precise, independent on outside temperature and gas consumer will always be able to compare quality of gas with one signed in contract. This turbine meter is going to have output, which could be connected to a central monitor. In this way, distributors would be able to have insight into gas consumption and it would make readings easier and more efficient.

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