Algorithm for Calculating the Natural Gas Flowrate with Taking into Account the Roughness Measured in Real Time

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Abstract – The calculation of gas volume flow, reduced to standard conditions, using differential pressure method, was analyzed. New algorithm for calculating natural gas volume flow, reduced to standard conditions, considering the equivalent roughness of the internal surface of the measuring pipeline, measured in real time, was obtained. It will allow to increase the accuracy of measuring natural gas volume flow by differential pressure method.

Key words - differential pressure method, algorithm of calculation, volume flow, natural gas, roughness.

I. Introduction

At the present stage of development of instrument engineering receiving highly accurate measurement results of roughness of the internal surface of the measuring pipeline is important. It stimulates the development of new approaches to the development of tools and methods for measuring roughness of the internal surface of the measuring pipeline in order to increase accuracy of measuring natural gas volume flow and quantity.

II. Analysis of Calculation of Natural Gas Volume Flow Considering Roughness of Internal Surface of Measuring Pipeline

The calculation of gas volume flow, reduced to standard conditions, carried out by the mathematical model [1] of differential pressure method, which includes equations [2-4]: to calculate coefficients and parameters that are included in gas flow equation; to determine the conditions of application and limitations of differential pressure method. However value of equivalent roughness of internal surface of measuring pipeline is given as the input value in this model, not measured in real time. It introduces additional component of measurement results uncertainty in the determination gas volume flow q_c, reduced to standard conditions. As can be seen from mathematical model of differential pressure method [1], determination q_c requires complex iterative process. Thus the task of development of the algorithm for determining gas volume flow, reduced to standard conditions, considering the equivalent roughness $R_ш$ of the internal surface of the measuring pipeline, measured in real time, for standard orifice plate with corner pressure tappings. It will increase the accuracy of measuring natural gas volume flow, reduced to standard conditions, by indirect method.

III. Algorithm of Calculation

The calculation of gas volume flow, reduced to standard conditions, considering roughness of internal surface of measuring pipeline, requires determination equivalent roughness $R_ш$ of internal surface of measuring pipeline in real time.

The input data for determination q_c considering equivalent roughness of internal surface of measuring pipeline, measured in real time:

– - value of gas absolute pressure p;

– - value of pressure drop Δp on standard orifice plate;

– - natural gas temperature t;

– - standard orifice plate diameter d_{20} at temperature 20 ^oC and linear expansion coefficient $\alpha_{tзп}$ of the material from which standard orifice plate is manufactured;

– - internal diameter of the measuring pipeline D_{20} at temperature 20 ^oC and linear expansion coefficient $\alpha_{tт}$ of the material from which measuring pipeline is manufactured;

– - initial radius $r_н$ of orifice plate input edge and the period of time of orifice plate exploitation $\tau_т$;

– - density ρ_c of natural gas at standard conditions;

– - molar fraction of carbon oxide x_y and molar fate of nitrogen x_a in natural gas;

– - the pressure loss Δp_L between the inlet face of a standard orifice plate and at a distance l from the standard orifice plate that arise due to friction of natural gas on the wall of the measuring pipeline.

The determination of gas volume flow, reduced to standard conditions, considering equivalent roughness of internal surface of measuring pipeline, , measured in real time, carried out by following algorithm:

1) calculate value of thermodynamic temperature T of natural gas by the equation [2]

$$T = f_T(t); \quad (1)$$

2) calculate average value of pressure $\overline{p}$ on section L of measuring pipeline by the equation [5]

$$\overline{p} = f_{\overline{p}}(p, \Delta p_L); \quad (2)$$

3) calculate isentropic exponent κ of natural gas by the equation [6]

$$\kappa = f_\kappa(p, T, \rho_c, x_a); \quad (3)$$

4) calculate natural gas dynamic viscosity μ by the equation [6]

$$\mu = f_\mu(p, T, \rho_c, x_a, x_y); \quad (4)$$

5) calculate average value of density ρ of natural gas by the equation [6]

$$\rho = f_\rho(p, T, \rho_c, x_a, x_y); \quad (5)$$

6) calculate average value of density $\overline{\rho_L}$ of natural gas on section L of measuring pipeline by the equation [6]

$$\overline{\rho_L} = f_{\overline{\rho_L}}(\overline{p}, T, \rho_c, x_a, x_y); \quad (6)$$

7) calculate standard orifice plate diameter d at operating temperature of natural gas by the equation [2]

$$d = f_D(d_{20}, \alpha_{tзп}, t); \quad (7)$$

8) calculate internal diameter D of the measuring pipeline at the entrance of standard orifice plate at operating temperature of natural gas by the equation [2]

$$D = f_D(D_{20}, \alpha_{tт}, t)\,; \tag{8}$$

9) calculate diameter ratio β of the standard orifice plate the equation [2]

$$\beta = f_\beta(d, D)\,; \tag{9}$$

10) for β value of input speed coefficient E by the equation [2]

$$E = f_E(\beta)\,; \tag{10}$$

11) determine the value of correction factor $K_п$, which takes into account blunting of the input edge of the standard orifice plate, by the equation [3]

$$K_п = f_{K_п}\left(d, r_п, \tau_T\right); \tag{11}$$

12) calculate value of expansion factor ε by the equation [3]

$$\varepsilon = f_\varepsilon(\beta, p, \Delta p)\,; \tag{12}$$

13) take the first approximate value of the Reynolds number Re_1, which is 10^6;

14) calculate value of discharge coefficient C_1 by the equation [2]

$$C_1 = f_{C_1}(\beta, Re_1, D)\,; \tag{13}$$

15) determine roughness $R_{ш1}$ of the internal surface of the measuring pipeline by the equation

$$R_{ш1} = D(3{,}71 \cdot 10^{-Re_1 A_Ш} - 18{,}68 A_Ш)\,, \tag{14}$$

where $A_Ш$ is coefficient determined by the equation

$$A_Ш = \frac{\mu}{2D}\sqrt{\frac{\overline{p}L}{\Delta p_L(2p + \Delta p_L)\overline{\rho_L}D}}\,; \tag{15}$$

16) calculate the value of correction factor $K_{ш1}$, which takes into account roughness of the internal surface of the measuring pipeline, by the equation [3]

$$K_{ш1} = f_{K_{ш1}}\left(R_{ш1}, \beta, Re_1, D\right); \tag{16}$$

17) calculate the value of gas volume flow q_{C1}, reduced to standard conditions,by the equation [4]

$$q_{c1} = f_{q_{c1}}\left(d, C_1, E, K_{ш1}, K_п, \varepsilon, \Delta p, p\right); \tag{17}$$

18) itemize value of the Reynolds number Re_2 by the equation [2]

$$Re_2 = f_{Re_2}\left(q_{c1}, D, \rho_c, \mu\right), \tag{18}$$

for which calculate value of discharge coefficient C_2, roughness $R_{ш2}$, value of correction factor $K_{ш2}$, which takes into account roughness of internal surface of pipeline, and value of gas volume flow q_{C2} by items 14)-17);

19) calculation of $R_ш$, Re, C, $K_ш$ and q_c carried out until the relative deviation δ_{qci} between obtained value of gas volume flow q_{ci} and its previous value q_{ci-1} will satisfy condition [4]

$$\delta_{qci} = 100\frac{\left|q_{ci-1} - q_{ci}\right|}{q_{ci}} < 10^{-3}\,. \tag{19}$$

During calculation of gas volume flow, reduced to standard conditions, considering roughness of internal surface of measuring pipeline, measured in real time, necessary to enforce system of conditions for execution and application of differential pressure method [1].

Conclusion

The calculation of gas volume flow, reduced to standard conditions, using differential pressure method, is analyzed in this paper.

New algorithm for calculating natural gas volume flow, reduced to standard conditions, considering the equivalent roughness of the internal surface of the measuring pipeline, measured in real time, is obtained.

References

[1] [L. Lesovoi, "Metodolohichni zasady normuvannya ta pidvyshchennya tochnosti vymiryuvannya vytraty ta kilkosti plynnoho enerhonosiya metodom zminnoho perepadu tysku" ["Methodological principles of standardization and increasing measurement accuracy of flow and quantity of fluid energy carrier by differential pressure method"], Dr. Sc. dissertation, Lviv Polytechnic National University, Lviv, 2012.

[2] Metrolohiya. Vymiryuvannya vytraty ta kilkosti ridyny i hazu iz zastosuvannyam standartnykh zvuzhuvalnykh prystroyiv. Chastyna 1. Pryntsyp metodu vymiryuvan ta zahalni vymohy [Metrology. Measurements of liquid and gas flow rate and quantity by means of orifice instruments. Part 1. Principle method of the of measurements general requirements]. DSTU GOST 8.586.1:2009. – 2010.

[3] Metrolohiya. Vymiryuvannya vytraty ta kilkosti ridyny i hazu iz zastosuvannyam standartnykh zvuzhuvalnykh prystroyiv. Chastyna 2. Diafrahmy. Tekhnichni vymohy [Metrology. Measurements of liquid and gas flow rate and quantity by means of orifice instruments. Part 2. Orifice plates. Technical requirements]. DSTU GOST 8.586.2:2009. – 2010.

[4] Metrolohiya. Vymiryuvannya vytraty ta kilkosti ridyny i hazu iz zastosuvannyam standartnykh zvuzhuvalnykh prystroyiv. Chastyna 5. Metodyka vykonannya vymiryuvan'. [Metrology. Measurements of liquid and gas flow rate and quantity by means of orifice instruments. Part 5. Measurement procedure]. DSTU GOST 8.586.5:2009. – 2010.

[5] B. Chaban, L. Lesovoi, "Definition of equivalent roughness of internal surface of a measuring pipeline", EPECS-2015, Lviv, 2015, pp. 152-153.

[6] Haz prirodnyi. Metody rascheta fizicheskikh svoistv. Opredeleniye fizicheskikh svoistv prirodnoho haza, eho komponentov i produktov eho pererabotki [Natural gas. Methods of calculation of physical properties. Definition of physical properties of natural gas, its components and processing product]. GOST 30319.1-96. – 1996.