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Two-Component Flow Measurement In Oil And Gas Pressure Systems

Zhonkobilov Ulugmurad Umbarovich[1], Zhonkobilov Sobir Ulugmurodovich[2], Khushiev Shukhrat Panzhievich[3], Zhonkobilov Kuvandik Ulugmurodovich[4]

[1]Doctor of Technical Sciences of Karshi Engineering Economic Institute

[2]Doctoral student of Tashkent Institute of Irrigation and Agricultural Mechanization Engineers

[3]Assistant of Karshi Branch of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers

[4]Student of Karshi Engineering Economic Institute

Abstract – The article discusses a method for measuring the volumetric flow rate of a two-component (oil + air) flow using a cylindrical nozzle. The results of the study of the proposed meter for the flow rate of a two-component flow are presented. Satisfactory agreement was obtained between the calculation results of the two-component flow rate and the experimental data with allowance for air.

Keywords – Two-Component Pressure Flow, Pressure Pipeline, Air, Flow Rate, Packing, Diaphragm.

I. INTRODUCTION

At present, the exact calculation of the flow rate of a liquid flow taking into account the components (water + air or oil + air) of oil pipelines, water pipelines and other resource-saving technologies is of scientific importance. Pipeline transportation systems for oil, gas and water. This type of very different liquids has a number of undoubted advantages over other means of delivery, namely: transport losses in pressure pipelines are minimal. The solution of the above problems requires further development of the methodology for measuring (accounting) a two-component flow, using the capabilities of new communication and innovative technologies.

In the oil and gas industry, in connection with the widespread introduction of an innovative system of pipeline gathering and transportation of oil and gas, a need arose for a simple and reliable method for measuring the flow rate of a mixture directly in the flow. The method based on the method of variable pressure drop created with the help of cylindrical nozzles seems to be very promising. Moreover, to regulate the operation of the formation at the mouth of gushing wells, it is often use fittings, which are exactly cylindrical nozzles [1,5].

The outflow of a two-component flow through cylindrical nozzles has its own characteristics and differs significantly from the outflow of one-component (water) flows. However, many of these features, as well as the outflow process itself, are poorly studied [2,3,4,5,6,7].

At the same time, it is of practical importance to study the flow rate of two-component flows common for single-phase liquids using diaphragms [1,9].

II. Research methodology

Experimental studies were carried out on a laboratory setup [6].

The thermodynamic character of the process of expansion of a two-component flow is determined from the equation of state, which, in the absence of phase slip and isentropic flow has the form [6, 9].

$$p\left(\frac{x}{\upsilon\beta}\right)^{-m} = const\,, \qquad (1)$$

where is the process indicator is

$$m = \frac{C_{\vartheta\,ж} - x(C_{\vartheta\,ж} - C_{p\,в})}{C_{\vartheta\,ж} - x(C_{\vartheta\,ж} - C_{\vartheta\,в})}\,, \qquad (2)$$

where ϑ – specific volume of two-component flow; β, x – volumetric and mass content of air, respectively; $C_{\vartheta\,ж}$ – specific heat of liquid at constant volume; $C_{p\,в}$, $C_{\vartheta\,в}$ – specific heat capacity of air at constant pressure and constant volume, respectively.

Similarly to a one-component gas flow, the rate of outflow of a two-component flow through cylindrical nozzles is limited by the sound speed of the mixture [6, 7]. In this regard, an equation was obtained for the speed of sound propagation in a two-component flow, taking into account the heat transfer between the components and assuming the homogeneity of the flow [6,7,8]:

$$a = \sqrt{\frac{mp}{\rho\beta}}\,, \qquad (3)$$

where ρ is the density of the two-component flow.

To determine the critical expiration rate, the following method of conducting experiments was used [5,6]. Previously, such an expiration mode was set, in which the ratio of static pressures ε = p2/p1 was obviously less than the critical one. At the same time, the flow rate of the liquid was maintained by the flow regulator, while the shut-off valves were fully open, so that the air flow was set to the maximum possible under this flow mode. Then the pressure was gradually increased after the nozzle, observing the changes in the flow rates of liquid, air and pressure before the nozzle. As long as the pressure was less than critical, the pressure in front of the nozzle and the flow of liquid and air remained unchanged. As soon as p2 became more critical, there was an increase in pressure in front of the nozzle and a drop in air flow. The beginning of the change in air flow and the pressure in front of the nozzle correspond to the transition from the critical flow area to the subcritical one.

Pressure ratio $\left(\frac{p_2}{p_1}\right)_{кр}$, appropriate start. in this case, the critical velocity of the pressure flow in the outlet section of the packing.

Studies have found that with a decrease in air, the critical pressure ratio decreases [5,6].

The values of the critical velocity of the mixture at a low critical pressure, obtained by the author [6], are located as much higher than the values of the speed of sound calculated by the formula (3). This is probably explained by the presence of relative motion of the components in the nozzle.

The analysis of the results of field studies on the outflow of gas and oil flows through the wellhead fittings of gushing wells showed that at high critical pressures (at least above 50 atm) there is practically no relative movement of the components, and the critical outflow velocity can be determined with sufficient accuracy by the formula (3). Thus, to accurately determine the critical velocity of a two-component flow, it is necessary to know the value of the relative velocity of the components.

In the subcritical mode, the experiments were carried out with a constant amount of air [6,9,10].

Experiments have established that for each volumetric air content there is a well-defined dependence of the flow rate on the pressure drop, and with a decrease the velocity value increases, reaching the critical velocity value for a given volumetric air content at a critical pressure ratio.

When flowing through the diaphragm, there are also quite definite dependences of the flow rate of the two-component flow on the pressure drop [6,9].

Research results

As a result of analytical studies, an equation for the flow rate of a two-component flow when it flows through the orifices is obtained, which has the form similar to the gas flow equation [6,8,9]:

$$Q_{см} = \alpha \varepsilon_p S \sqrt{\frac{2(p_1 - p_2)}{\rho}}, \quad (4)$$

where α – is a flow rate; S – diaphragm opening area; ε_p – expansion coefficient, which for isothermal outflow of a two-component flow without taking into account the relative motion of the components has the form

$$\varepsilon_p = \sqrt{\frac{1-\mu^2 m_0^2}{1-\mu^2 m_0^2[(1-\beta)+\beta\varepsilon]^2}\left[(1-\beta) - \frac{\beta\varepsilon}{1-\varepsilon}\ln\varepsilon\right]}, \quad (5)$$

Where m_0 – the ratio of the areas of the opening of the diaphragm and the section of the pipeline; μ is the compression ratio of the jet.

Without considering the relative movement of the components

$$\mu = \frac{1}{1+\sqrt{1-m_0[(1-\beta)+\beta\varepsilon]}}. \quad (6)$$

For a cylindrical packing *l / d> 4*, it is necessary to take μ = 1. Comparison of experimental data with formula (4) shows that the value of the flow coefficient [6]:

$$\alpha = \alpha^{/}\psi^{/}, \quad (7)$$

where $\alpha^{/} = \frac{\psi}{\sqrt{1-\mu^2 m_0^2}}$ - flow coefficient defined similarly to single-phase flow; $\psi^{/}$ - a correction factor that takes into account the deviation of the behavior of the two-component flow from the one-component (water or oil).

To establish the dependence of the flow coefficient α on the main parameters and properties of the flow requires a lot of experimental work. At the outflow of a two-component flow through the nozzles, if the critical parameters of the flow ωcr and εcr are known, the solution of the problem is greatly facilitated.

The following dependence of the dimensionless outflow velocity on the dimensionless pressure drop is proposed, which has the form:

$$\frac{\omega}{\omega_{кр}} = \sqrt{\frac{0{,}033(1-B)}{7{,}7B+1} - 0{,}763\lg(7{,}7B+1)}, \quad (8)$$

where

$$B = \frac{\varepsilon_{кр} - \varepsilon}{\varepsilon_{кр} - 1}.$$

If the critical flow parameters are given at the same pressure, then for different pressure values

$$\omega^{/} = \omega\left(\frac{p_2^{/}}{p_2}\right)^{n\,2}, \tag{9}$$

where $n = \sqrt{(1-\beta^3)^{0,8}}$.

The proposed method for calculating the flow rate has an error ± 4,5 %.

III. Conclusion

Based on the above, we can draw the following conclusions:

1. The analysis of literature sources shows that there is always a certain amount of air in a two-component flow (up to 1-2%) [6,9,10].

2. The influence of air on the pressure system is noticeable, that the exact determination of the volume content of air in such systems is of great scientific importance.

3. It should be noted that the influence of air on the main parameters of a two-component flow in stationary and non-stationary pressure modes is very noticeable [6,7].

4.A formula for calculating the flow rate of a two-component pressure flow for hydraulic systems is obtained.

5. The analysis of studies shows that the influence of flow components must be taken into account when calculating the costs of oil pipelines and water pipelines, as a result of which resource conservation is ensured.

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