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AUTO CALIBRATION METHOD OF PERIODIC DEVICE FOR MEASURING THE PRESSURE DROP VARIABLE COSTS

The method of periodic auto-calibration a device for measuring the flow of alternating pressure drop directly in terms of their operation, which are widely used in various industrial sectors for the control and accounting costs of various liquid substances (oil, hot water, food, etc.). The basis of the method is based on the use of structural and temporal redundancy measurement conversions, enabling algorithmic way to identify and consider an amendment to the progressive flow errors as additive and multiplicative nature. As aresult of increased flow metrological reliability in the process of continuous operation and, therefore, the reliability of process control volumetric flow of liquid substances.

Keywords: a device for measuring the flow of alternating differential pressure measuring conversion function, and cartoon additive error calibrated impact on zvuzhuvalnyy device, linear approximation, algorithm of flow, precision auto-calibration method.

Foreword

Improving product quality and production efficiency is closely linked with the development and use of more sophisticated and accurate methods of measuring instruments intended for regulation and control of technological processes (TP) in various industries Ukraine.

Many domestic enterprises used TP associated with transportation by pipelines of liquid substances such as oil, energy (hot water, steam, natural gas, etc.), food (alcohol, mineral water, juices, milk, etc.) and others. For regulation, control and accounting of these TP substances transported widely used a device for measuring the flow of alternating pressure drop, using the measurement and control of one of the defining parameters of TP - volumetric flow of liquid substances Q_X, ie the number of substances through section of pipe per unit of time or for a certain period of time. In practice, also used tachometric, Electromagnetic flowmeters rotametrychni but significant advantage device for measuring the flow pressure drop is their high reliability and performance in harsh industrial conditions, the relative simplicity and compact instrumentation. The main disadvantage of the data flow is their lack of precision. Measurement error can reach ± (5 ÷ 10)%, which presently does not meet the requirements of modern control systems.

As is known, the composition flow variable differential pressure transducer includes primary (PP) in the form of volumetric flow device (diaphragm) narrowing liquid flow controlled substance in the pipeline, as well as differential pressure gauge with fittings (pulse) tubes to determine the pressure drop across the input - output zvuzhuvalnoho device is dependent on the value of the volume flow of matter represented a known relation [1].

$$Q_x = 0.01252 \cdot \alpha \cdot \varepsilon \cdot \mathrm{m} \cdot D^2 \sqrt{\frac{1}{\rho}(P_1 - P_2)}, \tag{1}$$

where α-factor costs matter, dependent on the Reynolds number Re in the laminar region and not dependent in turbulent; ε-expansion coefficient of the liquid due to its passage through zvuzhuvalnyy device; m = d2 / D2 - module zvuzhuvalnoho device; d- diameter hole zvuzhuvalnoho device at a certain temperature controlled fluid; D - internal diameter of the pipeline; ρ - density of the liquid in the section in front of the hole zvuzhuvalnoho device; ΔP = P1-P2- pressure drop in zvuzhuvalnomu device.

The current procedure of experimental calibration flow is complex and takes a long chasu.Hraduyuvalni characteristics (GC) data flow is determined analytically by calculating the Special Rules - standards [2], which require strictly follow measurement procedures [3] and methods of installation and operation

zvuzhuvalnyh devices. If flow measurement is made under conditions in which the parameters of controlled substances differ from the parameters adopted to calculate zvuzhuvalnoho device, then there is the additional error. Improper installation or uncontrolled changes of geometrical parameters zvuzhuvalnyh devices during their operation lead to unacceptably large progressive appearance of errors as additive and multiplicative characters. The gradual change of the diameter and angle sharpening hole zvuzhuvalnoho device can occur for many reasons, and mainly under the influence of chemical aggressiveness of controlled substances and the presence in it of solid impurities. Therefore, to determine and compensate for the above mentioned error during continuous flow operation without removing and replacing zvuzhuvalnoho device or perehraduyuvannya impossible. Material flow measurement error can be caused by gradual drift GC differential pressure gauge and flow effects on various destabilizing influential factors. In addition, quite nonlinear functional dependence of controlled substances cost of pressure drop in zvuzhuvalnomu devices in vyhlyadiQ_x == f (k√ΔP) significantly limits the accuracy of the known methods for achieving invariance flow influential factors considered destabilizing because of the rather large error linear approximation of the above function measuring conversion of [4,5].
The article suggests to consider structural and algorithmic method автокалібруваннявитратомірів periodic alternating pressure drop directly into the operating conditions and during long periods of operation without cumbersome and inefficient operation of dismantling zvuzhuvalnoho device that makes it possible to increase the metrological reliability of flow, and thus ensure the reliability of the control normalized against 'capacious costs of various liquid substances.

The method of auto-calibration a device for measuring the flow of alternating pressure drop in operating conditions

Auto-calibration method based on the use of structural and temporal redundancy measuring change, the introduction of the scheme in calibrated flow device forming additive and animated tests that act directly on the device zvuzhuvalnyy at its installation on process equipment. Figure 1 shows the block diagram of microprocessor a device for measuring the flow of alternating differential pressure structural redundancy, which is implemented using the proposed method. The algorithm operation flow gives a basic and additional measurement results in which the value of controlled volumetric flow of liquid substances defined by the formula of auto-dominant progressive errors.
The method that is proposed is as follows. Based on measuring conversion equation (1), the pressure drop in zvuzhuvalnomu device 2 is

$$\Delta P = P_1 - P_2 = \frac{\rho}{(0.01252 \cdot \alpha \cdot \varepsilon \cdot m \cdot D^2)^2}, \qquad (2)$$

or

$$\Delta P = K_1 Q_x^2, \qquad (3)$$

$K_1=\frac{\rho}{(0{,}01252\cdot\alpha\cdot\varepsilon\cdot m\cdot D^2)^2}$ – conversion efficiency (sensitivity) weighing device 2.

The corresponding output signal of the differential pressure gauge 4 U is given by

$$U = K_1 K_2 Q_x^2, \qquad (4)$$

where K_2-conversion efficiency differential pressure gauge 4.
Taking into account the expressions (2) and (4) conversion of flow measurement equation be presented in the form

$$N = S Q_x^2 K_3, \qquad (5)$$

where N - number code of the output signal of the differential pressure gauge 4; K_3 - stable coefficient ADC 5.

During installation and adjustment of flow to process objects before long operation carried out its initial calibration with known values of volumetric flow of liquid rechovynyQk, which is defined by the formula:

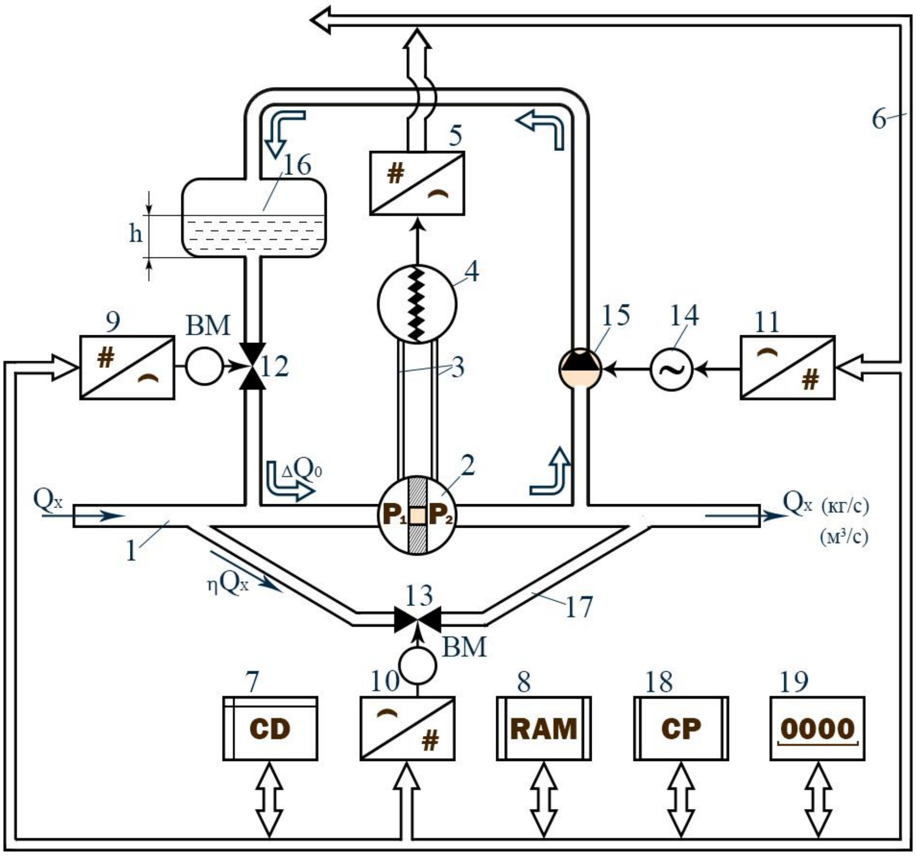

Figure 1. Block diagram of microprocessor a device for measuring the flow of alternating pressure drop with auto-progressive errors
:
1 - pipeline with the flow of controlled substances; 2 - zvuzhuvalnyy device; 3 - pulse tube; 4 - differential pressure gauge; 5 - analog-to-digital converter (ADC); 6 - Common rail PC; 7 - control 8 - Block RAM; 9,10,11 - Digital to Analog Converters (DACs) with actuators (VM); 12.13 - Automatic shut-off valves; 14 electric centrifugal pump 15; 16 - pressure-holding tank with stabilized level h liquid substance; 17 - bypass designed to bypass zvuzhuvalnoho device 2 and the reduction of controlled fluid flow through in the last η = 0,8 ÷ 0,9 times, 18 - computing device; 19 - digital display of controlled volumetric flow of liquid substances.

$$Q_k = \frac{Q_{min} + Q_{max}}{2} \ , \tag{6}$$

where Qmin Qmax- respectively lower and upper boundary of the range of volume flow measurement of liquid substances.
At the beginning of the primary calibration procedures operated valves 12, 13 are closed and controlled flow of liquid substances Qk in full is due zvuzhuvalnyy device 2.
Given the transformation function of flow (5) digital code output differential manometer will be important:

$$N_1' = SQ_k^2 K_3. \tag{7}$$

The resulting code N'1zapam'yatovuyut and stored in a block RAM 8.
Then change the sensitivity of the device in zvuzhuvalnoho η = 0.8 ÷ 0.9 times by opening the shut-off valve 13 shuntuyuchohobaypasa 17 This is done by command control unit 7 via digital-to-analog converter 10 and the actuator. As a result, the output signal manometer change and its digital code is set to

$$N_2' = \eta SQ_k^2 K_3 \ , \tag{8}$$

where η = 0.8 ÷ 0.9 - bypass flow rate of liquid substances through zvuzhuvalnyy prystriy2. The resulting digital kodN'2takozh memorable, then valve 13 is closed and this initial calibration ends.

During subsequent operation flow is a gradual drift of his GC as a result of him above influential factor in the emergence of progressive and additional errors. The result is a need for auto-calibration of flow, which is done automatically by the program according to the following algorithm.

Measure the liquid volume vytratuQx controlled substances in closed valves 12, 13 devices forming additive and multiplicative tests zvuzhuvalnyy device 2 digital code signal manometer 4 will have a value of:

$$N_1^{"} = [S_1(1+\gamma_1)Q_x^2 + \Delta U_1]K_3 = K_3 S_1 Q_x^2 + K_3 S_1 \gamma_1 Q_x^2 + K_3 \Delta U_1 = \qquad (9)$$

$$= K_3 S_1 Q_x^2 + \Delta N_1 + \Delta N_2 \, ,$$

where γ = ΔS / S; ΔS- absolute error sensitivity of flow or conversion factor S; ΔN1 = K3S1γ1Qx2 - multiplicative measurement error in digital code, is due, firstly, changes in sensitivity zvuzhuvalnoho device due to uncontrolled variations of its geometrical parameters calculated from their original values, but also because of the possible change in the parameters of the liquid substances included into (1), and, secondly, because of the possible change in the sensitivity of the differential pressure gauge 4; ΔN2 = K3ΔU1 - additive measurement error in digital code, caused by the drift of zero flow, ie the displacement of its GC.

Digital code N1 "recorded and remembered. In accordance with the expression (9) the value of the cost-volume-controlled liquid substance can be determined by the formula:

$$Q_x = \sqrt{\frac{N_1^{"} - \Delta N_1 - \Lambda N_2}{K_3 S_1}} \, . \qquad (10)$$

If expression (10) to introduce compensating adjustments for errors and ΔN1 ΔN2, it is possible to obtain values of Qx, which will be as close to the real value of it. Determination of the amendments carried out by means of additional measurement results calibrated tests zvuzhuvalnyy device 2.

To do this, the control unit 7 team goes to the DAC 9 of actuator which opens the valve 12 and the inlet controlled flow Qxna zvuzhuvalnoho device attached uniform controlled fluid flow ΔQ0z calibrated pressure-accumulation capacity of 16. In this case, the value selected in ΔQ0maye within 5 ÷ 10 threshold flow is formed with an error of ± (2.0 ÷ 3.0)% and pre-determined by the formula:

$$\Delta Q_0 = \frac{(Q_x + \Delta Q_0) - Q_x}{\Delta \tau} \, , \qquad (11)$$

where (Qx + ΔQ0) and Qx - respectively the volumetric flow rate of liquid material that passes through the device zvuzhuvalnyy 2 flow with calibrated flow ΔQ0ta without it for the same time intervals Δτ.

As a result, the output signal will change manometer, and its numerical code will be relevant:

$$N_2^{"} = [S_2(1+\gamma_2)(Q_X + \Delta Q_0)^2 + \Delta U_2]K_3 \, . \qquad (12)$$

Digital code N2 "reyestruyutta remember, then use the DAC 10 and the actuator 13 opens valve 17 bypass, which leads to a decrease of the total fluid flow through the device in zvuzhuvalnyy η = 0.8 ÷ 0.9 times. Measure the new factory default volume flow liquid substance. Digital manometer output code 4 will have a value of:

$$N_3^{"} = [S_3(1+\gamma_3)\eta(Q_X + \Delta Q_0)^2 + \Delta U_3]K_3 \, , \qquad (13)$$

where η - coefficient bypass fluid flow in zvuzhuvalnomu device 2.

Digital code N3 "is recorded and stored. Then at the command control unit 7 12 valve overlap calibrated liquid flow ΔQ0, so that the output signal is changed manometer, and its digital code equals:

$$N_4^{"} = [S_4(1+\gamma_4)\eta {Q_X}^2 + \Delta U_4]K_3 \, . \qquad (14)$$

Digital code N4 "is recorded and stored, and then close the valve 13 and the flow is transferred to the initial state of the current measuring volumetric flow of matter.

Given that the implementation in a short amount of time (15 ÷ 20 s) calibrated test device at 2 zvuzhuvalnyy zoom in and controlled expenses occurs within almost linear plot function measuring conversion flow (4) and in the vicinity of the operating point Qx2, we can assume the same in rivnotochnyh obtained

measurement results (9,12,13,14) values sensitivities S1 = S2 = S3 = S4 = Sta errors γ1 = γ2 = γ3 = γ4 = γ; ΔU1 = ΔU2 = ΔU3 = ΔU4 = = ΔU.
Next, using the obtained additional observations and the results of initial calibration (7) and (8) define the flow value adjustments for progressive additive and multiplicative measurement error volumetric flow of liquid substances in accordance with equations:

$$\Delta N_1 = N_1^{"} - \frac{(N_1^{"} - N_4^{"})(N_2^{"} - N_1^{"})}{(N_2^{"} - N_3^{"}) - (N_1^{"} - N_4^{"})} \; ; \quad (15)$$

$$\Delta N_2 = \frac{(N_1^{"} - N_4^{"})}{(N_1' - N_2')} - \frac{Q_x^2}{Q_k^2} N_1^{"} \, . \quad (16)$$

If we enter into the expression (10) obtained by compensating adjustments with opposite signs, then the value of the controlled cost liquid substance is very close to its actual value will be determined by the formula:

$$Q_x = Q_k \sqrt{\frac{N_1^{"}}{N_1'} - \frac{1}{2}\left[\frac{N_1^{"} - N_4^{"}}{N_1' - N_2'} - \frac{(N_1^{"} - N_4^{"})(N_2^{"} - N_1^{"})}{N_1^{"}(N_2^{"} - N_3^{"} - N_1^{"} + N_4^{"})}\right]} \, . \quad (17)$$

Findings

From the expression (17) shows that the calculated value of controlled volumetric flow of liquid substance is independent of the nonlinearity and drift GC flow, effects that various destabilizing factors and is determined by a digital code more results rivnotochnyh measuring change. Using the measuring conversion costs in the form ΔP = K1Qx2, instead of the traditional functions Q_x = k√ΔP, allows to eliminate the error of the linear approximation of flow in the vicinity of the operating point Qx2. The accuracy of the proposed method calibration of variable pressure drop depends mainly on the stability tests zvuzhuvalnyy calibrated flow device within a short time of their implementation and the accuracy of the calibrated volumetric flow Qk, which can be achieved at the level of ± (0.25 ÷ 0.5)%. As the results of the calculations error of this method auto-calibration of flow for a given operating range of the measurement is within ± 1.0%.
The value of compensating corrections Δi to the current measurement results volumetric flow of liquid substances determined by the difference Δi = Qx-Qxi, where Qx - values of obtained by the formula (17) during the regular auto-calibration of flow; Qxi - current result of direct measurement of volumetric flow until the flow meter calibration.
The capability for real-time auto-calibration of the necessary frequency flow directly in terms of their operation allows you to avoid unexpected major losses of various liquid substances transported by pipelines and provide them with accurate records and to achieve a balance of these substances on the input-output pipelines, and increase economic efficiency different TP, which improve the reliability of cost control liquid substances provides high-quality manufactured products.

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