ENVIRONMENT PROTECTION

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AIRLINE ENTERPRISES' WASTEWATER MEASURING WITH A DIFFERENTIAL PRESSURE WATER METER WITH A STANDARD METERING NOZZLE

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Abstract. *There are many flow meters and quantity-meters for liquids measuring with have sufficiently good metrological performance. In spite of this, in sewage systems of airline enterprises, as well as in many other sewage systems, registration of sewage water amounts is done mainly by estimation. The main reason of this situation is that those devices, which are successfully in use in water supply systems for clear water metering, does not perform good while being in use in sewage systems, because they are not tolerant to aggressiveness and disturbance of polluted sewage water. In this paper there is proposed a basic design principle of a differential pressure waste water quantity meter, which is based on a combination of a standard nozzle as a sensing device and a calculating device. There is shown that such a quantity meter will not have many drawbacks, which are appropriate to quantity meters with other principles of operation. There is analyzed metrological stability of the proposed quantity meter in comparison with a quantity meter, which uses a standard diaphragm as a sensing device. There are calculated metrological characteristics of the proposed quantity-meter. A conclusion is drawn that the proposed quantity-meter has advantages over a standard diaphragm, such as higher accuracy and better metrological stability.*

Keywords: measurement error; standard metering nozzle; throttle device; wastewater measuring; wastewater meter

1. Introduction

Wastewaters, that are discharged by airline enterprises, first of all by airports, appear as a mixture of sanitary and industrial wastewaters. Apart from contaminations, that are typical for sanitary sewage systems, these wastewaters contain specific ingredients, such as petroleum derivatives (fuels and lubricants), solvents (acetone, benzole and others), ions of heavy metals (lead, chromium and others), elements, that enter into the composition of aviation special liquids (phenol, ethylene glycol, surfactant species and others) [1, 2]. When these wastewaters have been treated with sewage-purification facilities a considerable part of the contaminations turn out to be extracted. But residual concentrations of them still remain in the purified waters. Amounts of these waters need to be measured in order to perform an effective monitoring of these enterprises' influence on environment.

2. Analysis of the research and publications

Conventional and the most simple methods of wastewaters amount estimation are the methods, in which calculating of their volumes is done on the basis of volumes of water consumption [3]. In this case two options are possible. The first – there is assumed a situation when the entire amount of water, consumed out of a plumbing system, goes into a sewage system, here the amount of discharged water is considered to be equal to the amount of consumed water. The second – a special coefficient of water discharge into a sewage system is introduced, using previous experience or technological calculations, then the amount of discharged water is calculated by multiplying the amount of consumed water by this coefficient.

In spite of obvious advantages (it is not necessary to use expensive measuring apparatus), these methods can not be called accurate. While using these methods fewer errors appear in household systems, in case that the amount of both cold and hot waters is measured with water meters. While calculating of discharged water amounts of nondomestic objects, for example airline enterprises, much more errors can happen. It is impossible to state that introduced coefficients, which can be either above or below one, objectively reflect real conditions. There are too many factors, which can influence ratios between amounts of consumed and discharged waters. Increasing in discharge amount can be caused by the next factors: rain water or water, remained after washing road surfaces on the enterprise's area, that can get into sanitary or industrial sewage systems through loose or open sewer manholes; water, delivered from other places that also released into a sewage system; accidental leaks from drinking or manufacturing water supply lines, that goes into sewage systems through soil porosity and looseness of sewage pipes. Factors, which can decrease discharge amount, are the next: irreversible using of water for technological purposes; supplying other consumers with water; evaporation; accidental leaks that do not get into sewage systems and others. Taking this into account, it is timely to estimate amounts of discharge waters exactly with measuring apparatus.

Measuring devices are divided into two groups. The first – devices for measuring flow rate of liquid (amount of liquid, which flows by in a time unit) are called flow meters. The second – devices for measuring volumes or masses of liquid are called quantity-meters. Nowadays there are great variety of different flow meters and quantity-meters with technical characteristics, which differ a lot [4]. There are much fewer problems with measuring apparatus in water supply systems, then in sewage systems [5, 6]. There are set up very many requirements for sewage water flow meters and quantity-meters, including specific ones: accuracy of measurement, reliable performance, independence of measuring results from variation of wastewater's physical parameters, dynamical characteristics and others. All these requirements are very actual because contaminations that are present in wastewaters cause specific (different) impact on performance of flow meters' and quantity-meters', which implement different basic principles of measuring. Specific impact on measuring results and performance reliability is mainly caused by characteristics of wastewaters, such as corrosiveness, abrasiveness, toxicity, explosibility and others. Because of irregularity of wastewater discharge, dynamical characteristics of meters (stability of measuring with preassigned accuracy in wide range of flow rates) are also very important.

Special characteristics of wastewaters cause a situation when not all flow meters and quantity-meters, which are successfully used in water supply systems, can satisfactorily perform in sewage systems. One of the most widespread meters in water supply systems are tachometers (there principle of operating is based on rotating of small turbine or impeller, caused by water flow). But they are not in use in sewage systems at all.

In sewage systems the next devices got distributed: flow meters of differential pressure, electromagnetic and ultrasonic flow meters and quantity-meters.

Principle of operation of ultrasonic flow meters and quantity-meters is based on measurement of difference in velocities of ultrasonic waves, released along the stream of wastewater and against the stream. The main shortcoming of this type of device is that ultrasonic waves are dispersed and change their velocity, while running into mechanical inclusions (solid particles) in a stream of wastewater. It can cause significant and uncontrolled errors in measurement results.

Principle of operation of electromagnetic flow meters and quantity-meters is based on measurement of voltage (electromotive force), which is induced by charged particles, present in wastewater and moving through the case of the device, while inside of the case magnetic field is created by a permanent magnet. The main shortcomings here are: technological electric and magnetic fields generate appearance of whirling currents inside the metal parts of the device's case. It influences the magnitude of induced electromotive force. In addition, these fields provoke occurrence of electrochemical processes in wastewater, which, in turn, cause deposition of charged particles on the surface of voltage measuring electrodes. Over time the electrodes become covered with layers of sediments in a form of slime. All this contributes to appearance of additional measurement errors.

Operation principle of differential pressure flow meters is based on measurement pressure difference, which is created by throttle device, installed into the pipeline. These type of measuring apparatus is saved from practically all shortcomings, listed above and can be very useful for measuring wastewaters in sewage systems [7]. The problem is that these apparatus are used nowadays mainly as flow meters. In order to estimate amounts of wastewaters, it is necessary to do manual calculations, using flow rate diagrams, written down by recording differential manometers. But nowadays there are many different integrating elements, which can be used as secondary transformers in combination with throttles as sensing devices. Apparatus of this type not only can perform functions of flow meters, but also functions of quantity-meters, automatically calculating amount of passed through wastewater.

As sensing devices different throttles can be used. First of all they are devices such as a standard diaphragm, a standard nozzle, a Venturi nozzle, a Venturi tube and others. In the article [8] the authors proposed a new construction of wastewater quantity-meter with a standard diaphragm as a sensing device. There was shown, that estimated value of measurement error, while using differential manometer of accuracy class 0,25, in operating range is from 1,67 to 1,91%; in transitional range is 2,72%. This is an acceptable error for quantity-meters of that type. Measurement errors for majority of water meters, which are in use nowadays, are up to 2% in operating ranges and up to 3% in transitional ranges. Standard diaphragm is one of the most simple and inexpensive throttle devices. But it has one very significant shortcoming, while using it in sewage systems. An opening of a diaphragm on incoming side should have sharp edge. The sharpness of its edge is defined by radius of rounding. Measurement error depends on this radius. Volumetric rate of flow, when using standard throttle device, is defined by the formula [9]

$$Q=\alpha\cdot\varepsilon\cdot\frac{\pi\cdot d^2}{4}\sqrt{\frac{2\cdot\Delta P}{\rho}},\ [m^3/s],\qquad(1)$$

where α – flow coefficient; ε – coefficient of wastewater expansion; d – diameter of throttle's opening, m; ρ – density of the measured medium, kg/m^3; ΔP – differential pressure, measured with differential manometer, Pa.

The formula implies using diaphragm with sharp edge. Over time the edge, being exposed to abrasive impact of wastewater flow, becomes blunt. It means that radius of rounding increases and flow coefficient value changes. Because of that, special coefficient, which takes this change into account, is introduced into the formula. In spite of the fact that diaphragms have to be made out of hard and wear-resistant material, it is difficult to prognosticate edge's blunting value, especially when measuring wastewaters with aggressive and abrasive characteristics. When established, this coefficient reflects just one blunting value, which changes over time (fig. 1). It introduced an additional error into measuring results, which was not taken into account during calculations.

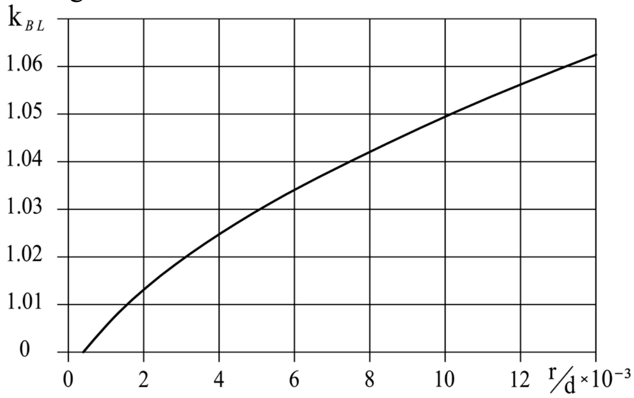

Fig. 1. Variation of the coefficient, which takes into account diaphragm's edge blunting

This shortcoming can be eliminated, if a standard diaphragm, as a sensing device, is replaced with a standard nozzle. Such nozzle has a gradually rounded opening, does not have any sharp edges and, correspondingly, does not need measuring correction, which takes into account blunting process. Also the nozzle is more complicate in manufacturing, but it has better metrological characteristics.

The authors have proposed here a basic design principle of wastewater meter, constructed on the basis of a combination of a standard nozzle as a sensing device and an integrator as a secondary transformer. Measuring error of the proposed meter has also been calculated in the paper.

3. Obtained results

3.1. Principle of flow and quantity metering with proposed wastewater meter

Proposed waste water meter consists of a standard nozzle, manufacturing in accordance with requirements [9], with a corner way of pressure difference measuring. Diameter of an inlet pipe before throttle is D = 50 mm, diameter of a nozzle's opening is d = 40 mm, modulus of the throttle is m = 0,64. Absolute equivalent roughness of inlet pipe wall is k = 0,1 mm. Pressure difference measuring is carried out with a diaphragm pressure manometer. Calculation of waste water amount is done with an integrator on the ground of measured waste water flow rate. Under such conditions daily flow (quantity) of waste waters can be calculated by the formula

$$Q_W = 0,24 \cdot C_Q \cdot N_{PL} \cdot K_t^2 \cdot k_{\mathrm{Re}} \cdot K_\rho \; [m^3/day], \quad (2)$$

where C_Q – constant of a standard nozzle; N_{PL} – planimetric number, which is obtained from a planimeter; k_{Re} – correction coefficient of flow rate, which takes into account variation of Reynolds number; K_t – correction coefficient, which takes into account thermal expansion nozzle's material; K_ρ – correction coefficient of flow rate, which takes into account variation of waste water's density.

Constant of a standard nozzle can be calculated by the formula

$$C_Q = 0,2109 \cdot \alpha \cdot d_{20}^2 \sqrt{\Delta P_{\mathit{\Pi P}}}, \quad (3)$$

where α – flow coefficient for the nozzle, which is obtained for $Re = 10^6$; ΔP – maximal pressure difference on the nozzle (when waste water's flow is maximal).

For the nozzles with $m \geq 0,13$, on condition that

$$\frac{k}{D} \times 10^4 \leq 3,9 + 10^3 \times \exp\left(-14,2\sqrt{m}\right), \quad (4)$$

flow coefficient α is calculated without factoring into correction for roughness of inlet pipe wall. So long as this condition is not satisfied with taken parameters of the nozzle

$$\frac{0,1}{50} \times 10^4 = 20 \; > \; 3,9 + 10^3 \times \exp\left(-14,2\sqrt{m}\right) = 3,9,$$

it is necessary to determine flow coefficient taking roughness correction into account

$$\alpha = \frac{1}{\sqrt{1-m^2}} \times \left[0,99 - 0,2262 m^{0,05} + \left(0,000215 - 0,001125 m^{0,5} + 0,00249 m^{2,35}\right) \times \left(10^6 / \mathrm{Re}\right)^{1,15}\right] \times K_R, \quad (5)$$

where K_R – correction coefficient, which takes into account roughness of inlet pipe wall.

Roughness correction coefficient for a standard nozzle with an inlet pipe's diameter D < 300 *mm* and $m \geq 0,27$ can be defined by the formula

$$K_R = \left(1,0020 - 0,0318 m + 0,0907 m^2\right) - \left(0,0062 - 0,1017 m + 0,2972 m^2\right)\frac{D}{10^3}. \quad (6)$$

With numerical substituting it is

$$K_R = \left(1,0020 - 0,0318 \cdot 0,64 + 0,0907 \cdot 0,64^2\right) - \left(0,0062 - 0,1017 \cdot 0,64 + 0,2972 \cdot 0,64^2\right)\frac{50}{10^3} = 1,0157$$

Flow coefficient α depends on Reynolds number, or on waste water flow rate. We can calculate flow coefficient value for different magnitude of Reynolds number, taking it's minimal magnitude Re_{min} = $2 \cdot 10^4$ according to recommendations [9]. Along with this we can calculate velocity of waste water flowing by the formula

$$V = \frac{\mathrm{Re} \cdot \upsilon}{D}, \; [m/sec], \quad (7)$$

and waste water flow rate by the formula

$$Q = \frac{\pi \cdot D^2}{4} \times V, \; [m^3/sec], \quad (8)$$

where υ – kinematic viscosity of waste water, m/sec^2.

If waste water's temperature is 20 ^0C, it's kinematic viscosity is $1,01 \cdot 10^{-6}$ m/sec^2.

Results of flow coefficient calculation, which is done according to the formula (5), is given in the table 1.

Table 1. Results of flow coefficient calculation for different Reynolds numbers

№	Re	V, *m/sec*	Q, $m^3/sec \times 10^{-3}$	α
1	2×10^4	0,404	0,79325	1,21111
2	3×10^4	0,606	1,18988	1,20281
3	5×10^4	1,010	1,98313	1,19660
4	10^5	2,020	3,96626	1,19234

3.2. Calculation of measurement error

Value of root-mean-square relative error of waste water flow rate measurement with standard nozzle as a sensing device can be calculated according to recommendations [9] by the formula

$$\sigma_Q = \left[\sigma_\alpha^2 + \sigma_{k_{\mathrm{Re}}}^2 + 0,25\sigma_{\Delta P}^2 + 0,25\sigma_\rho^2\right]^{0,5}, [\%], \quad (9)$$

where σ_α – relative error of flow coefficient determination, $\sigma_{k_{\mathrm{Re}}}$ – relative error of Reynolds number determination, $\sigma_{\Delta P}$ – relative error of pressure difference measuring with a differential manometer, σ_ρ – relative error of waste water density determination.

We can make the assumption that the components of the formula (9) do not have correlations and are subjected to the normal distribution law. As a maximal value of errors we can take a maximal error of single measurement with confidence probability 0,95.

For nozzles with modulus 0,25 < m ≤ 0,64, which is true in this case, root-mean-square relative error of flow coefficient determination can be calculated by the formula

$$\sigma_\alpha = \left[\left(m^{0,5} - 0,2 \right)^2 + \sigma_{\alpha_d}^2 + \sigma_{\alpha_D}^2 \right]^{0,5}, [\%], \quad (10)$$

where σ_{α_d} – error, that occurs because of permissible variation of the nozzle opening's diameter d, σ_{α_D} – error, that occurs because of permissible variation of the inlet pipe's diameter D. These errors can be defined by the formulas

$$\sigma_{\alpha_d} = 2\sigma_d \left(1 + m^2 / \alpha_y \right), [\%], \quad (11)$$

$$\sigma_{\alpha_D} = 2\sigma_D \frac{m^2}{\alpha_y}, [\%], \quad (12)$$

where σ_d, σ_D – permissible errors of manufacturing of (σ_d = 0,035 %) and inlet pipe's diameter (σ_D = 0,15 %).

The formula for calculation of flow coefficient α (formula 5) contains correction coefficient for inlet pipe wall's roughness K_R. This coefficient reflects only one preassigned absolute equivalent roughness of pipe's wall k. But the roughness does not remain steady over time and it's gradual change also causes gradual, not considered change of flow coefficient α, thus it introduced additional, not considered error in measuring results. On the basis of this fact, error of flow coefficient determination α, factoring into error of correction coefficient for inlet pipe wall's roughness determination, we can calculate by the formula

$$\sigma'_\alpha = \left[\sigma_\alpha^2 + \sigma_{K_R}^2 \right]^{0,5}, [\%], \quad (13)$$

where σ_{K_R} – relative error of inlet pipe wall's roughness coefficient determination. To calculate this error we can use the formula

$$\sigma_{K_R} = \left(0,109 - 1,47m + 4,64m^2 \right) - $$

$$- \left(0,338 - 4,55m + 14,9m^2 \right) \frac{D}{10^3}, [\%]. \quad (14)$$

The calculation gives the next value

$$\sigma_{K_R} = \left(0,109 - 1,47 \cdot 0,64 + 4,64 \cdot 0,64^2 \right) -$$

$$- \left(0,338 - 4,55 \cdot 0,64 + 14,9 \cdot 0,64^2 \right) \frac{50}{10^3} = 0,8923\ (\%).$$

Results of relative errors of flow rate calculation for a standard nozzle for flows with different values of Reynolds number, calculated by the formula (13), are given in the table 2.

Table 2. Results of root-mean-square relative errors of flow rate calculation for flows with different values of Reynolds number

Re	α	σ_{α_d}	σ_{α_D}	σ_α	σ'_α
2×10^4	1,21111	0,09367	0,10146	0,61569	1,08409
3×10^4	1,20281	0,09384	0,10216	0,61583	1,08417
5×10^4	1,19660	0,09396	0,10269	0,61593	1,08423
10^5	1,19234	0,09405	0,10306	0,61601	1,08428

Correction coefficient of flow rate, which takes into account variation of Reynolds number, can be defined by the formula

$$k_{\mathrm{Re}} = \frac{C + B\left(10^6 / \mathrm{Re} \right)^{0,75}}{C + B}, \quad (15)$$

In this formula C and B – coefficients, that for a standard nozzle can be defined by the formulas

$$C = \left(0,99 - 0,2262 \cdot m^{2,05} \right) \frac{1}{\sqrt{1 - m^2}}, \quad (16)$$

$$B = \frac{0,000215 - 0,001125 \cdot m^{0,5} + 0,00249 \cdot m^{2,35}}{\sqrt{1 - m^2}}. \quad (17)$$

Substitution nozzle's modulus in these formulas gives

$$C = \left(0,99 - 0,2262 \cdot 0,64^{2,05} \right) \frac{1}{\sqrt{1 - 0,64^2}} = 1,167852399$$

$$B = \frac{0,000215 - 0,001125 \cdot 0,64^{0,5} + 0,00249 \cdot 0,64^{2,35}}{\sqrt{1 - 0,64^2}} =$$

$$= 0,0002439.$$

Relative error of correction coefficient for Reynolds number can be defined by the formula

$$\sigma_{K_{\mathrm{Re}}} = (1 - k_{\mathrm{Re}}) \cdot \sigma_{\mu}, \quad (18)$$

where σ_{μ} – relative error of waste water's viscosity determination.

On the assumption that the temperature of waste waters can change from 5^0C to 40^0C and operating pressure in pipeline can vary by no more than 1 *MPa*, density of waste waters changes from 1000,4 kg/m^3 to 992,25 kg/m^3. For these conditions coefficient of dynamic viscosity changes from $151{,}6 \times 10^{-6}$ $kgf\,sec/m^2$ to 66×10^{-6} $kgf\,sec/m^2$. In this case relative error of waste water viscosity determination, normalized to lesser value of viscosity is

$$\sigma_{\mu} = \frac{151{,}6 \cdot 10^{-6} - 66 \cdot 10^{-6}}{66 \cdot 10^{-6}} = 1{,}29697\ (\%).$$

Results of correction coefficient for Reynolds number calculation (by the formula 15), and calculation of it's relative errors (by the formula 18), are given in the table 3.

Table 3. Results of calculation of correction coefficient for Reynolds number and root-mean-square relative errors of the coefficient determination

Re	k_{Re}	$\sigma_{K_{\mathrm{Re}}}$
2×10^4	1,03610	– 0,04682
3×10^4	1,02610	– 0,03385
5×10^4	1,01715	– 0,02224
10^5	1,00938	– 0,01217

Relative error of differential manometer, which has accuracy class, determined by pressure difference, can be calculated by the formula

$$\sigma_{\Delta P} = 0{,}5 \cdot \frac{\Delta P_{MAX}}{\Delta P} \cdot S_{\Delta P},\ [\%], \quad (19)$$

where $S_{\Delta P}$ – accuracy class of differential manometer; ΔP_{MAX} – maximal pressure difference, which is created by the nozzle when in use.

Pressure difference, created by a nozzle, is calculated by the formula

$$\Delta P = \frac{Q^2 \cdot 4^2 \cdot \rho}{\alpha_y^2 \cdot \pi^2 \cdot d^4 \cdot 2},\ [Pa]. \quad (20)$$

In the table 4 results of relative errors of pressure difference determination, calculated be the formula (19), are given. The calculation was done for the case, when pressure difference is measured with differential manometers of different accuracy classes, for example 0,4, 0,25, 0,15 and of maximal pressure difference 4 *kPa*, that can be measured.

Table 4. Results of calculation of root-mean-square relative errors of pressure difference measuring with the differential manometers of different accuracy classes

Re	ΔP	$\sigma_{\Delta P}$		
		$S_{\Delta P}$ = 0,4	$S_{\Delta P}$ = 0,25	$S_{\Delta P}$ = 0,15
2×10^4	135,59	5,90014	3,68759	2,21255
3×10^4	309,31	2,58640	1,61650	0,96990
5×10^4	868,14	0,92151	0,57594	0,34557
10^5	3 497,41	0,22874	0,14296	0,08578

Relative error of waste water density determination can be calculated by the formula [9] (while using tabular data)

$$\sigma_{\rho} = 50 \cdot \frac{\Delta\rho_{nom}}{\rho_{nom}},\ [\%], \quad (21)$$

where $\Delta\rho_{nom}$ – maximal absolute error of waste water density determination, using tabular data (it is taken equal to half the value of the last digit of tabular data); ρ_{nom} – nominal density of waste water, which at the temperature of 20 ^0C is 998,2 kg/m^3.

Relative error of waste water density determination is

$$\sigma_{\rho} = 50 \cdot \frac{0{,}05}{998{,}2} = 0{,}0025\ (\%).$$

Results of root-mean-square relative errors of waste water flow rate measuring with sensing device, consist of a standard nozzle, calculated by the formula (9), are given in the table 5

Table 5. Values of root-mean-square relative errors of waste water flow rate measuring with sensing device, consist of a standard nozzle

Re	Q, $m^3/sec\times10^{-3}$	σ_Q		
		$S_{\Delta P}$ =0,4	$S_{\Delta P}$ =0,25	$S_{\Delta P}$ =0,15
2×10^4	0,79325	3,14305	2,13902	1,54909
3×10^4	1,18988	1,68761	1,35238	1,18778
5×10^4	1,98313	1,17810	1,12185	1,09794
10^5	3,96626	1,09030	1,08664	1,08513

Relative error of waste water amount measuring with proposed quantity-meter can be determined as root-mean-square value of relative error of waste water flow rate measuring with sensing device and relative error of amount calculation with integrator by the formula

$$\sigma_W = \sqrt{\sigma_Q^2 + \sigma_{ST}^2},\ [\%], \quad (22)$$

where σ_{ST} – relative error of amount calculation with integrator.

Relative error of calculation with integrator can be defined by the formula

$$\sigma_{ST} = \sqrt{\sigma_{CM}^2 + \sigma_{ADC}^2 + \sigma_{CAL}^2 + \sigma_{IND}^2}, [\%], \quad (23)$$

where σ_{CM} – root-mean-square relative error of a constant multiplier (when using modern, nonexpensive, direct-current amplifiers with differential outputs, designed on the basis of integrated microcircuits, errors can be within 0,0025%); σ_{ADS} – root-mean-square relative error of analog-to-digital converter (modern converters, which are produced as commercial products, operate with error no more than 0,5%); σ_{CAL} – root-mean-square relative error of digital calculator (is determined be a number of operations and rounding errors of results, in the case of using ten-digit address buses, after a hundred of operations error does not exceed 0,001%); σ_{IND} – root-mean-square relative error of an indicator (when using digital indicators, error is equal zero).

In this case relative error of calculation is

$$\sigma_{ST} = \sqrt{0,0025^2 + 0,5^2 + 0,001^2 + 0^2} = 0,5 \ (\%).$$

Results of root-mean-square relative error of waste water measurement with a proposed quantity-meter of differential pressure with a standard nozzle, calculated according to the formula (22), are given in the table 6

Table 6. Values of root-mean-square relative error of waste water quantity measuring with a quantity meter of differential pressure with standard nozzle

Re	ΔP	σ_W		
		$S_{\Delta P} = 0,4$	$S_{\Delta P} = 0,25$	$S_{\Delta P} = 0,15$
2×10^4	0,79325	3,18257	2,19668	1,62778
3×10^4	1,18988	1,76012	1,44185	1,28873
5×10^4	1,98313	1,27981	1,22823	1,20643
10^5	3,96626	1,19948	1,19615	1,19478

4. Conclusions

Quantity meters of waste waters of differential pressure do not have many of shortcomings, appropriate to meters, which implement other methods of measuring. Using this type of quantity meters for measuring waste water quantities of airline enterprises allows to improve monitoring of their impact on the environment substantially, and, thereby, to increase level of environmental safety of these enterprise's sewage systems. Using a standard nozzle instead of a standard diaphragm as a sensing device of a waste water quantity meter has a bunch of advantages. Quantity meter with a nozzle, when using differential manometer of accuracy class 0,25, provides measuring error in transitional range – 2,2%, which is 20% less than a quantity meter with a diaphragm. In operating range this error is within 1,5%, which is 25% less. In addition, a quantity meter with a nozzle provides better durability of metrological characteristics, than a meter with a diaphragm in conditions of aggressive impact of waste water on them.

References

[1] Methodology of sanitary and hygienic assessment of environmental conditions on enterprises of civil aviation 05.12.1985, MSU MGA USSR. (In Russian).

[2] *Pavluch L. I.* Mathematical model of a treatment process of oil containing wastewaters // *Pavluch L. I., Boichenko S. V., O. G. Kucher* // Proceedings of the National Aviation University, 2012, №1(50). – P. 182-188. (In Ukrainian).

[3] *Anisimov D. L.* Waste water records: general information about methods and devices. Materials of 26-th conference «Commercial assessment of energy resource», November 2007. – SPb.: Politechnika. – 2007. – P. 236. (In Russian).

[4] *Kremlevskii P. P.* Flow meters and quantity meters / *Kremlevskii P. P.* /. L.: Mashinostroenije, 1975. – 776 p. (In Russian).

[5] *Shafranovskii M. N.,* Means of calculation in sewage systems. Three methods of waste water flow rate measuring / *Shafranovskii M. N., Ozerov A. V.* / // Water-supply and sanitary engineering, № 4, 1999 – P. 28-29. (In Russian).

[6] *Zaitsev A. P.* Determination of water consumption waste water real volume with measurement instrumentation / *Zaitsev A. P., Romanova N. L., Simachin V. M., Filipovskaja N. V.* // Water-supply and sanitary engineering, №1, 2006 – P. 33-38. (In Russian).

[7] *Shamanskyi S. I.* Sewage water volume assessment with flow meters of differential pressure / *Shamanskyi S. I.* // «Environmental safety as a basis of sustainable development of the society». International theoretical and practical conference: 29–30 November 2012.: proceedings, Lviv. – 2012. – P. 280–281. (In Ukrainian).

[8] *Shamanskyi S. I.* Calculation of metrological performance of a sewage water meter with throttle device / *Shamanskyi S. I., Boichenko S. V.* //

Measuring and computing devices in technological processes, 2015, №1. – P. 000–000. (In Ukrainian).

[9] RD 50-213-80 Measurement procedure of gases and liquids flow rate with standard throttle devices. M.: «Izdatelstvo standartov», 1985. – 319 p. (In Russian).

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Існує багато витратомірів та лічильників кількості для вимірювання витрат та кількостей рідин, які мають досить високі метрологічні характеристики. Незважаючи на це, в системах водовідведення авіапідприємств, як і в багатьох інших каналізаційних системах, облік стоків здійснюється переважно розрахунковим шляхом. Головною причиною є те, що ті прилади, які успішно використовуються в водопровідних мережах, часто не демонструють задовільної роботи в каналізаційних системах, оскільки не є стійкими до агресивної та збурюючої дії забруднених стічних вод. У цій статті запропоновано принципову схему лічильника кількості стічних вод змінного перепаду тиску на основі комбінації звужуючого пристрою, а саме стандартного сопла як первинного перетворювача та інтегратора. Показано, що такий лічильник не матиме багатьох недоліків, властивих лічильникам кількості, котрі реалізують інші способи вимірювання. Проаналізовано метрологічну стабільність такого лічильника у порівнянні з використанням стандартної діафрагми як первинного перетворювача. Розраховано його метрологічні характеристики. Зроблено висновок про наявність переваг стандартного сопла над стандартною діафрагмою таких як вища точність вимірювання та краща метрологічна стабільність.

Ключові слова: вимірювання кількості стічних вод, звужуючий пристрій, лічильник стічних вод, похибка вимірювання, стандартне сопло.

С.И. Шаманский[1], С.В. Бойченко[2] Измерение сточных вод авиапредприятий счетчиком перменного перпада давления со стандартным соплом
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Существует много расходомеров и счетчиков количества для измерения расходов и количеств жидкостей. Несмотря на это, в системах водоотведения авиапредприятий, как и во многих других канализационных системах, учет стоков производится преимущественно расчетным путем. Главной причиной является то, что те приборы, которые успешно используются на водопроводных сетях, часто не демонстрируют удовлетворительной работы в канализационных системах, поскольку не являются устойчивыми к агрессивному и возмущающему действию загрязненных сточных вод. В этой статье предложено принципиальную схему счетчика количества сточных вод переменного перепада давления на основе комбинации сужающего устройства, а именно стандартного сопла как первичного преобразователя и интегратора. Показано, что такой счетчик не будет иметь многих недостатков, присущих счетчикам количества, которые реализуют другие способы измерения. Проанализировано метрологическую стабильность такого счетчика в сравнении с использованием стандартной диафрагмы как первичного преобразователя. Рассчитаны его метрологические характеристики. Сделан вывод о наличии преимуществ стандартного сопла над стандартной диафрагмой, таких как более высокая точность измерений и лучшая метрологическая стабильность.

Ключевые слова: измерение количества сточных вод, сужающее устройство, счетчик сточных вод, погрешность измерения, стандартное сопло.

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