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# Development the Device of Automatic Dispensing Low Flowrates of Aggressive and Radioactive Liquids

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Currently, the problem of accurate metering micro-flows (up to 100 ml / min) liquid components of technological processes is acute in the chemical and nuclear industries. This problem is due to the fact that peristaltic pumps are used for batching, in which the slope of the flowrate characteristic changes with time. This is due to the wear of the flexible hose due to numerous compression cycles. Using of peristaltic pumps is due to the fact that in most technological processes in the nuclear and chemical industries, aggressive reagents are used and the use of other types of pumps is problematic because of the need to contact the moving parts of pumps directly with the environment.
This work describes the developed flowrate sensor, which is a capillary flowmeter, a measured volumetric flowrate. Metrological and production tests of the developed flowmeter are conducted and described. The variants of realization of the device of the automatic dispensing of low flowrate of aggressive and radioactive liquids.

## 1. Introduction

Nowadays, the State Corporation ROSATOM is implementing the Proryv (Breakthrough) project, one of whose tasks is the implementation of a closed nuclear fuel cycle. One of the key features of a closed nuclear fuel cycle is the low productivity of the devices, and consequently the low flowrate of material flows. Adamov et al. (2017) describe problems of making decisions on fast neutron reactors and closed nuclear fuel cycle. In work of Troyanov et al. (2014) is examined the present status of research on dense nitride fuel for liquid-metal cooled fast reactors. Kulikov et al. (2017) describe the possible role of existing thorium reserves in the Russian Federation on engaging thorium in being currently closed (U-Pu)-fuel cycle of nuclear power. In work of Shadrin et al. (2016) is shown different approaches to nuclear fuel cycle closure from the standpoint of plutonium utilization, fuel type, and reprocessing technology.
For radiochemical production of a closed nuclear fuel cycle the problem of measurement of low flowrate of technological solutions is particularly acute (up to 6 L/h). The problem of measuring low flowrate is that the specificity of radiochemical production places limitations on the use of known monitoring devices. For the solutions used in the technological processes of the radioactive chemical production of a closed nuclear fuel cycle, such parameters as aggressiveness and radioactivity are characteristic which impose additional requirements on the instrumentation used EC&I (increased resistance of instrument materials from radiation and aggressive media), and also increase the costs of maintenance and repair of instruments.
Measurements of the flowrate of the solutions used are necessary both for controlling the number of reagents used and for increasing the accuracy of dispensing solutions by adjusting the power value of the feed pumps from the measured flowrate. Accurate maintenance of the given flowrate of technological medias at the inputs of devices, especially extractors, is a necessary condition for the successful conduct of a technological operation.

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Feng et al. (2017) describe a new flow meter based on the double-capillary viscometer with the comparison calculation and the centrifugal effect due to coiling of the capillary being considered to revise the pressure drop of tested capillary. Parvizi et al. (2016) describe employing capillary tube mass flow meters instead of conventional counters in houses, assuming natural gas as pure methane, was proposed and investigated, resulting to satisfactory outcomes. Barbe et al. (2015) describe a development of a gas micro-flow transfer standard. In work of Farzaneh-Gord et al. (2015) was proposed the use of capillary tube mass flow meters for measuring residential natural gas consumption, where the flowrate is extremely low. In work of Ochoa Bique et al. (2016) described uranium crystallization process of radiochemical production of atomic industry. Vilnina et al. (2017) describe automatic control system of the evaporator in the technology of spent nuclear fuel processing.

## 2. Description the problem of dispensing solutions of radiochemical production

Currently, in radiochemical plants for dispensing solutions use peristaltic pumps with a known flowrate characteristic without feedback on the value of flowrate. But over time, these pumps change the slope of the flowrate characteristic. This is due to the wear of the flexible hose as a result of numerous compression cycles. The use of peristaltic pumps is due to the fact that in most technological processes in the nuclear industry aggressive reagents are used and the use of other types of pumps is problematic because of the need to contact the moving parts of pumps directly with the environment.
The results obtained in the research of the parameters of work the peristaltic pump with a tube made of the "tygon" material are shown in Figure 1.

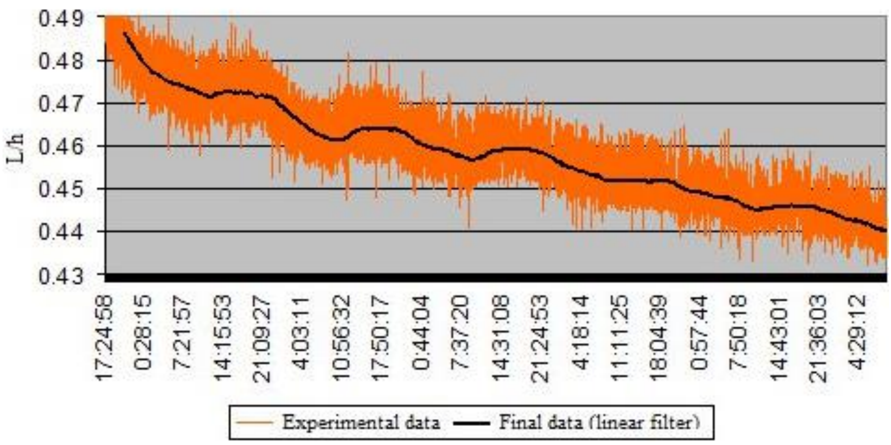


*Figure 1: Flowrate measurements for a peristaltic pump with a "tygon" tube*

The graph shows the measured and smoothed values of flowrate during dispensing. The decrease of flowrate value during the day is at least 0.01 L/h with an average flow rate of 0.46 L/h and is due to a decrease in the elasticity of the peristaltic tube due to the effect of significant periodic deformation on it.
Based on the obtained results, it is evident that to ensure a stable flowrate using peristaltic pumps, it is necessary to use the automatic control of the pump operation according to the indications of the device measuring this flowrate.

## 3. Description the problem of measuring low flowrates of solutions radiochemical productions

At present, on the market devices of control flowrate of liquid media exist a lot of sensors which based on various principles of action: tachometric, flowmeters of constant and variable pressure drop flowrates, ultrasonic coriolis flowmeters, etc. But not all devices allow to measure low flowrates in the range up to 6 L/h.
The following serially released sensors of measurement low flowrates of fluid environments are known:

- ultrasonic flowmeters of the Es-Flow series (Bronkhorst company);
- coriolis flowmeters-batchers of the series mini CORI-FLOW (Bronkhorst company);
- coriolis flowmeters of the LF series (Micro Motion company of Emerson Corporation).

But these meters of low flowrates cannot be used for radioactive fluids and cannot be installed in "hot" chambers (due to the impossibility of separation and remote removal of the electronic module from sensor).

From the analysis of the literature it is established that for the measurement of low flowrates in laboratory conditions it is possible to use capillary flowmeters, which are a subspecies of flowmeters with hydraulic resistance. Such a resistance is a capillary tube of a certain length, on the pressure drop on which the volume flow of the medium is determined. It is this type of flowmeters is taken as a basis for development of the device of control low flowrates of radiochemical productions.

## 4. Development of a device for measuring low flowrates

In the developed flowmeter, a capillary made of fluoropolymer tube TLM0302N and chemically resistant fluoropolymer fittings is used as the hydraulic resistance. The proposed scheme for the technical implementation of a device for measuring low flowrates in processing lines located in boxes or hot cameras is given in a Figure 2.

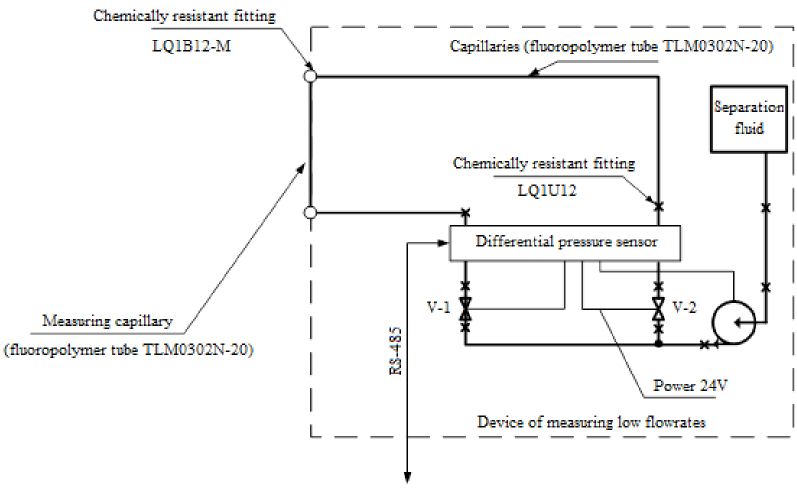


*Figure 2: Technical implementation of the device of measuring low flowrates*

Transfer of the differential pressure of the medium created by the hydraulic resistance to the differential pressure sensors is carried out by the capillary pulse lines which filled with the separation liquid, which allows to increase the life of the pressure sensors (due to the non-action of aggressive and radioactive media) and to remove the gauges from the hot chamber, which simplifies the maintenance and repair of these devices.
Performance checks, determination of calibration and metrological characteristics of the developed flowmeter were carried out on a laboratory bench, the structure of which is shown in Figure 3.

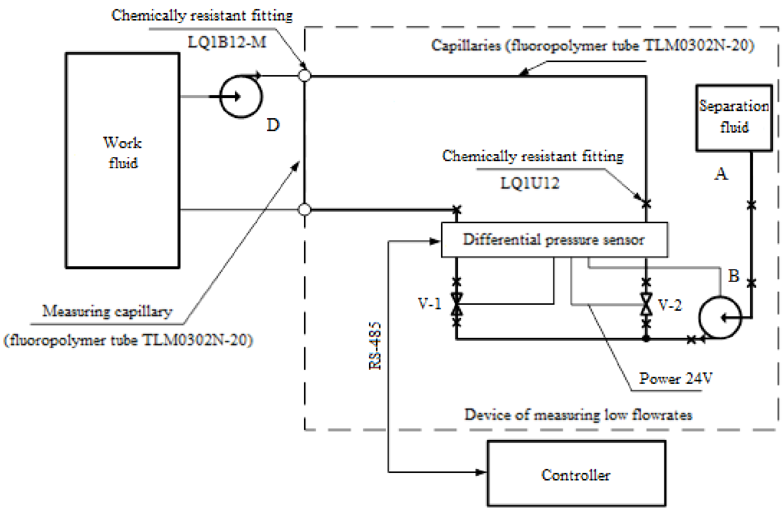


*Figure 3: Bench for test of experimental flowmeter*

## 5. Results tests of a device for measuring low flowrates

A series of experiments was conducted to measure the flowrate of artesian water using an experimental flowmeter, a gage tank and a stopwatch.
The averaged calibration characteristic is shown in Figure 4.

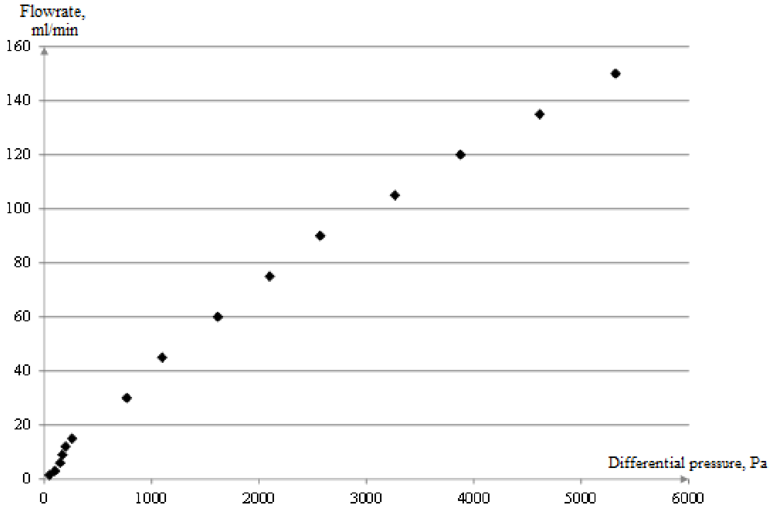


*Figure 4: Average calibrated characteristic of an experienced flowmeter*

The obtained data were approximated by a polynomial of the second order:

$$Q = -2 \cdot 10^{-6} \cdot P^2 + 0.0396 \cdot P + 1.792 \qquad (1)$$

In Figure 5 shows a comparison of the flowrates value, which was determined using a gage tank and a stopwatch and the flow values obtained from an experienced flowmeter.

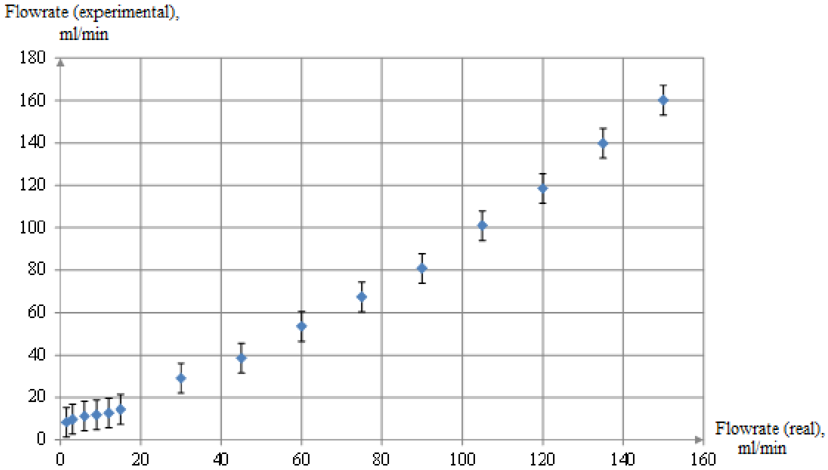


*Figure 5: Comparison of values of flowrates determined using a gage tank and a stopwatch and flow values obtained from an experienced flowmeter*

According to the data received the error of flowrate measurement which adduced to a scale was 4.6 %.

### 6. The device of the automatic dispensing of low flowrate of aggressive and radioactive liquids

The developed device of measurement of low flowrate can be used to automation of process of dispensing of solutions in technological processes of radiochemical productions. It is proposed to consider 3 variants of the automatic dispensing system.

In the first variant, it is proposed to use for dispensing a MasterFlex peristaltic pump and developed low flowrate sensor. In this case, the control action will be generated in the controller of the upper level of the automatic process control system based on the measured value flowrate. The proposed structural diagram is shown in Figure 6.

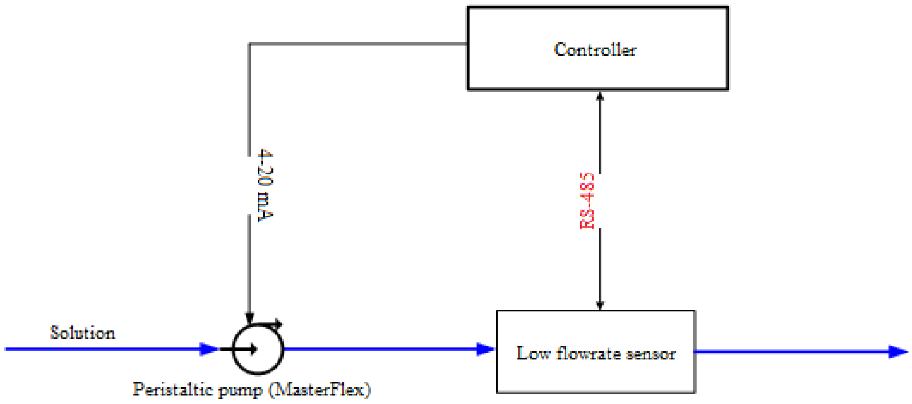


*Figure 6: Structural diagram of the first option of a control system of dispensing solutions*

In the second variant, it is also proposed to use a MasterFlex peristaltic pump and a low flowrate sensor, but now the control action to the pump will be generated by the intelligent part of the flowrate sensor itself (it will be calculated by the microprocessor installed in the low flowrate sensor). The proposed structural diagram is shown in Figure 7.

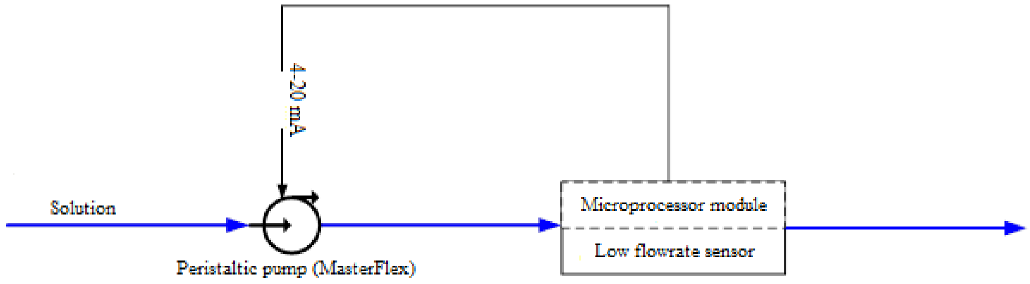


*Figure 7: Structural diagram of the second option of a control system of dispensing solutions*

The third option assumes manufacture of the automatic peristaltic batcher as the uniform device consisting of the made peristaltic pump and the microprocessor sensor of low flowrates. The proposed structural diagram is shown in Figure 8.

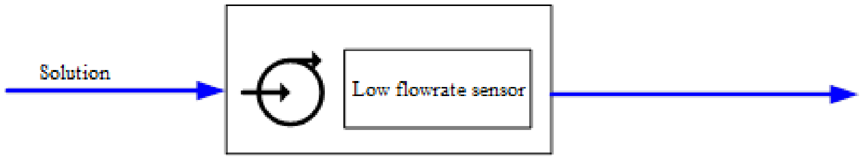


*Figure 8: Structural diagram of the third option of a control system of dispensing solutions*

The use of the proposed automatic dispenser with the developed device for control low flowrate up one of the presented structures will allow modernizing the dispensing systems in the technological processes of radiochemical production of the nuclear industry, which will stabilize material flows of substances and will increase quality of conducting technological processes.

## 7. Conclusions

In work the description of the developed sensor of measurement of low flowrate of solutions of radiochemical productions of the atomic industry which represents a capillary flowmeter. Measurement of flowrate happens on a pressure drop on a capillary. Metrological and production tests of the developed flowmeter are carried out and described.

In addition, the offered ways of realization of the automatic system of dispensing on the basis of the developed sensor and a peristaltic pump are given in work.

Application of an automatic batcher will provide stabilization of low flowrates that will increase quality of conducting technological processes in radiochemical productions of the atomic industry.

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