# Development of a national standard of water consumption in the Republic of Uzbekistan

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**Abstract**

The problem of water resources in Central Asia and, especially, in the Republic of Uzbekistan, requests to keep a high-quality and accurate accounting of water and/or liquid consumption using water flow meters of various types, classes and modifications. In turn, there is a need (in the Republic of Uzbekistan - once every two years) to verify and calibrate liquid flow meters, using a specific verification facility. Following the Resolutions of the President of the Republic of Uzbekistan No. PP-2935 dated April 28, 2017, and No. PP-4059 dated December 12, 2018, on December 2018 № PP-4059 for the development of the national standard base of the Republic of Uzbekistan State Institution "Uzbek National Institute of Metrology" (SI "UzNIM") in cooperation with the Agency on Technical Regulation the specifications have been developed for the delivery of Automated verification rig for flow meters, liquid meters (hereinafter referred to as - the rig) for the needs of the SI "UzNIM", approved on January 29, 2019.

## 1. Introduction

Water is a vital element of all aspects of the socio-economic activity in the Republic of Uzbekistan, and is a natural resource necessary for the life of households, agricultural manufacturers and all other industrial enterprises, as well as for maintaining the ecological balance.

According to the UN classification, the Republic of Uzbekistan belongs to countries experiencing water scarcity, the future balance of water resources of the republic will be affected by the intensive melting of glaciers that form the main rivers of the region, other aspects of climate change, as well as the growing needs of the population for water and the growth of industry. It is assumed that a 10-20% reduction in water supply may have serious consequences for the size of irrigated areas and the employed population, and will lead to a decrease in gross national income. Efficient water management to meet the needs of irrigated agriculture, municipal and industrial water use, the environment, etc. is crucial to guarantee the sustainable economic development of the country.

One of the main features of the modern period of development of the national economy of the Republic of Uzbekistan is the continuous increase in water consumption, including the household needs of the population. At the same time, the severity of the problem lies in the fact that water resources on the territory of the republic are distributed extremely unevenly, which is why the population of a number of regions constantly experiences difficulties associated with the provision of good-quality drinking water.

In this regard, the main goal of the development of the water sector of the Republic of Uzbekistan is to create conditions for meeting the ever-growing needs of the population, sectors of the economy and the environment with water, ensuring the effective management and use of water resources, the ameliorative state of irrigated lands, achieving water and food security in conditions growing scarcity of water resources, as well as global climate change.

In the Concept for the Development of the Water Resources of the Republic of Uzbekistan for 2020-2030, an important trend is the development of interstate relations on the use of transboundary waters, the development and promotion of mutually acceptable mechanisms for the joint management of transboundary water resources in the region, ensuring a balance of interests of the countries of Central Asia.

For metrological support of high-quality and accurate accounting of water and/or liquid consumption, it became necessary to create an appropriate standard.

For these purposes, the State Institution "UzNIM" developed a project, built and put into operation ETALON PARK, the site of one of the laboratories of which was provided for the operation of the Unit.

According to the agreement with the Customer, at the beginning of October 2021, the technicians of PJSC ENERGOUCHET within the territory of the ETALON PARK laboratory began to carry out commissioning and installation supervision for the subsequent commissioning of the Units, which (with a break) are planned to be completed in the fall of 2022.

APU-011/630 is the first and currently the only unit of this class in Central Asia, which in the future can and will be used by UzNIM State Institution as a reference calibration rig for verification and calibration of reference liquid meters used in calibration lower class installations.

## 2. The main material

*2.1 Calibration capabilities in the range of volume (mass) and liquid flow measurement*

Prior to designing this installation, the calibration capabilities existing in the world in the field of measuring volume (mass) and fluid flow were analyzed. For this, the information given in [1] was used. Some of them are shown in Table 1.

Based on the data given in [1], in 2019, the terms of reference were developed, according to which this installation was carried out. This specification took into account the technical achievements in the world in the field of liquid flow measurement.

**Table 1:** Calibration and Measurement Capabilities – CMCs

| Country Institute | Measurand Minimum value | Measurand Maximum value | Unit | Expanded uncertainty Minimum value, % | Expanded uncertainty Maximum value, % |
|---|---|---|---|---|---|
| Sweden RISE | 0.0017 | 1.5 | L/s | 0.1 | 0.1 |
| | 0.1 | 200.0 | L/s | 0.08 | 0.08 |
| | 0.0017 | 200.0 | L/s | 0.06 | 0.1 |
| Netherlands VSL | 0.001 | 150.0 | $m^3/h$ | 0.05 | 0.05 |
| | 0.001 | 150.0 | $m^3/h$ | 0.02 | 0.02 |
| | 0.001 | 60.0 | $m^3/h$ | 0.05 | 0.05 |
| | 0.001 | 60.0 | $m^3/h$ | 0.02 | 0.02 |
| Japan NMIJ AIST | 6.0E-4 | 0.33 | kg/s | 0.039 | 0.039 |
| | 0.083 | 8.33 | kg/s | 0.044 | 0.044 |
| | 1.39 | 83.3 | kg/s | 0.042 | 0.042 |
| | 13.9 | 833.0 | kg/s | 0.06 | 0.06 |
| | 208.3 | 3333.0 | kg/s | 0.081 | 0.081 |
| Austria BEV | 6.0 | 180000.0 | L/h | 0.05 | 0.05 |
| Germany PTB | 0.3 | 2100.0 | $m^3/h$ | 0.04 | 0.04 |
| | 0.3 | 2100.0 | t/h | 0.04 | 0.04 |
| Republic of Korea KRISS | 0.2 | 1.6 | kg/s | 0.08 | 0.08 |
| | 1.1 | 16.6 | kg/s | 0.05 | 0.05 |
| | 11.0 | 110.0 | kg/s | 0.08 | 0.08 |
| China NIM | 5.0 | 56.0 | kg/s | 0.045 | 0.045 |
| | 0.33 | 8.0 | kg/s | 0.045 | 0.045 |
| | 0.033 | 0.667 | kg/s | 0.045 | 0.045 |
| | 0.003 | 0.067 | kg/s | 0.045 | 0.045 |

*2.2 Description and operation of the rig*

*2.2.1 Function*

The unit is designed to reproduce and measure the volume and mass flow rate, volume and mass of water flowing through the pipeline.

The installation implements methods of static weighing and comparison of flow rates used for setting, calibrating, verificating, checking and other work to determine the metrological and technical characteristics of liquid meters, turbine, electromagnetic, ultrasonic, Coriolis, vortex and other flow meters, as well as rotameters for measuring liquid flow rate (hereinafter - LM).

The installation provides:

− adjustment of the verification flow rate;

- measurement of the flow rate or volume of the calibration medium according to the readings of the reference and calibrated measuring instruments in the same conditions;

− processing of the obtained experimental data to assess the metrological characteristics of verified meters.

The rig verifies the Liquid Meters that have a frequency (pulse) and current output information signals in automatical mode.

Operating conditions:
operating medium temperature (20 ± 5) °C;
ambient air temperature (20 ± 5) °C;
relative air humidity - from 40 to 60%;
atmospheric pressure - from 84.0 to 106.7 kPa.

A general view of the installation is shown in the figure 1.

**Figure 1:** General view

**Figure 2:** Unit assembling at the SD "UzNIM"

*2.2.2 Technical Specification*

Technical characteristics of the installation are given in table 2.

**Table 2:** Technical Specification

| Parameter | Value |
|---|---|
| Range of flow rate, $m^3/h$ | from 0,005 to 630 |
| Nominal diameters of flowmeters, mm | from 10 to 200 |
| Nominal diameters of rotameters, mm | from 10 to 50 |
| Stability of reproduction of the operating medium flow rate,%, not worse | 2 |
| Uncertainty of measurements in the mode of comparison with reference flow meters, % | ± 0,1 |
| Measurement uncertainty in static weighing mode, % | ± 0,04 |
| Limits of permissible absolute error in temperature measurement, °C | ± 0,2 |
| Limits of permissible basic relative error of pressure measurement, % | ± 0,2 |
| Limits of permissible basic absolute error of humidity measurement, % | ± 2 |
| Weighing range, kg | from 0,02 to 10000 |
| Number of simultaneously verified liquid meter:<br>flow meters<br>rotameters | <br>not more than 2<br>not more than 1 |
| Output signal from flowmeters:<br>frequency-pulse | from 0,001 to 2000 Hz; |
| Mounting of flowmeters | pneumatic |
| <u>Weight device</u> capacity, weight without tare: | |
| WD1 (storage tank 10000 l) | up to 15000 kg |
| WD2 (storage tank 6000 l) | up to 10000 kg |
| WD3 (storage tank 500 l) | up to 1000 kg |
| WD4 (storage tank 50 l) | up to 200 kg |
| WD minimum load, WD without taking into account the tare weight | 0,02 kg |
| Operating medium | water |
| Recycling tank capacity, l | 20000 |
| Pressure of the operating medium at the inlet of the working line, MPa, no more | 0,4 |
| Pipe material | stainless steel |
| Voltage (AC), V | 380 ± 38 |
| Frequency Hz | 50 ± 2 |
| Power consumption, kW, no more | 90 |
| Overall dimensions, m, not more than (LxWxH) | 10,0 x 4,5 x 4,0 |
| Weight (without water), t, no more | 24 |
| Average service life, not less | 12 years |

The general functional diagram of the installation is shown in Figure 3

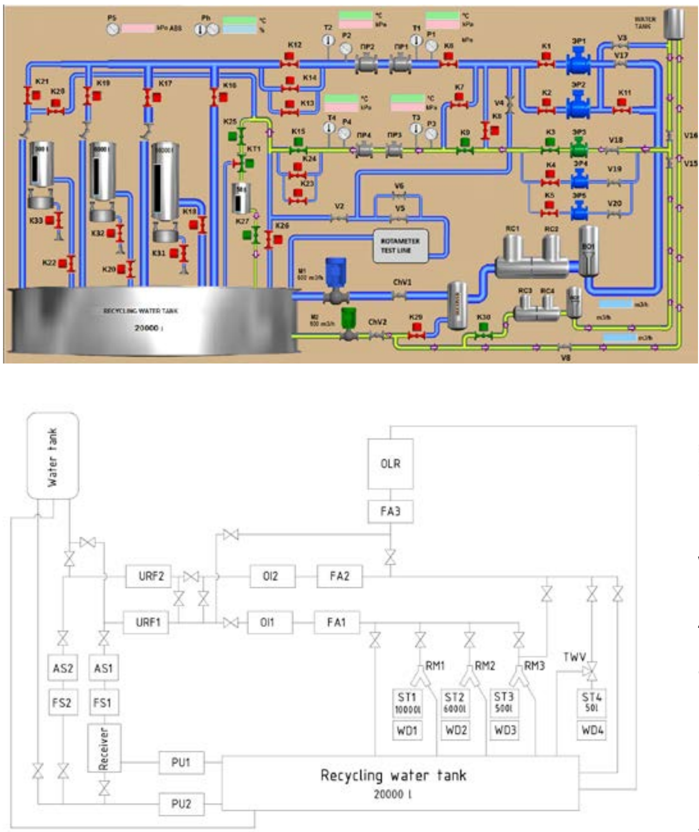


Figure **3:** The general functional diagram

The unit is manufactured in a block type in the form of various designs, including:

- recycling water tank with a capacity of 20,000 l;
- pressure generation system consisting of two pump units (PU1, PU2) and anti-vibration inserts;
- a deaeration and flow stabilization system, consisting of a receiver, flow stabilization unit (FS) and air separators (AS);
- units of reference flowmeters (URF1, URF2);
- operating lines (OI1, OI2) to install the meters;
- operating line (OLR) to install the rotameter;
- flow rate adjusting units (FA1, FA2, FA3);
- reversing mechanisms (RM1…RM3) and a three-way valve (TWV) for flow shifting;
- weighing devices (WD1…WD4) with storage tanks installed on them (ST1…ST4);

The functional diagram of reference flow meter units with flow control nodes is shown in Figure 4.

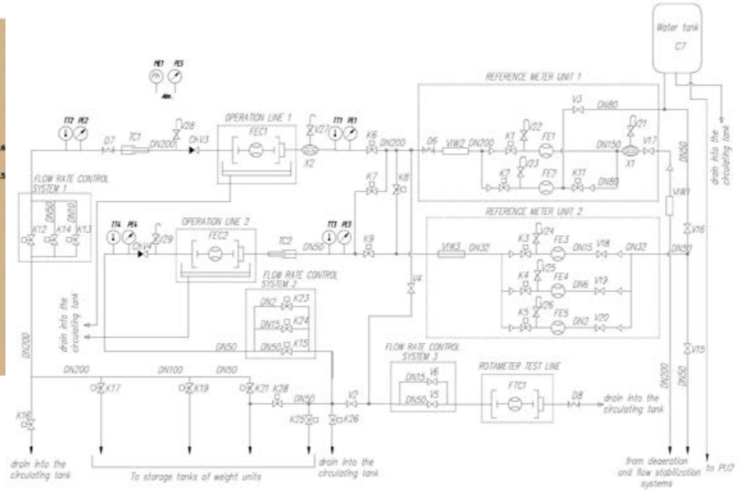


**Figure 4:** The functional diagram of reference flow meter units with flow control nodes

## *2.2.3 Water accumulation system*

To create the necessary water supply in the system, a recycling tank with a capacity of 20,000 litres is used, which has filling and drain valves, and a hatch with a lid to access service personnel. Baffles are installed inside the tank to reduce wave formation and reduce the formation of air bubbles in the water. The functional diagram of the water accumulation system is shown in Figure5.

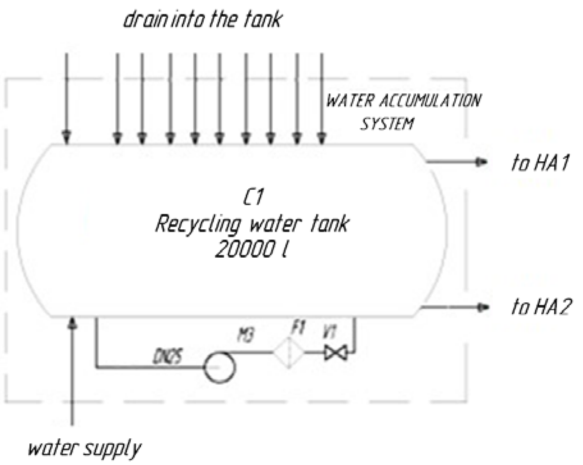


**Figure 5:** The functional diagram of water accumulation system

## *2.2.3 Pressure generation system*

The pressure generation system consists of two pump units of different capacities, valves installed at the outlet of the pumps, check valves and pressure gauges. The pump unit PU2 reproduces the flow rate up to 100 $m^3$/h, if it is required to reproduce the flow rate from 100 to 630 m$^3$/h, the pump unit PU1 is switched on. The functional diagram is shown in Figure 6.

Flow stabilization units (anti-vibration inserts) D1…D4 (see Figure 6) provide a reduction in the amplitude of pressure pulsations (in the frequency range of 0.1÷10 Hz) at the pump outlet to a level that is below the sensitivity limit of reference flow meters.

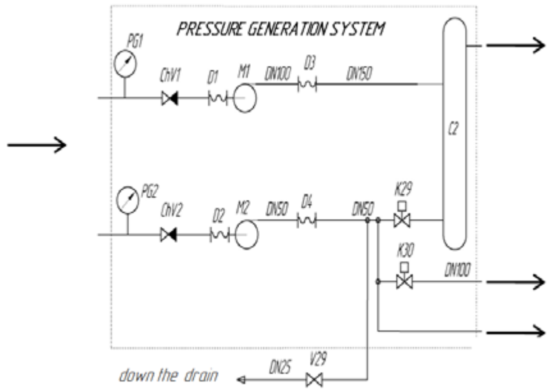


**Figure 6: Functional diagram of the pressure generation system**

*2.2.4 Reversing Mechanism*

Reversing Mechanism (RM) are designed to switch the flow to a recycling tank (RT) or to an storage tank (ST) mounted on a corresponding weighing unit. The RM has a movable nozzle and is equipped with an electromagnetic pneumatic actuator. The RM is placed in a casing, divided by a partition into two cavities: from one cavity the liquid flows to the storage tank, from the second - to the pipe line. The RMs are mounted on frames, which are installed on the support beams for the STs of 10000, 6000 and 500 liters capacity.

Three-way valve TWV1 performs the function of a Reversing Mechanism (RM) and is controlled by commands from the automated workplace.

STs are equipped with shutoff valves, through which water is discharged into the recycling tank RT after the measurement is completed.

*2.3 Calculation of uncertainty in measuring the mass and volume of liquids using weighing units*

Following paragraphs. 6.3 [2] and [3] we calculate the uncertainty of measurement of mass and volume of liquid.

Calculation of the uncertainty of measuring the mass of the liquid is carried out by the formula 1:

$$U_m = 100 \cdot K \sqrt{\begin{array}{c} \left(\frac{u(m)}{m}\right)^2 + \left(\frac{u(m)}{m+mt}\right)^2 \\ + \left(\frac{\Delta\tau}{t}\right)^2 + \left(\frac{u(t)}{t}\right)^2 + \left(\frac{u(\rho_a)}{\rho_t-\rho_a}\right)^2 \\ + \left(\frac{\rho_a}{\rho_t}\cdot\frac{u(\rho_t)}{\rho_t-\rho_a}\right)^2 + \left(\frac{u(g)}{g}\right)^2 \end{array}} \quad (1)$$

Calculation of the uncertainty of liquid volume measurement is carried out according to the formula 2:

$$U_V = 100 \cdot K \sqrt{\begin{array}{c} \left(\frac{u(m)}{m}\right)^2 + \left(\frac{u(m)}{m+mt}\right)^2 \\ + \left(\frac{\Delta\tau}{t}\right)^2 + \left(\frac{u(t)}{t}\right)^2 + \left(\frac{u(\rho_a)}{\rho_t-\rho_a}\right)^2 \\ + \left(\frac{u(\rho_t)}{\rho_t-\rho_a}\right)^2 + \left(\frac{u(g)}{g}\right)^2 \end{array}} \quad (2)$$

$u(m)$ – uncertainty of mass measurement by scales, kg;
$m$ - mass of water in the storage tank during measurement, kg;
*mt* – tank mass, kg
$u(\rho_a)$ - uncertainty of determination of air density by calculation method according to [4], [5], kg/m$^3$, $u(\rho_a)$ = 0,0025 kg/m$^3$;
$\rho_t$ – density of water in the installation at measuring temperature, kg/m$^3$, $\rho_t$ = 998,2 kg/m$^3$ (at 20 deg C);
$\rho_a$ – air density at measuring conditions, kg/m$^3$, $\rho_a$= 1,21 kg/m$^3$ (at a temperature of 20 degrees C and a pressure of 1 atm.);
$u(\rho_t)$ - uncertainty in determining the density of water in the installation at the measurement temperature, kg/m$^3$, $u(\rho_t)$ = 0,05 kg/m$^3$;
$\Delta\tau$ - diverter asymmetry, s, $\Delta\tau$ = 0,002 s;
$u(t)$ - time measurement error, s, $u(t)$ = 0,0001 s;
$t$ - time of mass measurement cycle, s;
$u(g)$ - the measurement uncertainty of the free fall acceleration, m/s$^2$, $u(g)$ = 0,0001 m/s$^2$;
$g$ - acceleration of free fall, m/s$^2$, $g$ = 9,8010 м/с$^2$ valid for Tashkent.
K – coefficient of dependence on confidence level, K = 1.4 for confidence level P = 0.99.

Results of calculations of uncertainty of measurement of mass and volume of liquid for different modes of operation of the installation are given in Tables 3-6.

**Table 3**

| Components of uncertainty | Q = 630 m3/h<br>t = 60 s<br>WU 1<br>m = 10500 kg | | Q = 240 m3/h<br>t = 60 s<br>WU 1<br>m = 4000 kg | |
|---|---|---|---|---|
| | $U_m$ | $U_V$ | $U_m$ | $U_V$ |
| Determination of water weight | $4,6\cdot10^{-5}$ | | $1,2\cdot10^{-4}$ | |
| Determination of tare mass | $4,2\cdot10^{-5}$ | | $0,96\cdot10^{-4}$ | |
| Determination of the asymmetry of the diverter movement | $3,3\cdot10^{-5}$ | | $3,3\cdot10^{-5}$ | |
| Determination of gravity acceleration | $1,02\cdot10^{-5}$ | | $1,02\cdot10^{-5}$ | |
| Determination of air density | $2,5\cdot10^{-6}$ | | $2,5\cdot10^{-6}$ | |
| Determination of water density | $6,08\cdot10^{-8}$ | $5,02\cdot10^{-5}$ | $6,08\cdot10^{-8}$ | $5,02\cdot10^{-5}$ |
| Time estimation | $1,7\cdot10^{-6}$ | | $1,7\cdot10^{-6}$ | |
| **Uncertainty, %** ***(K=1,4 with P=0,99)*** | ***0,01*** | ***0,0122*** | ***0,022*** | ***0,0232*** |

**Table 4**

| Components of uncertainty | Q = 240 m3/h<br>t = 60 s<br>WU 2<br>m = 4000 kg | | Q = 30 m3/h<br>t = 240 s<br>WU 2<br>m = 2000 kg | |
|---|---|---|---|---|
| | $U_m$ | $U_V$ | $U_m$ | $U_V$ |
| Determination of water weight | $0,8\cdot10^{-4}$ | | $1,6\cdot10^{-4}$ | |
| Determination of tare mass | $0,67\cdot10^{-4}$ | | $1,14\cdot10^{-4}$ | |
| Determination of the asymmetry of the diverter movement | $3,3\cdot10^{-5}$ | | $8,3\cdot10^{-6}$ | |
| Determination of gravity acceleration | $1,02\cdot10^{-5}$ | | $1,02\cdot10^{-5}$ | |
| Determination of air density | $2,5\cdot10^{-6}$ | | $2,5\cdot10^{-6}$ | |
| Determination of water density | $6,08\cdot10^{-8}$ | $5,02\cdot10^{-5}$ | $6,08\cdot10^{-8}$ | $5,02\cdot10^{-5}$ |
| Time estimation | $1,7\cdot10^{-6}$ | | $4,2\cdot10^{-7}$ | |
| **Uncertainty, %** ***(K=1,4 with P=0,99)*** | ***0,0154*** | ***0,0169*** | ***0,0276*** | ***0,0285*** |

**Table 5**

| Components of uncertainty | Q = 30 m3/h<br>t = 60 s<br>WU 3<br>m = 500 kg | | Q = 3 m3/h<br>t = 300 s<br>WU 3<br>m = 250 kg | |
|---|---|---|---|---|
| | $U_m$ | $U_V$ | $U_m$ | $U_V$ |
| Determination of water weight | $0,64\cdot10^{-4}$ | | $1,28\cdot10^{-4}$ | |
| Determination of tare mass | $0,53\cdot10^{-4}$ | | $0,91\cdot10^{-4}$ | |
| Determination of the asymmetry of the diverter movement | $3,3\cdot10^{-5}$ | | $6,7\cdot10^{-6}$ | |
| Determination of gravity acceleration | $1,02\cdot10^{-5}$ | | $1,02\cdot10^{-5}$ | |
| Determination of air density | $2,5\cdot10^{-6}$ | | $2,5\cdot10^{-6}$ | |
| Determination of water density | $6,08\cdot10^{-8}$ | $5,02\cdot10^{-5}$ | $6,08\cdot10^{-8}$ | $5,02\cdot10^{-5}$ |
| Time estimation | $1,7\cdot10^{-6}$ | | $3,3\cdot10^{-7}$ | |
| **Uncertainty, %** ***(K=1,4 with P=0,99)*** | ***0,0127*** | ***0,0145*** | ***0,0221*** | ***0,0232*** |

**Table 6**

| Components of uncertainty | Q = 3 m3/h<br>t = 60 s<br>WU 4<br>m = 50 kg | | Q = 0,005 m3/h<br>t = 48 min<br>WU 4<br>m = 4 kg | |
|---|---|---|---|---|
| | $U_m$ | $U_V$ | $U_m$ | $U_V$ |
| Determination of water weight | $0,3\cdot10^{-4}$ | | $1,25\cdot10^{-4}$ | |
| Determination of tare mass | $0,25\cdot10^{-4}$ | | $0,36\cdot10^{-4}$ | |
| Determination of the asymmetry of the diverter movement | $3,3\cdot10^{-5}$ | | $6,9\cdot10^{-7}$ | |
| Determination of gravity acceleration | $1,02\cdot10^{-5}$ | | $1,02\cdot10^{-5}$ | |
| Determination of air density | $2,5\cdot10^{-6}$ | | $2,5\cdot10^{-6}$ | |
| Determination of water density | $6,08\cdot10^{-8}$ | $5,02\cdot10^{-5}$ | $6,08\cdot10^{-8}$ | $5,02\cdot10^{-5}$ |
| Time estimation | $1,7\cdot10^{-6}$ | | $3,5\cdot10^{-8}$ | |
| **Uncertainty, %** ***(K=1,4 with P=0,99)*** | ***0,0073*** | ***0,01*** | ***0,0183*** | ***0,0196*** |

## 3. Conclusion

The installation is at the stage of implementation, studying its characteristics is in progress, and preparations for comparisons are underway.
The results of the comparisons will make it possible to publish calibration and measurement capabilities of UzNIM" in the database of key comparisons (KCDB).
By its technical characteristics, the rig is not inferior to the standards of the leading countries.
Availability of own etalon in such an important for Central Asia area of measurements as water flow brings Uzbekistan to the leading position in the region, will allow creating a traceable system of measurements.

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