Digital traceability of measuring information

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Abstract. The issues of improving the quality of measurements on the basis of ensuring digital traceability of measuring information for measuring the volumetric flow rate of liquid on the example of water meters are investigated. The main technical and metrological characteristics of portable calibration facilities were considered. Comparative analysis of portable installations by differential and complex methods was carried out. New requirements for measuring equipment are substantiated. Based on the use of information technology, a model for ensuring the traceability of measuring information when checking water meters was developed.

1. Introduction

The most significant condition for the reliability of measurement information is the traceability of the measurement. The implementation of the program for digitalization of the Russian economy requires the transition of metrology to digital support, the creation of a digital information metrological platform.

The "On ensuring the uniformity of measurements" law dated 26.06.2008 No. 102-FZ was amended in 2020 with a view to establishing the priority of electronic information over paper media. All results of activities in the field of metrology must be recorded in the Federal Information Fund for Ensuring the Uniformity of Measurements (FIF EUM). Since September 2020, without transferring information to the Federal Information Fund for Ensuring the Uniformity of Measurements, the results of metrological work are invalid. The issues of creating a digital metrological infrastructure are actively discussed at specialized forums, in the national and foreign press [1, 2]. The concept of digitalization of metrology establishes the creation of a unified information environment with free access to information databases.

The information environment of FIF EUM contains Russian and international normative documents on metrology, a list of measuring instruments in the field of state regulation, information on standards, certified measurement techniques, on approved measuring instruments, standard samples of an approved type, and the results of verification of measuring instruments. The digital transformation of metrological assurance requires the installation of sensors and instruments on measuring instruments capable of transmitting information through telecommunication networks to a single information base of the FIF EUM.
New requirements are being formed for measuring equipment, measurement procedures, verification automation, and the creation of intelligent measuring instruments. Thus, in the power industry, digital current and voltage transformers, smart meters, and a digital reference base are actively used [3].

The basis for ensuring the traceability of the measurement result is a verification scheme, where each instrument through a series of documented verifications is correlated with the state primary standard of the highest accuracy. Requirements for the metrological characteristics of the reference base when verifying water meters are established in the state verification scheme [4]. In accordance with MI 1592-2015, calibration of water meters can be carried out without dismantling at the place of their operation or during dismantling of the meter on a stationary installation in a special laboratory [5].

The meter dismantling takes time and availability of a spare meter for the verification period, therefore, the verification of water meters without dismantling on portable calibration installations has become widespread. According to the verification scheme, the installations should be of 3-grade standards. To confirm their metrological characteristics, verification is carried out using a 2-grade standard with the one-year period of the calibration interval. The purpose of the study is to analyze the possibility of ensuring the traceability of measuring information when calibrating water meters using portable calibration installations according to the requirements of the digital metrological infrastructure.

2. Methods and materials
The theoretical and empirical basis of the study is the regulatory - legal and regulatory - technical documentation on technical regulation and metrology. Metrological and technical data on the verification scheme, verification methodology, technical descriptions of verification installations are analyzed. The empirical base shows the results of monitoring the procedure for verifying water meters at various calibration installations, written analysis of the verification results.

The study is based on a systematic approach, qualimetric methods of assessment, analysis and synthesis, classification and schematization of the results obtained, methods of mathematical statistics and theory of accuracy. The paper uses statistical data analysis, differential and complex methods for assessing quality.

3. Results and discussion
To ensure the traceability of the measurement information, the possibility of on-line control of the completeness and reliability of the calibration procedure for water meters, it is necessary that the portable calibration rig has the following functions:

- Electronic document of verification results
- Automatisation of verification with the recording of the beginning and the end of verification
- Time recording intervals for verification
- Recording the conditions for carrying out the verification according to the verification procedure: pressure, ambient temperature, air humidity.

Let us consider the metrological and technical characteristics of the main automated portable calibration installations for calibrating water meters: UPPA-3A, Nepton, VPU-Energo-M, Kaskad-2P, UPRS-P, UPSZh-5P [6 - 11] (Table 1).

Table 1. Technical and metrological characteristics of portable calibration equipment.

| Characteristics                      | UPPA - 3A | Nepton | VPU - Energo - M | Kaskad - 2P | UPRS - P | UPSZh5P |
|--------------------------------------|-----------|--------|------------------|-------------|----------|---------|
| Operating medium                     | Water     |        |                  |             |          |         |
| Nominal bore diameter of the devices under test, mm | 10 - 20   | 10 - 32 | 4 - 32           | 10 - 32     | 4 - 32   | 10 - 20 |
| Flow measurement range, m³ / h       | 0.02 - 5  | 0.01 - 3.5 | 0.01 - 15      | 0.02 - 3    | 0.01 - 3 | 0.02 - 5 |
Limits of permissible relative inaccuracy when measuring volume and volumetric flow rate, %

| Indicator                              | UPPA-3A | Nepton | VPU Energo-M | Cascade-2P | UPRS-P | UPSZH5P |
|----------------------------------------|---------|--------|--------------|------------|--------|---------|
| Power consumption, W, max.             | 20      | 20     | 10           | 20         | 15     | 2       |
| Pressure of the measured medium, MPa, max. | 1.6    | 0.6   | 1            | 1          | 0.6    | 0.6     |
| Weight, kg, max.                       | 2.5     | 8      | 5.4          | 14         | 7      | 12      |
| Overall dimensions, height, mm, max.   | 150     | 310    | 192          | 175        | 210    | 190     |
| Overall dimensions, width mm, max.     | 160     | 300    | 310          | 445        | 350    | 380     |
| Overall dimensions, length, mm, max.   | 100     | 600    | 390          | 520        | 430    | 480     |
| Mean time to failures, h               | 20000   | 20000  | 30000        | 20000      | 20000  | 20000   |
| Average service life, years            | 12      | 12     | 15           | 12         | 12     | 10      |

A comparative analysis of portable installations will be carried out by qualitative methods of assessment [12]. The results of assessing the quality of portable calibration installations according to the above characteristics by the differential method are shown in (figure 1).

Whereas, the differential assessment method does not give ambiguous results, to calculate the arithmetic mean and geometric mean and apply a comprehensive quality assessment method a hierarchical tree of quality property indicators should be constructed.

The expert assessment was conducted by a group of metrologists. The reliability of the expert method is estimated as a degree of consistency based on the concordance coefficient. The verification of the significance of the values of the coefficient of concordance $W$ is carried out on the basis of the criterion $\chi^2$ by Pearson [12]. An important characteristic for the verifier is the overall dimensions and weight of the portable installation. The results of comprehensive assessment show that, in general, all installations correspond to their characteristics (table 2).
Table 2. Comprehensive quality indicators.

| Assessment methods         | UPPA – 3A | Nepton | VPU Energo -M | Kaskad – 2P | UPRS - P | UPSZH5P |
|---------------------------|-----------|--------|---------------|-------------|----------|---------|
| Hierarchical arithmetic avg. | 1.23     | 1      | 1.13          | 1.05        | 0.90     | 0.95    |
| Hierarchical geometric avg. | 1.1       | 1      | 1.03          | 1.01        | 0.92     | 0.99    |
| Expert avg.               | 1.20      | 1      | 1.10          | 1.04        | 0.95     | 0.98    |

The UPPA-3A was chosen as the best installation, the smallest in size and the lightest in weight.

The extent to portable calibration rigs meet the traceability requirements of measurement information. The measuring capabilities of information technology-based calibration facilities are shown in table 3.

Table 3. New measurement capabilities based on information technology.

| Capabilities                               | UPPA – 3A | Nepton | VPU Energo-M | Kaskad – 2P | UPRS - P | UPSZH5P |
|--------------------------------------------|-----------|--------|--------------|-------------|----------|---------|
| Automatic measurement of ambient temperature | +         | +      | -            | +           | -        | -       |
| Automatic measurement of the temperature of the measured medium | +         | +      | -            | +           | -        | -       |
| Automatic measurement of atmospheric pressure | +         | +      | +            | +           | -        | -       |
| Automatic measurement of ambient relative humidity | +         | +      | -            | +           | -        | -       |
| Automatic measurement of time intervals    | +         | +      | -            | +           | +        | +       |
| Automatic POP file formation               | +         | +      | -            | -           | -        | -       |
| Automatic ION file formation               | +         | -      | -            | -           | -        | -       |
| Automatic formation of the verification protocol file | +         | +      | +            | +           | +        | +       |
| Automatic file formation for sending to FSIS "ARSHIN" | +         | -      | -            | -           | -        | -       |
| Sending electronic files over wireless networks | +         | +      | +            | -           | -        | -       |
| Wi-Fi, the Internet                        | Wi-Fi     | Wi-Fi  | Option: Internet, Bluetooth |
| Wi-Fi, the Internet                        | Wi-Fi     | Wi-Fi  | Option: Internet, Bluetooth |
Photographic fixation of meter readings + - Option: only final indicators - - - -

Controlling the verification process via smartphone (Android) + - + - - -

Illumination of the place of verification + - + - - -

Sensors for automatic determination of the verification conditions: temperature of the ambient and measured environment, pressure, relative humidity

Time sensor for recording verification results in real time

Photographic recording of meter readings at all points of water consumption

Paperwork automation

Transfer of verification results via wireless networks WiFi, Bluetooth, the Internet

Application of information technologies to improve the quality of calibration of water meters

Time reduction for measuring the verification conditions

Inability to carry out verification in inappropriate conditions

Exact implementation of the verification procedure in accordance with MI 1592-2015

Ensuring the reliability of verification in accordance with MI 1592-2015

Electronic registration of verification results

Obtaining information about the results of verification and the status of the measuring instrument by any concerned person

Generation of up-to-date information on the meter calibration results on the digital metrological platform

Control capabilities:
1. Suitability of the standard (calibration rig)
2. Compliance with the verification conditions
3. Completeness of the verification work
4. Qualification of testers
5. Validity of verification

Figure 2 Model for ensuring traceability of measurement information when calibrating water meters.
Let us analyze the influence of the measuring capabilities of calibration facilities on the duration and quality of verification by means of information technology.

Water meters are often located in hard-to-reach dark places, thus, the ability to illuminate the place of verification reduces the verification time.

The ability to set up automatically measures the ambient and measured temperatures, atmospheric pressure, ambient humidity, time intervals allows to reduce the time for using additional verification tools (preparation, measurements, reading, recording). Calibration in inappropriate conditions is excluded.

Thanks to the function of photo fixation of meter readings, the minimum measurement time (for UPPA-3A) at all flow points (3 points with 1 measurement) is 20 minutes ($Q_{\text{min}}=12$ minutes + $1.1Q_{\text{trans}}=6$ minutes + $Q_{\text{max}}=2$ minutes). Whereas, if this function is not provided (all other settings), it is necessary to measure 3 times at each point (20 minutes x 3 = 60) only for the flow of water (according to MI 1592-2015, clause 2.7.3).

The possibility of automatic processing of documents significantly saves time. The database allows to find the required number in the register by the name of the meter. All lines of the verification certificate are automatically filled in, the file can be immediately printed or sent via Wi-Fi, Bluetooth or the Internet, only a verification mark and a signature should be put.

In the course of the study, a model for ensuring the traceability of measurement information was developed (figure 2). The model clearly shows the factors that contribute to improving the quality and reliability of the calibration of water meters. The openness, reliability and timeliness of the provision of measurement information, the use of automated control methods set new requirements for measurement technology.

4. Conclusion
Thus, basing on the conducted studies:

- the metrological and technical characteristics of the main automated portable calibration installations for calibrating water meters were analyzed;
- comparative analysis of portable installations, quality assessment by differential and complex methods was carried out;
- the possibilities of ensuring the traceability of measuring information when calibrating water meters using portable calibration installations were investigated;
- a model for ensuring the traceability of measuring information when checking water meters was developed.

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