



METROLOGICAL CHARACTERISTICS OF MEASURING INSTRUMENTS AND MODERN REQUIREMENTS

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Abstract

This article highlights the metrological characteristics of measuring instruments, their main indicators, as well as the technical and operational requirements imposed on modern measuring devices from a scientific-theoretical perspective. Along with classical metrological parameters such as measurement accuracy, sensitivity, repeatability, reliability, stability, and measurement limits, modern indicators of digital and intelligent measuring instruments—such as IP protection level, electromagnetic compatibility, signal interfaces, calibration interval, metrological traceability, and others are analyzed. The role of metrological characteristics in ensuring the reliability of measurement results is substantiated in the article.

Keywords: Metrological characteristic, accuracy class, error, sensitivity, repeatability, stability, IP rating, electromagnetic compatibility, calibration, metrological traceability, digital measuring instruments.

Introduction

The rapid development of modern industry, energy, chemical technology, and information-communication systems significantly increases the demand for measurement accuracy and reliability. The validity of measurement results is primarily determined by the metrological characteristics of the measuring instruments used. Metrological characteristics represent a set of normative-technical indicators that determine the quality, accuracy, operating conditions, and reliability of a measuring instrument. These characteristics are formed in accordance with state standards and international regulatory documents,



particularly the requirements of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).

Theoretical Foundations of Metrological Characteristics

A measuring instrument is defined as a device used in engineering, industry, and production processes that possesses standardized metrological characteristics. After production, each measuring instrument is evaluated according to its functional capability. The main metrological characteristics of measuring instruments include the following parameters:

Measurement error: Measurement error is the difference between the measured value and the true (reference) value of a quantity. The most commonly used types of errors are absolute and relative errors.

Absolute error:

$$\Delta X = X_0 - X_h$$

Where:

ΔX – absolute error

X_0 – measured value

X_h – true value

Relative error:

$$y = \frac{\Delta X}{X_h}$$

Where:

γ – relative error (usually expressed in %)

ΔX – absolute error

X_h – true value

Measuring instruments must possess an important characteristic—sensitivity, meaning they should detect even very small changes. Sensitivity is defined as the ratio of the change in the output signal to the change in the input quantity:

$$S = \Delta X / \Delta Y$$

Where:

S – sensitivity coefficient

ΔY – change in output signal

ΔX – change in input quantity



The higher the sensitivity, the greater the ability to detect small variations. During operation, measuring devices must exhibit repeatability. Repeatability refers to the closeness of measurement results obtained under identical conditions. Reproducibility refers to the degree of agreement between results obtained under different conditions or by different operators.

Measurement Range: With the development of innovative technologies, the demand for wider measurement ranges is increasing. The measurement range is the interval between the minimum and maximum values within which the instrument operates within permissible error limits. For example, an analog micrometer with a measuring range of (50–75) mm is designed to measure parts from 50 mm to 75 mm, and its span (range width) equals 25 mm.

Modern Characteristics of Digital and Intelligent Measuring Instruments:

The emergence of digital and intelligent measuring instruments has expanded the system of metrological characteristics. Today, devices operating via software and microprocessors possess the following modern features:

IP (Ingress Protection) Rating. The IP rating indicates the degree of protection against dust and moisture.

For example:

- IP54 – partial protection against dust and splashing water
- IP65 – complete protection against dust and water jets
- IP67 – resistant to temporary immersion in water

IP ratings are established based on the IEC 60529 standard developed by the International Electrotechnical Commission.

Electromagnetic Compatibility (EMC): In modern industrial environments, electromagnetic interference can affect measurement results. Therefore, measuring instruments and electric vehicles are tested for electromagnetic compatibility, including:

- resistance to electromagnetic radiation;
- not emitting excessive electromagnetic interference.



Digital Interfaces: Modern measuring instruments are equipped with the following interfaces:

- RS-485
- USB
- Ethernet
- Modbus protocol

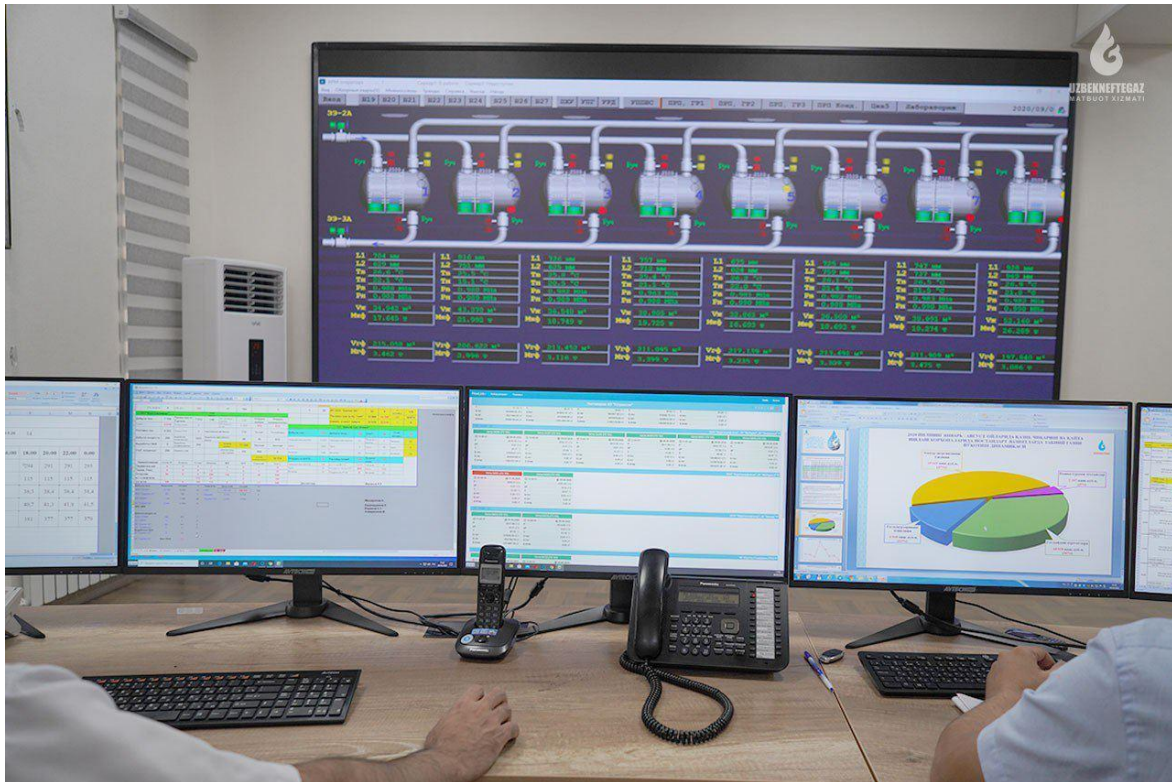
This ensures integration into automated control systems.

Metrological Traceability: Every measurement result must be traceable to national or international standards. This principle is internationally coordinated by the International Bureau of Weights and Measures (BIPM).

Calibration Interval: The calibration interval is determined based on the period during which the instrument maintains its metrological characteristics (the verification and calibration intervals of measuring instruments are defined in Order No. 78 dated January 7, 2025, of the Director of the Uzbekistan Technical Regulation Agency under the Cabinet of Ministers of the Republic of Uzbekistan). Modern intelligent instruments include self-diagnostic functions.

Energy Efficiency and IoT Integration: Modern measuring instruments must meet requirements related to energy consumption and data processing capabilities and provide the following features (**1-image**):

- low power consumption;
- remote monitoring;
- cloud storage systems;
- real-time data transmission.



1-image

Practical Significance of Metrological Characteristics: In industry, manufacturing, and construction, metrological characteristics provide the following advantages:

- ensuring industrial safety;
- enabling product quality control;
- contributing to energy savings;
- assisting in optimization of technological processes.

Conclusion

The metrological characteristics of measuring instruments constitute a set of essential indicators that ensure the scientific validity, reliability, and repeatability of the measurement process. In modern digital and intelligent measuring instruments, alongside classical metrological parameters, indicators such as IP protection level, electromagnetic compatibility, digital interfaces, metrological traceability, and measurement uncertainty are gaining increasing importance. Further improvement of metrological characteristics, especially the development



of self-calibrating measurement systems based on artificial intelligence, represents one of the most relevant scientific directions for the future.

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