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Quality Criteria Inspection of Measurement Means

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ABSTRACT: This article discusses the quality criteria of verification of measuring instruments, on the basis of which the permissible errors of verification are established in regulatory documents on the verification of measuring instruments. A graphical illustration of the quality criteria for verification is presented using the operational characteristic for P (x) - the probability of recognizing the device under verification as suitable for specific values of X. The margin of accuracy that the reference device should have when calibrating measuring instruments is mathematically substantiated.

KEYWORDS: measuring instruments, calibration of measuring instruments, quality criteria of calibration of measuring instruments, measurement error, verified measuring instrument.

I. INTRODUCTION

The problems of the unity and accuracy of measurements are primarily of professional interest to metrologists - verifiers. However, to one extent or another, they relate to everyone involved in measurements - whether it is measuring the pressure in the tires of a personal car or measuring when drilling holes in the frame of the rocket engine.
One of the main forms of maintaining a measuring instrument in a metrologically sound condition is its verification.
It is carried out by metrological services in accordance with the rules set forth in the special regulatory and technical documentation.
Assessing the quality of verification of measuring instruments (SI) has several aspects that can be reduced mainly to a discussion of the statistical model of measurements during verification, ways of presenting quality indicators and directions for taking into account the variability of calibration conditions.
When verifying any SI, the decision on its suitability (unsuitability) is based on a comparison of its error with a predetermined threshold value. One of the main procedural methods for estimating the error, which in its technical essence is calibration, consists in performing repeated repeated measurements of the same object by the verified and reference SI under the same conditions, followed by determining the difference between the obtained sample means. Another way is to measure the verifiable SI standardized object, so that the reference SI is not necessary.
When both methods are implemented, the variability of the measurement results is inevitably caused by both the errors of the verified SI and the errors of the measurement procedure. Since the measurement error during verification is a random variable, the quality indicators of verification should be probabilistic in nature.
In the normative and technical documentation (NTD) on the methods and means of verification of measuring instruments (SI), the permissible errors of measuring instruments are established according to the specified criteria for the quality of calibration. The NTD indicates:
• permissible error of verification;
• control clearance;
• the value of the criteria adopted in their determination.
The nomenclature of the quality criteria for verification of SI and auxiliary parameters necessary for assessing the quality of verification is determined by monitoring the characteristics of the error of the SI for compliance with the norm established in the technical documentation on the measuring instrument.

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When checking the measuring device (IP), the errors of its readings are determined and compared with the data specified in the technical requirements.
Δφ are the actual errors of the readings, [Δφ] are the limits of the permissible errors established by the standards and other norms.
If Δφ <[Δφ], then the IP is recognized as suitable. However, when checking, there are errors. As a result, the accuracy of verification is violated. For example, the device under test, which is actually suitable, is rejected due to the error of verification. This case is called a mistake of the first kind (or GB, t, i.e., the conversion of the fit into defective). The opposite phenomenon is also possible: the device under verification is actually unsuitable, but it can be accepted as suitable also due to the error of verification. The second case is called a mistake of the 2nd kind (or G-D, i.e. the transfer of defective to fit).
The indicated phenomenon should be minimized. For this, the systematic errors of verification are first excluded. There remain random verification errors. They can not be excluded, you can only consider.
Verification error is the difference between the error of the testimony of the IP found experimentally and the true value of the error of the readings Δ0φ. But Δ0φ always remains unknown, therefore, the required exact error value is accepted instead of it, for which they establish their confidence interval (much narrower than for the error of the testimony of the verified IP). In practice, this required exact value of the error of readings is found as an estimate of the average value of the error of readings with repeated verification Δ2φ.
Thus, the verification error Δ0 is the measurement error when checking the SI. It includes the error of the standard SI, errors due to auxiliary SI, and methodological errors of verification.
Verification errors are not detected during the operation of the SI, since the SI recognized as suitable is considered to be such throughout the entire verification interval. Obvious economic damage from the use of SI, erroneously recognized as suitable or unfit. This is precisely what led to the formulation of the problem of applying the criteria of reliability of verification and the parameters of verification methods that limit the allowable number of incorrectly verified SI.

II. PROBLEM DEFINITION AND ITS DECISIONS

The following verification quality criteria are established:
P_{HM} –the greatest probability of accepting any unusable device as suitable (undetected marriage);
$\delta_M = |\Delta_M|/|\Delta_\Pi|$–the ratio of the largest possible value of the error characteristic of the device, recognized by the results of verification as suitable, but in fact unfit, to the limit of its permissible values (the largest exit for tolerance);
P_{ϕ}– the ratio of the number of suitable but rejected measuring instruments to the number of all actually suitable (fictitious marriage on average);
$P_{\phi M}$–the greatest likelihood of accepting any suitable instance of the device as unusable (fictitious instance marriage).
To ensure the uniformity of measurements, the main criteria are P_{HM} and δ_M, and additional - P_{ϕ}.
MI187-86, MI188-86 "Guidelines. GSI. Reliability and requirements to the verification methods of measuring instruments ”establish the nomenclature of criteria for the reliability of verification that are common to a wide range of verification methods. These criteria are used as the basic input data when setting the values of the parameters of verification procedures. To solve this problem, operational characteristics used in statistical quality control, which are the probability of acceptance, are used. Verification reliability criteria are parameters of operational characteristics. The criteria provided by the methodology take into account that the verification result is determined by the interaction of two probable distributions of the verification error and the verified MI error, as a result of which verification errors are inevitable. According to these criteria, the ratio of the errors of verification and verified MI is established, as well as the value of the control tolerance.
We illustrate the quality criteria of verification using the operational characteristics for $P_{(X)}$ –the probability of recognition of the device under test, provided that X has some specific meaning.
X is the ratio of the controlled characteristic Δ of the error of the measuring instrument to the limit Δp, where Δp is the limit of the permissible values of the error (the largest tolerance):

$$X = \Delta / (\Delta p) \tag{1}$$

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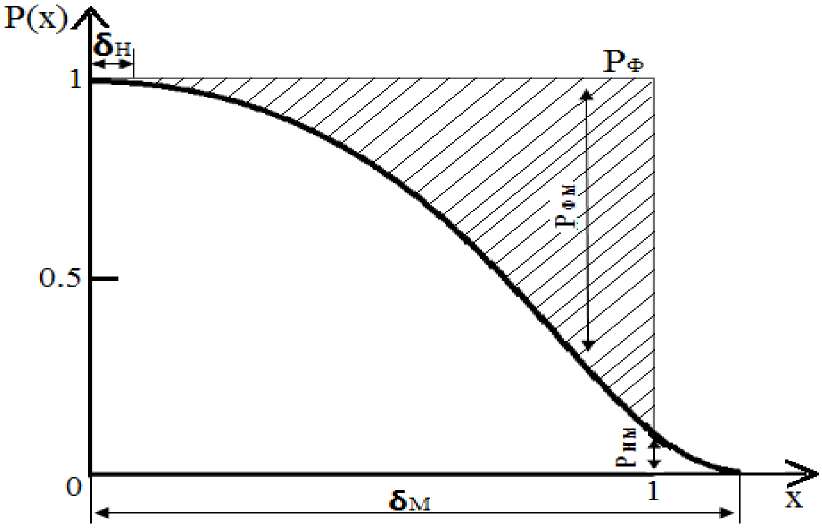

Fig.1. Operational characteristics for P (x).

All possible values of X for suitable in reality measuring instruments lie in the zone (0–1), for unfit - outside the zone.
P_{HM} corresponds to the ordinate of the curve P (X) at X = 1;
δ_M corresponds to the value of X at which P (X) = 0;
P_{Φ}numerically coincides with the ratio of the hatched area to the area (wound unit) of the rectangle with the sides P(X)=1(on the ordinate axis)and X = 1(on the abscissa axis);
$P_{\Phi M}$ –the greatest likelihood of accepting any suitable device as unusable (fictitious copy marriage);
$\delta_{M=}|\Delta_M|/|\Delta_П|$ lower boundary of the zone of fixed rejection, the ratio of the smallest possible value Δ_H error characteristics of the device, recognized by the results of verification as unusable, but in reality a suitable device, to the chapel $\Delta_П$ its allowed values.
With the current state of development of measuring equipment, a real opportunity has been obtained to ensure that when checking instruments in the field of radio measurements - tenfold, electrical measurements - five times and pressure measurements - four times the ratio of errors of standard and calibrated instruments.
A further increase in the requirements for the ratio of errors of reference and verified devices is possible, but not ad infinitum, since a reasonable balance must be maintained between the material costs of developing and manufacturing reference devices and the measurement accuracy worthy for this stage of development of the technology.
When checking most measuring instruments, they consider an acceptable ratio of standard errors γ_M and the attorney γ_A appliances like 1/3.
The dependencies given in the answer to it, we can argue that the measurement accuracy Q, the same with the actual accuracy of instrument A is estimated by the error γE_A:

$$\gamma E_A = \sqrt{\gamma_A^2 + (\gamma'_A)^2 + \gamma_M^2 + (\gamma'_M)^2 + \gamma_E^2}. \quad (1)$$

From dependencies

$$Q = UE_A; \;\; Q = U_A + C_A; \; C_A = U_{E_M} - U_A \quad (2)$$

follows that

$$U_{E_A} = U_A + U_{E_M} + U_{A_M} \quad (3)$$

$$\pm\gamma E_A \pm E_A \pm \gamma E_M \pm \gamma'_A. \quad (4)$$

This shows that the error γE_A ,determining accuracy of the verified instrument A, depends on the error γ_A, determining its nominal accuracy, from the error γE_A, the determining reality is the accuracy of the reference device M, and from the error γ'_A determining the accuracy of the readings of instrument A during calibration, which cannot be exceeded by its nominal accuracy with any calibration method, i.e. $\gamma'_A = \gamma_A$.
Based on the previous formulas, we can write that

$$\gamma E_A = \sqrt{\gamma_A^2 + (\gamma'_A)^2 + \gamma^2 E_M} = \sqrt{2\gamma_A^2 + \gamma^2 E_M} \quad (5)$$

Since the error is usually expressed by no more than two significant digits, the second being obviously indicative, so that the inaccuracy of the reference device M does not reduce the accuracy of the tested device A, it is necessary that:

$$\sqrt{2\gamma_A^2 + \gamma^2 E_M} - \sqrt{2\gamma_A^2} < 0{,}05\sqrt{2\gamma_A^2 - \gamma^2 E_M} \quad (6)$$

Or, that, the same thing,

$$\gamma E_M \leq \frac{1}{3}\gamma E_A \quad (7)$$

In this case, the value $\gamma^2 E_M$ under the root in the general expression for γE_A we can neglect, i.e.

$$\gamma E_A = \sqrt{2\gamma_A} \quad (8)$$

This means that even under the best conditions, the actual accuracy of the measuring device is about one and a half times less than its nominal accuracy.
Similarly

$$\gamma E_M = \sqrt{2\gamma_M} \quad (9)$$

Having addictions

$$\gamma E_M \leq \frac{1}{3}\gamma E_A;\ \gamma E_A = \sqrt{2\gamma_A}\ u\gamma E_M = \sqrt{2\gamma_M} \quad (10)$$

Get

$$\gamma_M = \frac{1}{3}\gamma_A \quad (11)$$

From here it's clear, what γ_M–the error assessing the nominal accuracy of the reference device, γ_A – the error assessing the nominal accuracy of the instrument being verified shows that, with the correct setting of the verification case, it is necessary for the model instrument to provide at least three times greater accuracy of the instrument being verified.
The fact that we usually do not take into account the error of the reference device does not mean that it does not affect the verification. It is estimated that when the ratio between the limits of the permissible errors of the reference and verified devices is 1: 3, the probability of defective calibration does not exceed 0.035 (on average 35 devices from each 1000 will be rejected incorrectly, and 35 devices may be recognized as invalid).
In the practice of verification work, the probability of marriage of 0.035 is still allowed, but has already been recognized as unsatisfactory.

III. Conclusion

In conclusion, it must be said that, with the correct setting of the verification case, it is necessary to provide an exemplary instrument with at least three times greater accuracy of the instrument being verified.
Application as a criterion $\delta_м$ makes it possible to determine the maximum error when using this SI. The used quality criteria for verification are independent of the distribution of the error of the verified SI, and the adoption of the maximum rather than the average probability of a verification error of the second kind, allows to show the degree of risk not for everyone, but for a particular consumer of the used SI.

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