The application of the law of the normal distribution of random errors for evaluating accuracy in calibrating
standard resistors is justified by the possibility of a large repetition of observations, by the almost complete elimina-
tion of systematic errors in the bridge comparator, and by its sufficiently high sensitivity.

The limiting errors in calibrating standard resistors obtained in the period from 1959 to 1962 are given in the
table.

The errors listed in the table are determined with a probability of 0.997 by handling series of results contain-
ing up to 30-40 measurements of the same value. If the accuracy of these results is evaluated by means of Student-
Fisher tables, the probability of the above errors will only change to 0.97. Such a small discrepancy can serve as a
criterion for justifying the application of the normal random error distribution law for evaluating accuracy in cali-
brating standard resistors.

Conclusions. 1) The use of the type MKS-1 bridge comparator and new intermediate standards has ensured the
development of an improved technique in calibrating resistance standards and has made it possible to account for
accumulated errors in transferring a resistance unit directly from the primary State Standard of an ohm.

2. The accuracy in evaluating the standards has been raised by at least one order as the result of applying the
new technique. Moreover, calibration by two operators taking five to six months has been reduced to calibration by
one operator taking two weeks. High precision in the calibration of standards has been obtained without mercury
contacts, which affect to a considerable extent the health of the operators.

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EFFECT OF THE POWER FACTOR ON ELECTROSTATIC
WATTMETERS

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Effect of cos \( \varphi = 0 \) and method for determining the pointer deviation. The deviation of the instrument pointer
from the zero mark at normal voltage, current and frequency, and a cos\( \varphi = 0 \) must be determined according to the
current GOST-8476-60 on wattmeters.

This deflection is due to the existence in the instrument of an internal uncompensated angle difference \( \delta \) (in-
trinsic angular error) between vectors (\( A_1 \) and \( A_2 \) in Fig. 1) whose scalar product is proportional to the power, so that
the reading of the power is no longer proportional to cos\( \varphi \), but to cos(\( \varphi \pm \delta \)). Phenomena not related to phasing can
also produce such a deflection. The latter include asymmetry, which is due to various factors and can also be present
in wattmeters of other systems. The zero displacement of the pointer in electrostatic wattmeters can also be due to
electrostatic effects. It is known [1] that the displacement of the electrostatic moving part depends both on the
applied voltage \( U_1 \) and \( U_2 = U_2 - U_3 \) (Figs. 2a and 2d), and on the difference on the derivatives of capacitances \( C_{12} \)
and \( C_{13} \) with respect to angle \( \alpha \). Here \( C_{12} \) is the capacitance between the capacitor's moving plate and the two fixed
plates to which the former is being attracted, and \( C_{13} \) is the capacitance between the moving plate and the two fixed
plates from which it is being repelled.

Since \( C_{12} \approx b_{12} \alpha \) and \( C_{13} \approx b_{13} \alpha \), we find that \( \Delta C = b_{12} + b_{13} \) and is tending to zero, since coefficients \( b_{12} \)
and \( b_{13} \) are close to each other in their absolute value and have opposite signs.
When this condition is not met an additional torque is produced

\[ \Delta M_1 = \frac{1}{2} \Delta C \frac{U_{2,3}^2}{4} + \frac{1}{2} \Delta C U_1^2. \]

The torque \( \Delta M_1 \) is fully accounted for in calibrating the shunt circuit \( U_1 = \text{const} \), and no additional error is produced.

The series circuit voltage \( U_{2,3} \) for a phase shift of 90° is set to its nominal value, and hence, the moving part is deflected from zero by the torque

\[ \Delta M_1' = \frac{1}{2} \Delta C \frac{U_{2,3}^2}{4}. \]

This deflection appears as a phase error, whereas it is due to the asymmetry of the capacitor's electrodes.

The presence of angle \( \delta \) leads to a wattmeter referred relative phase error, which is determined for normal voltages and current as

\[ \gamma_\psi = \delta \frac{\sin \varphi}{\cos \varphi_n}, \]

where \( \cos \varphi_n \) is the nominal power factor of the wattmeter.

For the case under consideration \( \varphi = \pi/2 \) and the phase error should not exceed the permissible value of the basic error \( \gamma_{\psi 0} \), hence

\[ \gamma_{\psi 0} \approx \delta \frac{\varphi}{\cos \varphi_n}. \]

This formula holds even when angle \( \delta \) represents an inaccuracy of 90°, in setting the phase difference between vectors \( A_1 \) and \( A_2 \), thus making it possible to calculate the permissible error \( \delta_0 \) of a reference equipment for determining this angle.

The permissible value of angles \( \delta \) of the tested high-precision instruments and angles \( \delta_0 \) of the reference equipment used for testing them are very small, as will be seen from Table 1. To provide such precision is a difficult metrological task.

Some of the known methods and devices for indicating a phase difference of 90° [2] can provide theoretically the required precision, even if it were only for some of the classes of the above wattmeters. However, the intrinsic angular errors in electromechanical phase meters, in reference mutual inductances, or in the input voltage dividers of other devices described in [2] severely restrict the practical possibilities of applying these known methods to a wide frequency range.

The advantage of electrostatic meters consists of the fact that they provide constant precision over a very wide frequency range (with the exception of their input circuit), hence, methods for determining the deviation from zero of an electrostatic wattmeter pointer for a phase shift of 90° are undoubtedly of considerable practical interest.

For this purpose let us examine the source of phase errors in an electrometer and evaluate them.

Assuming approximately that the current in the shunt circuit is determined only by capacitance \( C \) between moving plate 1 and stationary plates 2 and 3 (Fig. 2a and Fig. 2b), its value is

\[ I_c \approx U_1 \omega C. \]