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Methods of Measuring Time Constants of Low Resistances.[1]

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ALL values heretofore obtained for the residual inductance of "non-inductive" standards of low resistance have been based upon the calculated inductance of some conductor. This calculation of the inductance from dimensions involves serious assumptions as to current distribution, inductive effects in potential leads, etc.

The first method discussed below gives primarily the sum of the time constants of the two resistances used. By using three resistances three sums can be measured from which each time constant can be obtained, without calculation of the inductance of a resistance standard. In this method the resistances are each connected in series with a mutual inductance as indicated in the figure and excited by alternating currents substantially in quadrature. The constants of the circuits are then adjusted so that no current flows in either galvanometer. It can easily be shown that the following relations then hold:

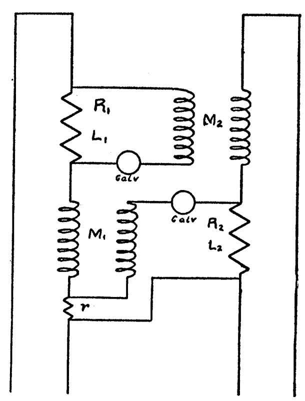

Fig. 1

$$R_1R_2 = p^2(M_1M_2 + L_1L_2) \tag{1}$$

$$\frac{pL_1}{R_1} + \frac{pL_2}{R_2} = \frac{prM_2}{R_1R_2} \quad \text{or} \quad \frac{r}{pM_1} \quad \text{very closely,} \tag{2}$$

where $p = 2\pi \times$ frequency. The first of these equations can be used in the absolute measurement of resistance and the second gives a measure of the sum of the phase angles of the two resistances.

This method requires (1) that the mutual inductances be pure, *i. e.*, give e.m.f.'s in exact quadrature with the primary current, (2) that the frequency be

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held very constant during the measurement and (3) that the current be sinusoidal or that the detectors be sufficiently selective to the fundamental frequency.

The second method makes use of a standard whose resistance can be changed without changing its inductance. This can be done for example by using a copper standard whose temperature can be varied. Then if the observed decrease in phase angle be $\Delta\theta$ and the corresponding proportional increase in resistance be a we have

$$\frac{pL}{R} = \frac{1 + a}{a} \Delta\theta \tag{3}$$

This method requires merely an accurate measurement of the change in the phase angle.

In order to test the practicability of these methods the authors have made measurements on four low resistances. First, all of the six possible sums were measured directly by the first method. The phase angles of the individual standards at 60 cycles are given in Table I. These four values satisfy the six observations to within two minutes.

TABLE I.

Designation.	Resistance.	Phase Angle.
C	.000337 ohm	29.0′
K	.01 ohm	2.5′
R	.001 ohm	19.0′
S	.001 ohm	16.5′

Measurements by the second method on the copper standard (C), using a temperature rise of about 60° C., gave a phase angle of 30.5 minutes. This value agrees fairly well with the value given above.

To get further checks on the results several differences of the phase angles were determined by an independent method. The observed differences and those computed from the values in Table I. are given in Table II. below.

TABLE II.

Designation.	Differences Observed.	Computed.
$R-S$	1.9′	2.5′
$C-R$	10.1′	10.0′
$R-K$	14.8′	16.5′

It is interesting to note that accurate calculations assuming uniform current distribution give $C = 24.1$ minutes and $K = .8$ minute.

The above results indicate the methods to be entirely practicable and it is thought that by taking further precautions as to frequency control, purity of mutual inductance and sensitivity a precision of several tenths of a minute can be obtained.