ELECTRICAL MEASUREMENTS

NEW MODEL OF A HIGH-RESISTANCE SIX-DECADE POTENTIOMETER

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GOST (All-Union State Standard) 9245-59 specifies, in response to the requirements of our national economy, grade 0.005 potentiometers. The most accurate potentiometers produced to date by our instrument-making plants only meet grade 0.015 requirements. The top measuring limit of existing dc potentiometers does not exceed (or approaches) 2 v, although in many instances the measurement of much higher emfs is required.

Table 1 provides the basic information on certain most accurate high-resistance potentiometers.

The new high-resistance potentiometer KRV-8 developed by us* fills the existing deficiency in this sphere.

In designing the KRV-8 potentiometer we aimed at obtaining an instrument of a higher grade of precision than the existing instruments. This determined the choice of a six-decade circuit. The most accurate modern high-resistance potentiometers are made with six decades, thus providing readings with an error of 0.001%. However, in the majority of cases such high reading accuracy is superfluous, and sometimes can even deceive the operator, since the potentiometer error is much greater than the above value, for instance, in grade 0.015 potentiometers.

Potentiometer circuits with replacement decades have proved to be satisfactory in practice, and although the existence of additional decades at first sight seems to complicate the construction of the potentiometer, the simplicity of the circuit and its setting, as well as the ease of checking and introducing corrections during the operation of the potentiometer, completely outweigh the complication introduced in the circuit [1].

The new potentiometer model is based on a circuit with four replacement decades. The values of the various decade coils are given in the schematic of Fig. 1, in which the value of the decade calibrations such as ×0.1 v, ×0.001 v, etc. is marked on the range switch which is shown in position ×1.

The main peculiarity of this potentiometer consists in the existence of two limits of measurement (1.9 and 19 v). In switching over to the higher measuring limit the operating current of the potentiometer is raised by a factor of 10 (from 0.1 to 1 ma) without changing the potentiometer resistance. For this purpose a battery with a nominal voltage of 20 v is used. The changing over to the other battery is made by means of switch S1. The operating current is adjusted by three groups of resistors in steps of 0.2 ohm which provide variations in the potentiometer operating current of 0.001%.

The operating current is accurately set against a standard cell by means of adjusting decades in steps of 0.001% of the basic resistance value. The operating current is set by means of three adjusting decades only; moreover, only two of them are used for each selected measuring range.

When working in the range of ×1, the adjusting resistance consists of 11 resistors of the first decade 9 × 1 and 10 × 0.1 ohm. The adjusting resistance can then be set between 10190.0 and 10180.0 ohm, thus making it possible to compensate with a current of 0.1 ma the variations of the standard cell emf in the range of 1.01800 to 1.01900 v. When working in the range of ×10, the adjusting resistance consists of the first two resistors of the first decade, which include the adjusting decades of 10 × 0.1 and 10 × 0.01 ohm. The maximum value of the adjusting resistance in this case is equal to 1019.10 ohm and the minimum to 1018.00 ohm.

The potentiometer measuring resistors are wound with manganin wire. For the first three decades resistances with temperature coefficients which do not differ from each other by more than 0.001%/1°C were selected.

The thermal emf generated in the potentiometer measuring circuit with stationary wipers does not exceed 0.2 μv. The wiring and contact resistances of switches provide with an operating current of 0.1 ma a constant voltage

* A. A. Skragan and E. E. Luûé, members of the VNIIM (All-Union Scientific Research Institute of Metrology) design bureau participated in the development of this potentiometer.

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drop across terminals $E_x$ of $0.8 \mu V$ for a zero setting of the potentiometer. Variations in the zero voltage drop do not exceed $0.1 \mu V$.

**Table 1.**

<table>
<thead>
<tr>
<th>Potentiometer type; manufacturing plant</th>
<th>Number of measuring decades</th>
<th>Measuring limits, $\mu V$</th>
<th>Calibration of the smallest measuring decade, $\mu V$</th>
<th>Resistance of the measuring circuit, ohm</th>
<th>Operating current, ma</th>
<th>Error in setting the operating current, %</th>
<th>Maximum permissible error when all the decades are used, %</th>
<th>Circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolf</td>
<td>5</td>
<td>10.9999</td>
<td>100</td>
<td>10999</td>
<td>1</td>
<td>0.01</td>
<td>0.001</td>
<td>Double series connected (3 replacement decades)</td>
</tr>
<tr>
<td>PV-6 &quot;Étalon&quot;</td>
<td>5</td>
<td>1.9</td>
<td>10</td>
<td>19000</td>
<td>0.1</td>
<td>0.001</td>
<td>0.015</td>
<td>The same</td>
</tr>
<tr>
<td>PV-7 &quot;Étalon&quot;</td>
<td>6</td>
<td>1.9</td>
<td>1</td>
<td>19000</td>
<td>0.1</td>
<td>0.001</td>
<td>0.015</td>
<td>Double series connected (with replacement decades)</td>
</tr>
<tr>
<td>R-300, ZIP (modernized PPTV-1)</td>
<td>5</td>
<td>1.9</td>
<td>10</td>
<td>19000</td>
<td>0.1</td>
<td>0.005</td>
<td>0.015</td>
<td>Double series connected (3 replacement decades)</td>
</tr>
<tr>
<td>PPTV-1, ZIP</td>
<td>5</td>
<td>1.2</td>
<td>10</td>
<td>12000</td>
<td>0.1</td>
<td>0.01</td>
<td>0.03</td>
<td>3 replacement decades, 2 cascade decades</td>
</tr>
<tr>
<td>R-375, ZIP</td>
<td>6</td>
<td>1.2</td>
<td>1</td>
<td>12000</td>
<td>0.1</td>
<td>0.005</td>
<td>0.015</td>
<td>The same</td>
</tr>
<tr>
<td>R-307, ZIP (modernized R-375)</td>
<td>6</td>
<td>1.9</td>
<td>1</td>
<td>19000</td>
<td>0.1</td>
<td>0.1</td>
<td>0.001</td>
<td>Double series connected (4 replacement decades)</td>
</tr>
<tr>
<td>KRV-8, &quot;Étalon&quot;</td>
<td>6</td>
<td>1.9</td>
<td>10</td>
<td>19000</td>
<td>0.1</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In testing the potentiometer its errors were determined both at room temperature and in the range of 20 to 30°C. The errors were determined by checking each component in the manner used for testing reference potentiometers. After each component had been checked the readings of the new potentiometer were compared with those of a VNIIM reference potentiometer, whose components had also been previously checked one by one. The method of checking one component at a time in six-decade potentiometers is described in detail in [2].

The existence of an additional measurement range in the new potentiometer made its checking slightly more complicated owing to the necessity of determining the ratio of two setting resistances. This operation was carried out by means of an auxiliary potentiometer whose operating current was set by one standard cell when the tested potentiometer was switched to range $x 1$, and by means of 10 series connected 1st grade standard cells when the potentiometer was switched to range $x 10$, thus raising the reference testing voltage by a factor of 10. This method of determining the ratio leaves the setting resistance and the measuring resistance of the reference potentiometer unchanged, and does not actually require any corrections to be applied to the reference potentiometer.

Table 2 shows the basic test results* of the first three models of potentiometer KRV-8.

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*E. K. Vesso-Ado carried out the experimental investigation of the potentiometer.