A COMBINED ELECTROMETER AND THERMIONIC VOLTMETER.

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Received August 23, 1937.
(Communicated by Prof. K. C. Pandya, M.A., Ph.D.)

Abstract.

Design data are given for a thermionic voltmeter which can also be used as an electrometer. The A.C. ranges are 0–6 and 0–10 volts R.M.S., the D.C. ranges 0–3 and 0–6 volts. The input capacity and resistance compare favourably with the best commercial instruments.

Introduction.

The thermionic valve is being increasingly used in general physical measurements and it is thought that a description of the design and performance of a combined portable electrometer and thermionic voltmeter might be of interest. The circuit used is due to Hoare and slightly modified to suit the apparatus chosen. The instrument is in the form of a direct current bridge (Fig. 1) and aims at eliminating changes in calibration due
to small fluctuations in battery voltages. The D.C. plate resistance of the valve is balanced for zero volts input by a suitable choice of the resistances Q, R and S. Any voltage applied to the grid changes the D.C. plate resistance, unbalances the bridge or forces current through the microammeter. Grid bias is produced by the voltage drop across resistance A, while B is chosen to give the correct filament voltage. D is a rheostat to bring the instrument to the calibrated conditions before readings are taken.

Design Considerations.

The valve used was an Osram Electrometer type T, nominal rating:— anode voltage 4–10 volts, filament 1.0 volt, 0.1 amp. Insulation between grid and other electrodes $10^{15}$ ohms, capacity 1.6 micro-micro farads. In order to give as large a range as possible the anode and grid voltage were kept reasonably high without exceeding the nominal ratings. The total voltage supply necessary in this case is about 20 volts supplied by two small 10-volt H.T. accumulator units.

In order to make the scale more linear Moullin has suggested the incorporation of a fairly high resistance in the anode circuit. This is done by making Q and S each 10,000 ohms. The condenser $C_1$ has a capacity of 2.0 microfarads in order to bypass the alternating component of anode current. $C_2$ is a small mica condenser across the grid biasing resistance to bypass stray currents when the instrument is used on high frequencies. The microammeter (Electradix) (G) has a range of 0–50 microamperes. The other resistances have the following values:—

\[ R = 500,000 \text{ ohms}, \quad A = 100 \text{ ohms}, \quad B = 80 \text{ ohms}, \quad D = 60 \text{ ohms variable}, \quad E = 700 \text{ ohms}. \]

Resistances Q, R and S are of the carbon type. It would probably be better to use wire wound resistances but as the currents passing are so small no ill-effects on the calibration have yet been noticed owing to their use. Resistances A and B are wound on a mica card.*

The valve (H) is mounted in a large brass screen (I, Fig. 2), the grid terminal (J) projecting through the end and connected through a large hole (K) in the top panel to a standoff terminal. The valve is in this way protected from mechanical damage and also in the dark which is a condition for highest insulation. The guard rings on the valve were connected to the negative end of the filament. The remainder of the components were arranged round the valve as shown in the figure.

* Lettering of Fig. 1 and Fig. 2 corresponds.
Before calibrating the meter the pointer of the microammeter was brought to the zero mark by adjusting the resistance D with the input terminals short circuited. After calibrating, whenever readings are to be taken the above adjustment reproduces the calibration conditions. The instrument was calibrated on 50 cycle A.C. against a commercial thermionic voltmeter using a potentiometer, and also on D.C. using an ordinary voltmeter. The ranges on A.C. are 0—6 and 0—10 volts R.M.S. and on D.C. 0—3 and 0—6 volts. The scales are reasonably linear.

**Characteristics.**

The two most important characteristics of a thermionic voltmeter are the apparent resistance due to grid current, and the input capacity.

The input capacity was measured by the following arrangement. A standard variable condenser was connected across the tuned circuit of a valve oscillator, which was tuned into the zero beat position on a receiver fitted with a beat frequency oscillator. The voltmeter was then connected in parallel with the standard condenser and the change in capacity of the standard necessary to give the zero beat condition was the input capacity of the voltmeter. Results gave an input capacity of 4·9 micro-micro farads.
between the standoff and earth and 2.8 micro-micro farads as the capacity measured directly between the grid terminal of the valve and earth.

The grid current on such a valve is extremely small. Using a galvanometer sensitive to 0.05 microampere, no grid current was detected on the D.C. ranges, and on the A.C. ranges the valve only commenced to draw grid current when the applied potential exceeded 8.0 volts. Actually, on most of the ranges there appeared to be a slight inverse current but as it was at the limit of measurement, in order to get a better idea of the losses due to grid current the following experiment was performed. A 0.1 microfarad standard mica condenser was connected between the input terminals of the instrument and charged to a potential of 5.0 volts and left connected to the voltmeter. In 38 minutes the potential between the plates of the condenser as measured by the instrument had fallen to 1.0 volts. From this it is calculated that the overall resistance of the thermionic voltmeter and condenser due to leakage and grid current was 1.7 x 10^10 ohms. The resistance of the electrometer itself would, of course, be much better than this as there was probably considerable leakage at the surface of the standard condenser.

Uses.

The thermionic voltmeter can be used of course for measuring R.M.S. values of voltage up to very high frequencies as it is effectively screened and bypassed. As an electrometer these types of valve are said to make other electrometers obsolete as they are so convenient, portable and robust. The instrument described above has been successfully used in determining capacity by the method of Faraday.

REFERENCES.

   Terman, Radio Engineering, p. 613.
3. Reports on Progress in Physics, 1, 327.