A SIMPLE FORM OF VOLTAGE STABILIZER.

By N. K. Saha, B. S. Chandersekhara *and* M. K. Sundaresen, *Physics Department, University of Delhi, Delhi.*

(Communicated by Dr. R. C. Majumdar, F.N.I.)

(*Received December 22, 1949 ; read March 3, 1950.*)

1. Introduction.

Usual forms of Geiger counters are generally operated at a voltage between 1000 and 2000 volts, and since their counting rate is a function of the applied voltage, this voltage should remain constant. Many vacuum tube circuits have been devised for this purpose. The main principle employed in some of these voltage stabilizers is that the variations in the output voltage, after rectification, bias the grids of a thermionic tube so as to maintain a constant plate current. Street and Johnson (1932) have devised two circuits using tetrodes, but they include batteries from which current is drawn and are therefore likely to lose their efficiency in long runs. Richards (1933) has given a circuit which eliminates batteries by substituting a separate full-wave rectifier, the control grids of the two triodes in the main rectifiers being biased by this auxiliary rectified voltage. But the apparatus is bulky, and the different time constants of thermal response of the filaments in the seven tubes in the circuit introduce large transients when the primary voltage is suddenly changed. Evans (1934) has described a stabilizer using only one battery from which current is not drawn. Gingrich (1936) has modified Evans' circuit, using a neon tube instead of the battery. He also describes a second circuit using a bank of neon tubes across which the stabilized voltage is obtained.

Neher and Pickering (1939) employ a different principle, where fluctuations of the input voltage vary the plate current in a pentode such that a constant output voltage is obtained, the excess voltage being dropped off across a series resistance. But two dry batteries are required. Banerjee (1942) has modified the Neher-Pickering circuit so as to use only one battery.

In all these circuits the point at which the voltage is stabilized is determined by varying one or more resistances. Most of them also require the use of one or more dry batteries. These are avoided in a stabilizer we have constructed, similar in principle to Gingrich's circuit using a bank of neon tubes, but eliminating the actual use of neon tubes.

2. Description and Working.

In the present form of voltage stabilizer the property of gas ionization at reduced pressure is utilized. The circuit is shown in figure 1. T is the high tension transformer fed from the variac A. The output voltage is rectified by means of the tube *2X2* and impressed on the 2-microfarad condenser C. A brass tube about a meter long and 12 millimeters in diameter with an axial insulated steel wire of 0·33 millimeter diameter constitutes the stabilizing tube, the two electrodes of which, the central wire and the body, are connected across the condenser plates in series with a high resistance R of about 30 megohms. The tube can be exhausted and filled with dry air at a desired pressure by means of a suitable system of stopcocks, drying tubes, manometer and vacuum pump.

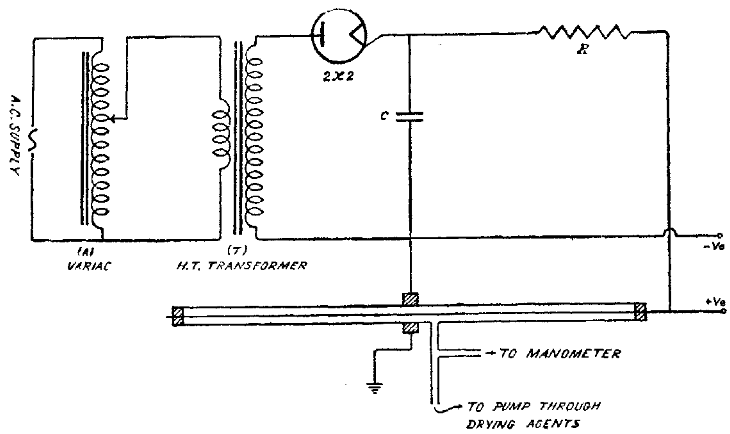

FIG. 1. The Experimental arrangement.

As the transformer output is increased from its lowest value (by means of the variac in its primary circuit), the voltage drop across the tube also increases. At a certain voltage characteristic of the pressure inside the tube, this voltage becomes constant, and remains so practically over a very large range of the transformer

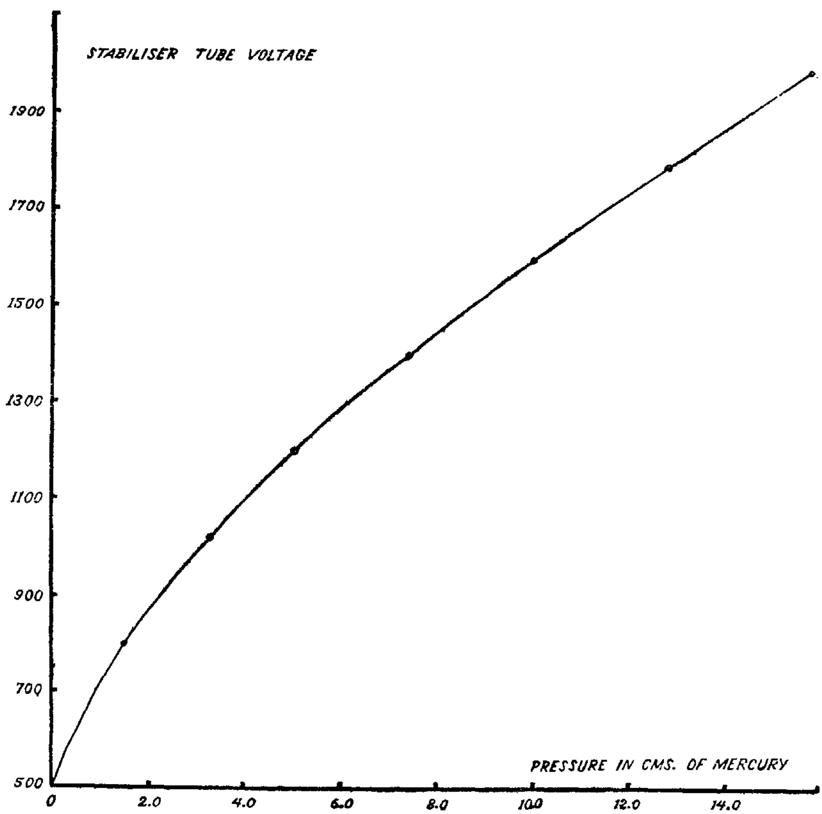

FIG. 2. The Pressure-Voltage Calibration Curve.

output voltage. This stabilized voltage depends entirely on the pressure in the tube and increases steadily with pressure, as shown in figure 2, which acts as the calibration curve for the stabilizer. The stabilization of the voltage at a given pressure is due to the fact that any increase in the transformer output causes a higher ionization current to flow in the tube; this leads to a higher potential drop across R which compensates the increase in the transformer output and the potential across the stabilizer tube remains constant.

3. CHARACTERISTICS.

The voltage across the stabilizer tube is shown as a function of the transformer output (rectified), for various fixed pressures inside the tube, in figures 3 A, B, C and D. At the region where stabilization just starts, spontaneous fluctuations of the tube voltage for a fixed transformer output are observed (as shown by the shaded areas in figures 3 A, B, C, D). These can be explained as follows: Let the transformer output voltage be equal to or slightly greater than the stabilized voltage. The stabilization just starts, the tube becomes suddenly conducting and this causes a large current to flow in the circuit. This in turn causes a large ohmic drop of potential across the series resistance R, and the available voltage across the tube instantaneously drops below the stabilized voltage. The gas ionization in the tube, however, tends to cease at the lower tube potential, resulting in a rapid fall in the current and a smaller potential drop across R. Eventually the original stabilized voltage across the tube is restored. The whole process appears as a current and voltage fluctuation with time in opposite senses somewhat like that shown in Fig. 4. The phenomenon can repeat itself several times. The fluctuations disappear when the transformer output is so large that, in spite of the voltage drop across R at the instant of striking of the ionization, the available voltage across the tube is equal to its striking voltage.

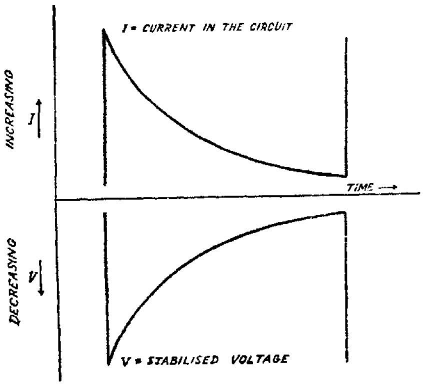

FIG. 4. Curve illustrating the initial current and voltage fluctuations at threshold.

The stabilization effect has also been tested for different values of the series resistance R. It is observed that a higher resistance ($R \simeq 40$ megohms) gives a better stabilization than a lower resistance ($R \simeq 10$ megohms). With the lower resistance, there is a slight increase in the stabilized voltage as the transformer output is increased steadily from the lower limit of stabilization up to the maximum output. The effect is more pronounced for high stabilized voltage. For example, when the transformer output is increased from about 2,000 to 3,500 volts (Fig. 3A), $R \simeq 40$ megohms, the stabilized voltage at 8·6 cm. Hg pressure starts at 1,500 and increases steadily to 1,540, the increase being 40 volts over a range of 1,500 for the transformer output. With a series resistance of 10 megohms the stabilized voltage for the same pressure increases steadily from 1,500 to 1,580 over a range of the transformer output from 1,700 to 3,500 (Fig. 3D). Again as can be seen from the lowest curve of figure 3A, which is the voltage stabilization curve at the lowest attainable pressure at $R \simeq 40$ megohms, the stabilized voltage is practically steady over a wide range of the transformer output. The second, third and fourth curves are respectively for the pressures 3·1, 8·6 and 15·6 centimeters of mercury. At these higher pressures, the stabilization naturally starts at gradually higher voltages ($<$1,000, 1,500 and 2,000), but the stabilized voltage also increases slightly by 20,

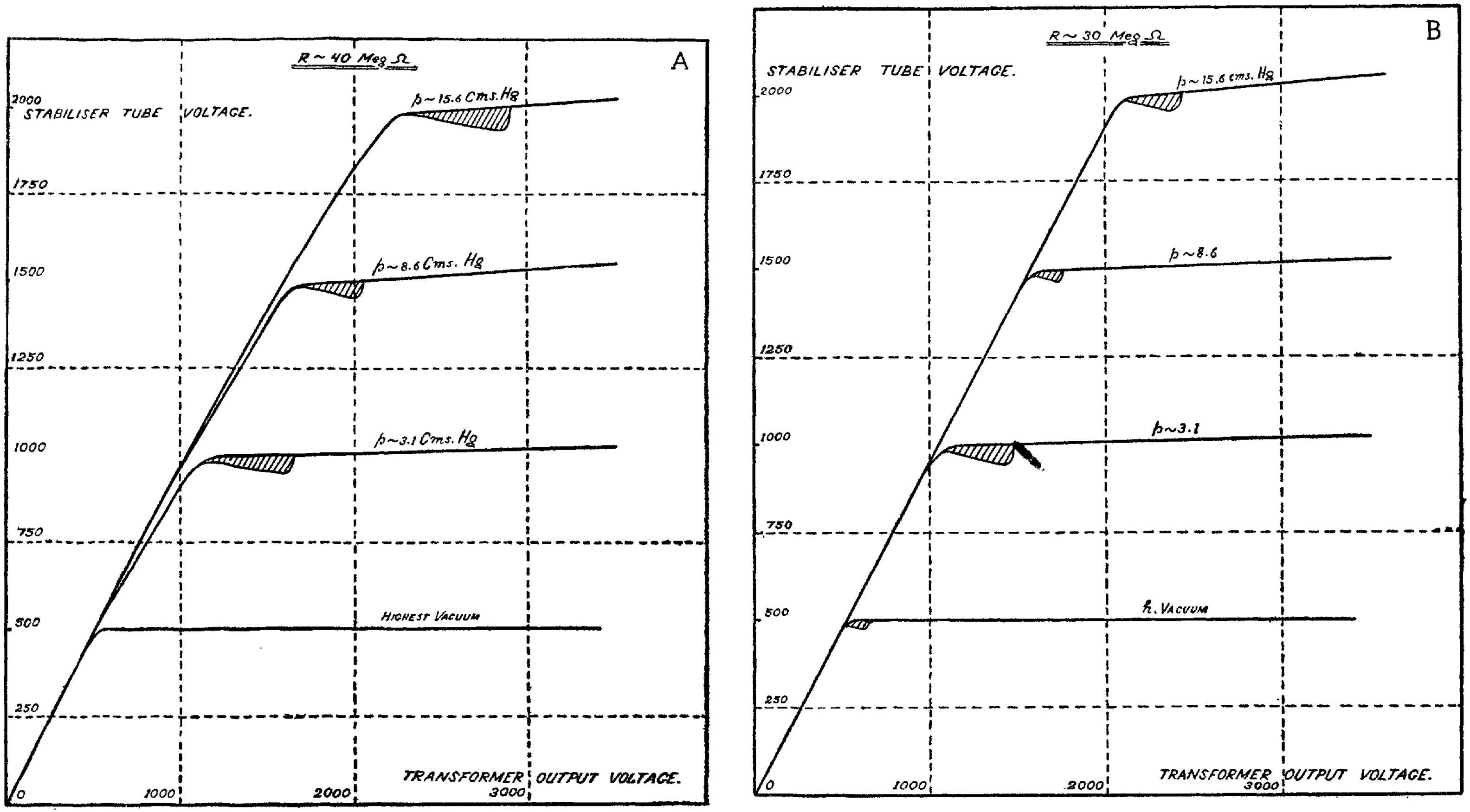
A
R ~ 40 Meg Ω
STABILISER TUBE VOLTAGE.
TRANSFORMER OUTPUT VOLTAGE.
p ~ 15.6 Cms. Hg
p ~ 8.6 Cms. Hg
p ~ 3.1 Cms. Hg
HIGHEST VACUUM
2000
1750
1500
1250
1000
750
500
250
0
1000
2000
3000
B
R ~ 30 Meg Ω
STABILISER TUBE VOLTAGE.
TRANSFORMER OUTPUT VOLTAGE.
p ~ 15.6 cms. Hg
p ~ 8.6
p ~ 3.1
h. VACUUM
2000
1750
1500
1250
1000
750
500
250
0
1000
2000
3000

FIG. 3.

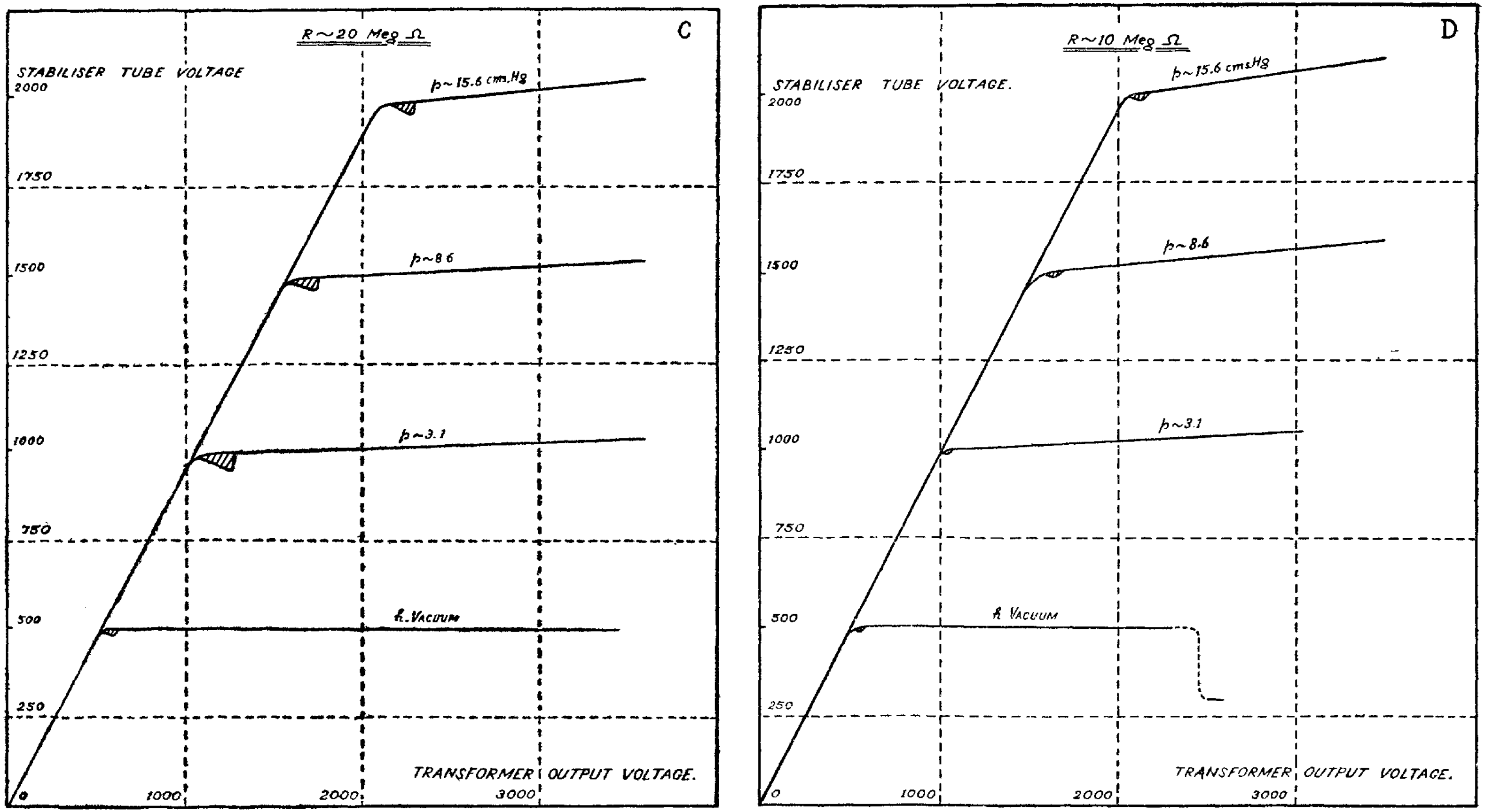

FIG. 3. *A, B, C, D*. The abscissa represents rectified transformer output voltage and the ordinate the voltage drop across the stabilizer tube. The stabilized values of 500, 1,000, 1,500 and 2,000 volts are clearly seen to set in at full vacuum, the pressures of 3·1 cm., 8·6 cm. and 15·6 cm. mercury respectively. The Figs. *A, B, C, D* are for 40, 30, 20 and 10 megohms respectively as series resistance.

40 and ~ 20 (uncertain) volts respectively as the transformer output is varied steadily up to the maximum (3,500 volts).

It is to be understood that the success of the gas ionization tube as a voltage stabilizer is to be expected only when the current in the circuit remains within the linear part of the ionization current-voltage curve; the slight increase of the stabilized voltage observed under certain conditions as described above is due to the fact that the ionization current under these conditions has a less-than-linear increase with

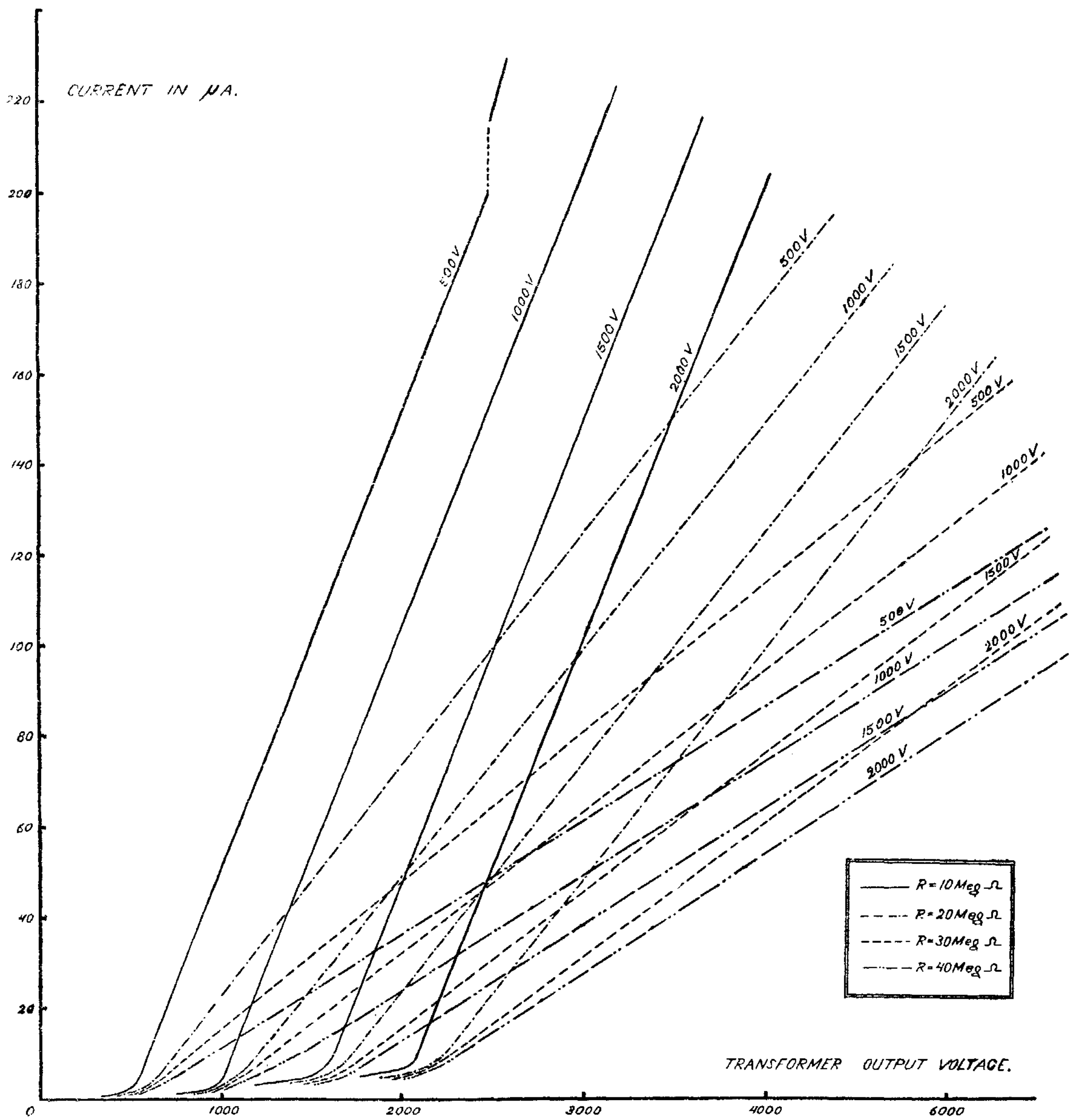

FIG. 5. The abscissa represents transformer output voltage after rectification, the ordinate the current through the stabilizer tube. The four sets of parallel curves are for the four series resistances 10, 20, 30 and 40 megohms. The four curves in each set are respectively for the stabilized voltages 500, 1,000, 1,500 and 2,000.

voltage. At a given series resistance the non-linearity increases with increasing pressure and at a given pressure the non-linearity increases with decreasing series resistance.

For a low series resistance ($R \sim 10$ megohms) and a low stabilized voltage (at the lowest attainable pressure) an interesting effect was observed. When the transformer output was increased beyond a limit there was a sudden drop in the stabilized voltage, which continued steady at this lower value for further increase of the transformer output. The effect is probably due to complicated gas ionization phenomena setting in at the high ionization current ($\sim$ 215 microamperes) flowing through the discharge tube.

Figure 5 shows the variation of the current in the stabilizer tube as a function of the D.C. input voltage from the transformer. For a given series resistance the current variation is shown for the four different stabilized voltages 500, 1,000, 1,500 and 2,000 V. forming a family of four curves with a nearly parallel run. Four such families of curves have been plotted for the series resistances 10, 20, 30 and 40 megohms. The stabilized voltage corresponding to any curve sets in just beyond the sharp kink in the curve, beyond which the curve is, in each case, sensibly linear, having a slope corresponding to the series resistance. The current in this region is therefore to be ascribed mainly to the corona discharge, since, on resolving the characteristic into two parts—one for the ohmic resistance R and the other for the stabilizer tube—the latter characteristic is nearly a straight line parallel to the current axis. The current in the pre-stabilization region is due to the primary ions present in the stabilizer tube produced by cosmic rays, stray radioactive radiation, etc., and also slightly due to the large ohmic resistance of the circuit.

For the series resistance $R = 10$ megohms and a stabilized voltage of 500, there is a discontinuity in the current characteristic at an input voltage of 2,500. This is simultaneous with the drop in the stabilizer voltage which has already been mentioned (see Fig. 3*D*, lowest curve) and is probably due to some kind of complex ionization of the gas setting in at a large current density.

The behaviour of the voltage stabilizer has been investigated up to the maximum transformer output of 3,500 volts available. The stabilization range of the curves in Fig. 3 probably extends to a higher voltage.

ABSTRACT.

A simple form of voltage stabilizer for the range 600–2,000 volts, suitable for use with G.M. counters, is described. The stabilization is effected with the help of gas-ionization in an air discharge tube of variable pressure connected in parallel to the transformer output. At a stabilized voltage of $\sim$ 1,500 volts a deviation of $\sim$ 2·5% was observed when the transformer output was varied between 2,000 and 3,500 volts. As such a wide variation in the transformer output is not likely to occur in practice, the stabilization attained is generally satisfactory. Simplicity of the electrical circuit, ease of operation in changing the range of stabilized voltage, good accuracy and low cost are the main features of the method.

REFERENCES.

Banerjee (1942). Voltage Stabilizing Circuit. *Ind. J. Phy.*, **16**(II), 87.

Evans, R. D. (1934). Voltage Stabilizer controlled by a thermoionic Pentode. *Rev. Sci. Inst.*, **5**, 371.

Gingrich, N. S. (1936). Voltage sources and Amplifiers for Geiger Counters. *Ibid.*, **7**, 207.

Neher, H. V. and Pickering, W. H. (1939). Two voltage Regulators. *Ibid.*, **10**, 53.

Richards, L. A. (1933). The use of triode vacuum tube rectifiers to supply constant voltage. *Ibid.*, **4**, 479.

Street, J. C. and Johnson, T. H. (1932). Use of Tetrode for voltage Control. *J. Franklin Inst.*, **214**, 155.