A Method of Measuring Small Capacities by A Neon-Tube

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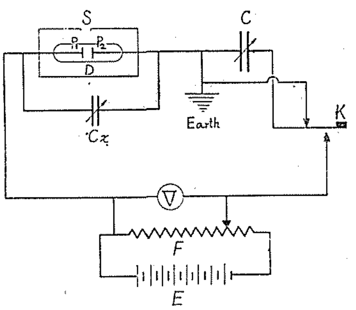
(Received January 17, 1940)

Abstract

The paper describes a simple method of measuring small capacities to the order of a few micro- microfarads by connecting a battery, a condenser, a Morse key and a neon-tube in series, with the addition of a voltmeter which is in parallel with the battery.

In Fig. 1, C and C_x are two condensers in series, C_x being in parallel with a neon-tube D of low pressure, and for the sake of convenience the tube D is enclosed in an ebonite box having a narrow slit S. K is a Morse key, E a battery of a few hundred volts, F a potentiometer and V a voltmeter.

Fig. 1



If the Morse key K is depressed the condenser C is charged by the battery E. When the applied voltage V is sufficient, a "flash" which is clearly seen through the slit S, appears in the tube D at the same time as the circuit is closed, but when the key K is released it does not appear and the terminals of the condenser C are simply shunted. The minimum voltage V that must be applied to cause a "flash" depends upon the capacity of the condensers C and C_x, that is, it increases with the capacity C_x when C is kept constant, while it decreases with the increase of the capacity C when C_x is constant.

Keeping C_x constant–530 and 111 micro-microfarads-respectively, the writer measured minimum voltages V causing a "flash" to appear in the neon-tube with various values of the capacity C. From these results the curves could be plotted as shown in Fig. 2, C and V being taken as the abscissa and ordinate respectively. It may be seen from the curves that the relation between the capacity C and minimum applied voltage V is represented by a hyperbola.

In Fig. 3 were plotted the minimum voltages V applied to cause a "flash" corresponding to various values of C_x which were obtained when the capacities of the condenser C were kept at constant values of 2100, 1090, 800 and 500 micro-microfarads respectively. From these results it is seen that the relation between V and C_x is represented by straight lines, all intercepting at a point T, the coordinates of the point being $V=126$ volts and $C_x=250$ micro-microfarads. Here it is to be added that the value of 126 volts is equal to the sparking potential V_m and 250 micro-microfarads is the apparent capacity of the neon-tube as will appear later in the discussion.

Fig. 2

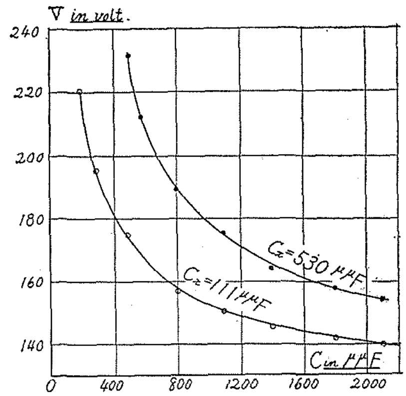
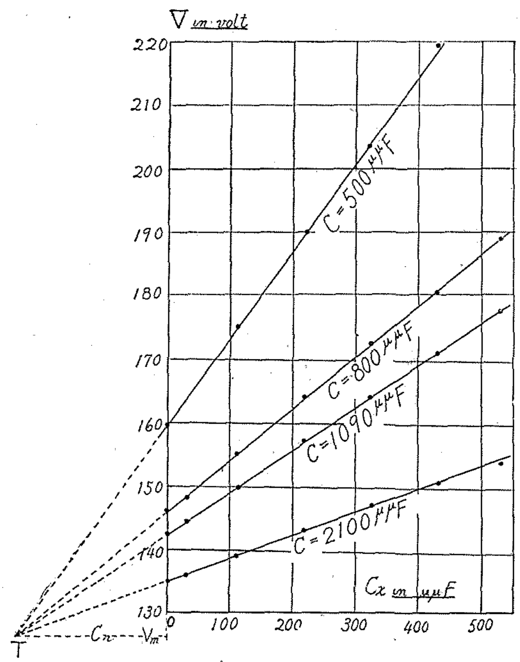


Fig. 3



The "flash" of the neon-tube will occur when the potential difference between the electrodes P_1 and P_2 of the neon-tube in Fig. 1 reaches the sparking potential V_m. If we represent the capacity between the electrodes of the neon-tube by C_n and the total potential difference applied to the circuit by V, then the potential difference V_n between the electrodes of the neon-tube will be given by the formula

$$V_n = V\frac{C}{C+C_x+C_n} \qquad \text{(1)}$$

Thus, the flash discharge appears in the tube only when this value of V_n becomes equal to the sparking potential V_m: that is

$$V_m = V\frac{C}{C+C_x+C_n},$$

or rewriting

$$V = V_m\left\{1+\frac{C_x+C_n}{C}\right\}. \qquad \text{.........................(2)}$$

From this equation, it is seen that when the capacities C_x and C_n are kept at constant values, the relation between V and C should be the hyperbolic curve as shown in Fig.2, and that when the capacities C and C_n are constant, the relation between V and C_x must be linear as indeed, they appear in Fig.3. Moreover, it is easily seen that the coordinates of the intercepting point T of these lines must be $-C_n$ and V_m, where C_n is the apparent capacity of the tube, whose value has been found from Fig.3 to be 250 micro-microfarads, V_m being the sparking voltage (126 volts). Consequently, the curves $V-C_x$ are obtained by joining the point T and a point on the V-axis, which corresponds to the minimum flash voltage for any value of C and $C_x=0$. Using the lines thus obtained, we can measure the various values of the capacity of the condenser. For example, the writer could easily measure a small capacity of the order of 3 micro-microfarads with the line of $C=1090$ micro-microfarads, and capacities of the order of 1.5 micro-microfarads or less by means of the line of $C=500$ micro-microfarads. The values thus measured are of an order comparable with those obtained by L. Hartshorn[1] with a bridge-arrangement.

A special point in the method described above is its being very simple as compared with the other one, though its accuracy mainly depends upon that of the voltmeter and also the electric leakage between the terminals of the condensers. When the leakage at the terminals of the condenser C is much more marked periodic "flashing"[2] will be repeated in the tube with voltages lower than those required for the single flash already described.

In conclusion the writer wishes to express his sincere thanks to Professor U. Yoshida for the interest he has taken in the research.

1. L. Hartshorn: Phys. Soc. Proc. **36**, 399 (1924).
2. T. Terada: These Memoirs, **17**, 85 (1934); **17**, 381 (1934).