Prediction of conditions for a single pulse discharge

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An empirical method is presented for the prediction of conditions necessary to obtain a single pulse discharge with no oscillation, no restrike, and no residual energy stored with zero current and zero voltage at the end of the pulse. An LRC circuit with a 14.7-μF capacitor charged to voltages between 2000 and 20000 V and discharging through wires of different metals was employed to obtain the necessary conditions. It is shown that specific resistivity and specific heat of fusion of the wires can be used to predict the charge voltage necessary for the single pulse discharge for a given system.

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It has been previously shown[1,2] that for a discharge through a thin wire, conditions can be obtained which produce a single pulse with no oscillation, no restrike, and no residual energy stored (zero current and zero voltage at the end of the pulse). Figure 1 shows current and voltage traces for such a discharge. There has been no way, however, of predetermining the conditions for such a discharge. Furthermore when conditions were found for a given metal, there was no good way of guessing conditions necessary for a different metal. Trial and error over a large range of charge voltages had always been used. Presented here, however, is an empirical way of extending data to approximately predict the necessary conditions for a single pulse discharge for differing materials.

A low-inductance (<1 μH) *LRC* circuit was employed with a 14.7-μF capacitor charged to voltages between 2000 and 20000 V. (In all cases there was wire evaporation.) Currents were measured with a T & M Current Viewing Resistor and voltage across the wire was measured with a Tektronix High Voltage Probe. Figure 2 shows the results obtained. Charge voltage required for a single pulse discharge divided by the specific resistivity of the wire material is plotted versus the specific heat of fusion (calories per cm^3 of wire) divided by the specific resistivity of the wire material. Seven different materials are included. The curve was actually drawn before the aluminum was used and was employed to guess at the charge voltage necessary for aluminum.

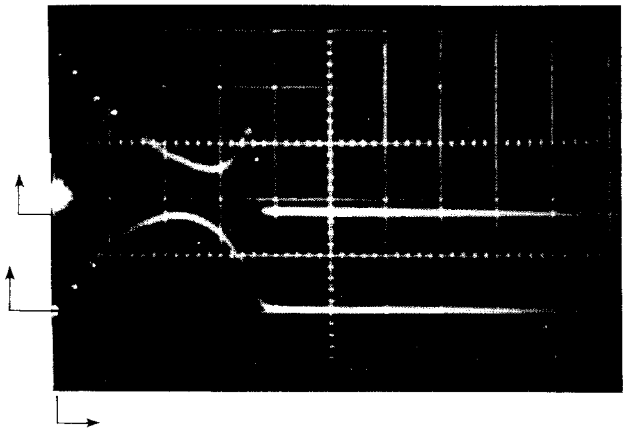

FIG. 1. Current and voltages traces: upper trace— 2 kV/div; lower trace—20 kA/div; sweep speed at 1 μs/div.

The "correct" charge voltage (~7200 V) was very close to that chosen from the curve. For a given system then, all one needs are two experimental points and knowing the physical properties of the material it is possible to approximate the conditions that yield the single pulse discharge for any other material.

Figure 2 is based on No. 24 gauge wire. However, it has been shown[1,2] that the charge voltage necessary for a single pulse discharge is proportional to the cross-sectional area of the wire and is independent of the length (for wires between ~1 and 7 in. long). Figure 3 (taken from Ref. 2) shows these results for wires 1–7 in. long. Since the voltage for the single pulse discharge is shown to be independent of length, it is independent of volume or mass of the wire for changes in mass up to a factor of about 7. Since the curve of Fig. 2 involves the square of the voltage, it will simply shift

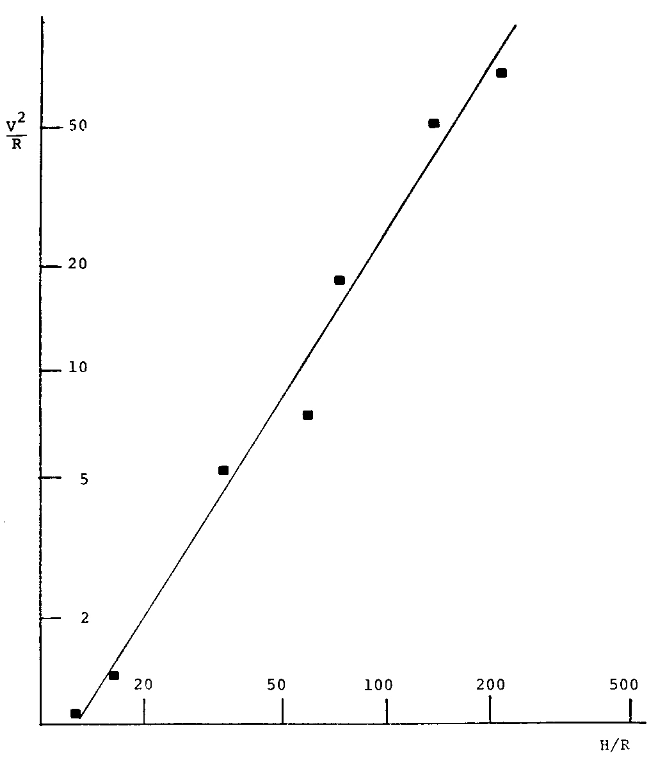

FIG. 2. Parameters for a single pulse discharge: $V \equiv$ charge voltage (kV); $R \equiv$ specific resistivity ($\mu\Omega$ cm); $H \equiv$ specific heat of fusion (cal/cm^3). Points are for No. 24 gauge wire. In order of increasing voltage, points are for tin, cadmium, zinc, platinum, aluminum, silver, and copper.

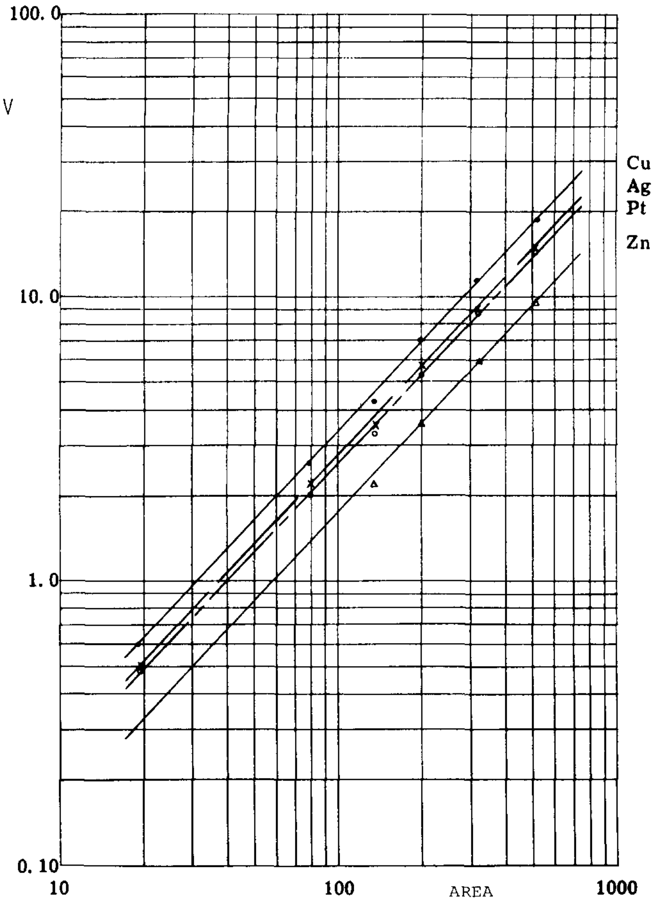

FIG. 3. Capacitor charge voltage in kilovolts for a single pulse discharge as a function of wire cross-sectional area in in.^{2} $\times 10^{+6}$; for copper, silver, platinum, and zinc wires 1–7 in. long.

up or down in proportion to the increase or decrease in the square of the cross-sectional area when a different gauge of wire is used.

It is interesting to note that the abscissa in Fig. 2 (the specific heat of fusion divided by the specific resistivity) is proportional to the "action integral", k, of Ref. 3, if it is assumed that the total energy transferred is proportional to the total heat of fusion for the wire, and considering the average resistance proportional to the initial resistance of the wire; that is,

$$\int_0^{t_1} i^2 R' \, dt \sim \bar{R} \int_0^{t_1} i^2 \, dt \propto (\rho l A) H'$$

or

$$\frac{H'}{\bar{R}} \frac{l}{A} \sim \frac{H}{R} \propto \int_0^{t_1} \frac{i^2}{A^2} \, dt \equiv K,$$

where H is the heat of fusion per unit volume, H' is the heat of fusion per unit mass, $\rho l A$ is the initial mass of the wire, R is the initial specific resistivity of the wire, and A is the initial cross-sectional area of the wire. The ordinate of Fig. 2, the charge voltage squared divided by the specific resistivity, V^2/R, can be considered some measure of the rate of energy transferred, but it is not at all clear why the correlation shown in Fig. 2 should exist.

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