INVESTIGATIONS OF PULSE DISCHARGES AT HIGH CURRENTS
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We present the results of an experimental investigation of intense pulse discharges with rapidly increasing current. A brief description of the experimental method used is given. The pulsation processes of the plasma column are described.

The purpose of our experiments was to study the properties of pulse discharges with intense currents. In such discharge, contraction of the plasma should take place under the influence of electrodynamic forces (attraction of parallel currents). The energy of the electromagnetic forces that compress the plasma is expended on the kinetic energy of the charged particles. As a result of this, the plasma temperature and pressure in a high current discharge can achieve extremely great values. The study of some properties of pulse discharges in rarified gases at currents from $10^3$ to $10^4$ amps was the subject of references [1] and [2]. We investigated pulse discharges in hydrogen, deuterium, helium, argon, and xenon at initial gas pressures from 0.005 mm to several millimeters. The maximum current strength in the various experiments was from 100 kiloamps to one million amps. The discharge voltage was from 20 to 50 kv. The voltage sources were banks of condensers with capacitance from several times ten microfarads to 400 μF. The rate at which the current increased in the initial phase of the discharge, that is, the quantity $\frac{-di}{dt}$, was $3 \cdot 10^{10}$ amp/sec to $1.5 \cdot 10^{11}$ amp/sec, and the time in which the current increased from zero to the maximum value was from 8 to 17 μsec. The discharge tubes were porcelain cylinders from 60 to 100 cm long and from 20 to 40 cm in diameter. The electrodes were flat rings of copper or dural. Before each pulse discharge, the tube was evacuated to a very low pressure, and then filled with a fresh sample of the gas. The quantities that characterize the state of the plasma during the pulse discharge were measured by means of an oscillograph. The current was measured with a Rogovsky bridge with an RL integrating circuit. Low resistance voltage dividers connected in parallel with the discharge gap were used to measure the voltage. Oscillographic measurements of the magnetic field strength at various points of the plasma were used to clarify the current distribution in the cross section of the tube. The pressure pulses of the plasma were recorded by piezoelectric elements. Detailed accounts of the method and results of the investigations of intense pulse discharges will very soon be published in the J. Expf.-Theo-ret. Phys. Here we give merely the general properties of such discharges.

For the conditions of the experiments described, the pulse discharge is a periodic process with strong damping. The investigation of the first half period of the discharge is most interesting. Figure 1 shows two oscillograms of the current and voltage on a double beam pulse oscillograph. One of these is taken for discharge in deuterium at an initial pressure of 0.03 mm Hg. The second oscillogram is for deuterium at a pressure of 0.2 mm Hg. The initial voltage in both cases is 40 kv. The maximum currents are practically identical, being 500 ka. We see that at the very beginning of the discharge, after breakdown, both the current and voltage in the discharge gap are increasing. Then at a certain instant of time a sharp drop in voltage takes place. At the same instant there appears a kink in the oscillogram of current. After the first drop the voltage begins to rise rapidly, and then decreases sharply again. At the instant of the second discontinuous voltage drop, there appears a second kink in the current oscillogram. These fluctuations from a smooth variation in the development of the discharge are
a distinguishing feature of high current pulse discharges, and occur regularly. They are especially distinct in those cases in which the discharge takes place in gases with low atomic weights (hydrogen, deuterium, helium) at low initial pressures.

When the initial rate of current increase is of the order of $10^{11}$ amps/sec, the time interval $\tau$ from gas breakdown to the first drop in voltage is a few microseconds. The magnitude of $\tau$ is a function of parameters that characterize the initial conditions of the discharge. Figure 2 shows the dependence of $\tau$ on $M$, where $M$ is the mass of the gas per unit length of the discharge tube. The values of $\tau$ are obtained from oscillograms taken for pulse discharges in hydrogen, deuterium, helium, argon, and xenon (with the same initial voltage on the tube, and the same geometric parameters). The approximate dependence is $\tau \sim \frac{1}{\sqrt{M}}$. For a given value of $M$, the value of $\tau$ increases with increasing discharge tube radius, and decreases for increasing $\left(\frac{dl}{dt}\right)$. 

In pulse discharges with sharply increasing currents the inductive potential drop is substantially greater than the resistive one. It is therefore possible, by making use of the oscillograms of the current and voltage, to find the dependence of the inductance of the plasma column on time, and from this data to determine the time variation in the radius of the plasma column (assuming that the column is in the form of a cylinder with a well defined boundary).

Such an analysis shows that the initial stage of the process is characterized by increasing inductance caused by the contraction of the plasma onto the discharge tube axis. The plasma contracts more rapidly when $\left(\frac{dl}{dt}\right)$ is greater and the gas density is smaller. At the instant when the kink occurs in the oscillogram of current, the inductance starts to drop. This means that this instant corresponds to the maximum degree of compression of the plasma column. After this, a rapid expansion of the plasma takes place, and it is followed by a second contraction phase. If a few kinks are observed on the current oscillogram, this means that successive contractions and expansions are taking place. Knowing the radius of the plasma at various instants of time, it is possible to determine the velocity with which the plasma is moving toward the axis. This velocity depends on $M$ and $\left(\frac{dl}{dt}\right)$.

In our experiments, the velocity of the plasma varied between the limits of $1 \times 10^6$ cm/sec for discharges in gases with a high initial density, and