Letters to the Editor

MEASUREMENT OF THE IONIZING ABILITY OF PARTICLES IN A SPARK CHAMBER

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We have investigated the sensitive time in a spark chamber with a large (30 cm) interelectrode spacing. The sensitive time of the spark chamber, which was filled with pure inert gases, turned out to be large (tens of microseconds). However, a small admixture of air, propane, or alcohol strongly reduces the sensitive time.

In studying the operation of the spark chamber with admixtures of air, propane, and alcohol, we observed a structure of the spark discharge. As an example, Fig. 1 shows photographs of tracks in a spark chamber filled with helium ± 1% air, for different delays in application of the high voltage pulse. It can be seen from Fig. 1 that characteristic bunches appear in the tracks. For inclined tracks the discharge has a steplike appearance.

The appearance of the discharge, for example, the number of bunches, turns out to depend on the delay of the high-voltage pulse—with an increase in delay, the number of bunches decreases. A similar picture results from an increase in the amount of admixture, for a constant delay time.

For explanation of the observed effects it is necessary to assume a connection between the structure in the spark chamber discharge and the ionizing ability of the particles.[1] The action of an electronegative gas admixture and also of diffusion results in a decrease of the ionization density during the delay time of the high voltage pulse, and thereby in a decrease in the number of centers with a given ion density.

There is another mechanism for the action of polyatomic gases. An admixture of these gases leads to an effective quenching of the photon mechanism of the discharge. The discharge process is strongly slowed down in time. For a given length of high voltage pulse, an earlier stage of the discharge development will be recorded, which leads again to a decrease in the number of bunches in the spark breakdown.

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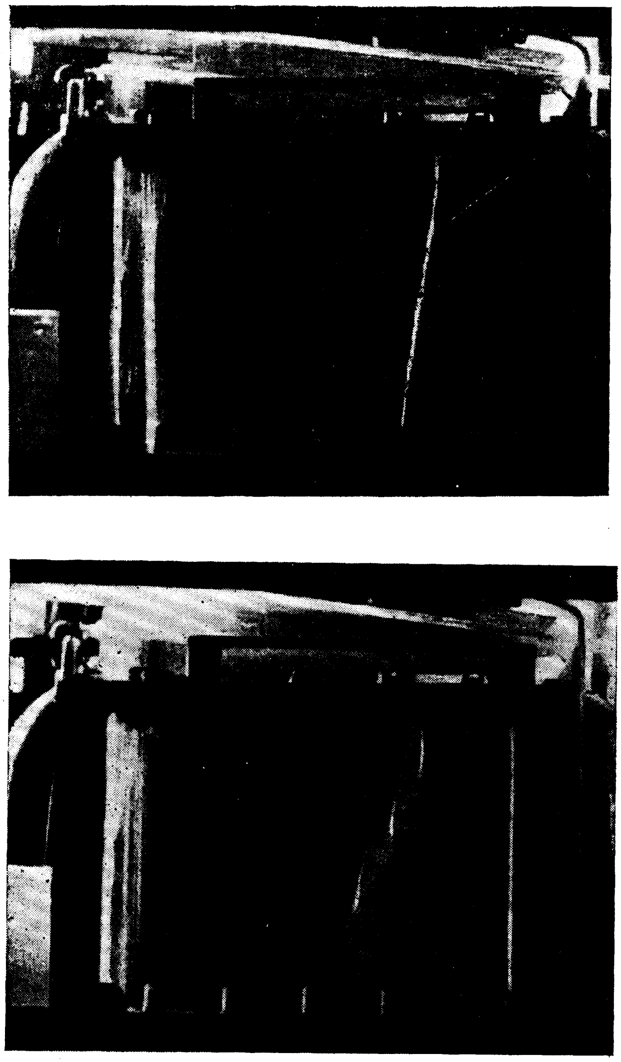

FIG. 1. Photographs of track discharges exhibiting structure, in a spark chamber filled with He + 1 % air to a pressure of 280 mm Hg: a) High voltage pulse delay $\tau = 0.8$ μsec; b) $\tau = 2.8$ μsec.

To verify this reasoning, we made a direct measurement of the ionizing ability of particles in a spark chamber. In this work we used two spark chambers with dimensions 44 × 60 cm and an interelectrode gap of 15 cm. The chambers were exposed in a beam of positive particles with a momentum of 600 MeV/c from the synchrotron at the Institute of Theoretical and Experimental Physics. Protons and π mesons were separated by means of their ranges.

The spark chambers could be triggered both by particles with a range after passing through the chamber of 7—20 g/cm^2 Cu (protons with an ionizing ability of (2.8—4.5) I_{min}), and by particles with ranges greater than 60 g/cm^2 Pb (π mesons with an ionization close to minimum). The chambers were filled with neon + 0.03% pro-

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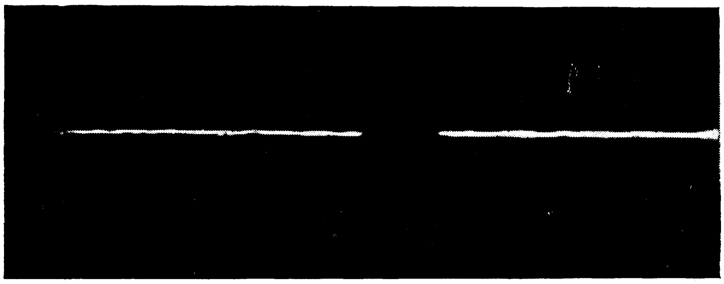

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FIG. 2. Tracks of particles with different ionizing ability in spark chambers working in the discharge structure regime. The chambers were filled with Ne + 0.03 % C_3H_8 to a pressure of 540 mm Hg. The shunting resistance R = 1.5 kΩ. a) π meson with minimum ionization; b) proton with ionizing ability ≈ 3.5 I_{min}.

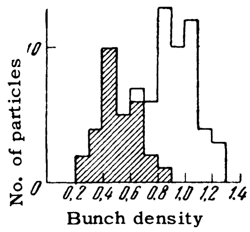
pane to a pressure of 540 mm Hg. The chambers were placed close together, so that particles which produced a triggering pulse passed through both chambers. The outer electrodes were grounded, and a high voltage pulse of ≈ 150 kV was fed to the center electrodes. The pulse length was controlled by the value of RC and was not directly measured (C = 100 pF is the output capacity of the pulser; R is the nominal value of the distributed resistance shunting the chamber).

The delay time in application of the high voltage pulse was 0.7 μsec. For R ≈ 1.5 kΩ the spark tracks exhibited structure. Tracks of π mesons and protons were easily distinguished from each other. The spark discharges produced by the highly ionizing particles had a substantially larger number of bunches than the discharges from the particles with minimum ionization (Fig. 2).

Figure 3 shows the distribution of particles as a function of the density of bunches in the tracks. The ratio of the bunch density in proton tracks to that in π-meson tracks was 1.9 ± 0.1, which is less than the ratio of the mean values of ionization of the protons and π mesons (3.5). This is explained by the fact that the bunch density in the proton tracks is too great for complete resolution of the bunches. In fact, when the bunch density was somewhat reduced by increasing the delay of the high voltage pulse to 1.5 μsec[2]), the ratio of the bunch densities in proton and π meson tracks became larger (2.5 ± 0.2).

As the result of the increase of bunch density

FIG. 3. Distribution of particles in bunch density of the tracks: Hatched area – particle with range > 60 g/cm² Pb (π mesons with minimum ionization); blank area – particles whose range after passing through the chamber is 7-20 g/cm² Cu (protons with a mean ionizing ability ≈ 3.5 × I_{min}).



in tracks of highly ionizing particles, the brightnesses of proton and π meson tracks differ strongly. In Fig. 4 we have plotted the results of photometry of proton and π meson tracks. The ratio of the brightnesses was found to be 3.0 ± 0.4 (an average for the two chambers), which is close to the ratio of the ionizing abilities of the particles.

It should be said that the tracks of particles with different ionizing abilities continue to be distinguished by brightness even when the track structure becomes too fine to discern the details. For example, in pure neon the structure of the tracks may not be visible for a given amplitude of the high voltage pulse, but tracks of particles with different ionization can be distinguished according to their brightness. Thus, in our experiment, when the chambers were filled with pure neon (p = 760 mm Hg), for a shunting resistance R = 1.0 kΩ (the corresponding pulse length RC = 10^{-7} sec) the ratio of the brightnesses of proton and π-meson tracks was large, but the brightness of the π-meson tracks was very small.

For R = 1.5 kΩ (RC = 1.5 × 10^{-7} sec) the

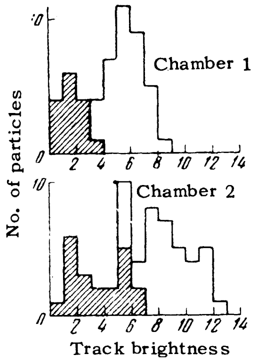


FIG. 4. Distribution of particles in track brightness: Hatched area—particles with range > 60 g/cm² Pb (π mesons with minimum ionization); blank area—particles whose range after passing through the chamber is 7-20 g/cm² Cu (protons with a mean ionizing ability $\approx 3.5 \times I_{min}$).

brightnesses increased by ≈ 13 times, but the ratio of brightnesses dropped to ≈ 2.0, which indicated a transfer to a regime of saturation (the operating regime for most spark chambers), where tracks of particles with different ionization are not distinguished by brightness.

Up to this time, as far as we know, there has been only a single observation in a spark chamber of track brightness differentiation produced by ionization: In the decay of Λ particles in a multilayer spark chamber, Cronin [1] observed that protons had a greater brightness than π mesons. However, this observation, interesting in itself, does not indicate the possibility of measuring ionization in a spark chamber. In this case the important circumstance was that the protons and π mesons passed through the chamber strictly simultaneously, and the energy of the high voltage pulse was divided in accordance with the ionization of the particles (the tracks created conducting channels with different resistance). Here the spark chamber, in the operating regime used, did not give a difference in brightness for solitary tracks with different ionization.

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1)Strictly speaking, a connection between track structure and ionization density follows just from the dependence of the number of bunches on the high-voltage pulse delay time. In this experiment the conditions of the discharge development were held constant (gas composition, and height and length of the high-voltage pulse were not changed) and only the initial conditions connected solely with the ionization density of the particle track at the time of arrival of the high-voltage pulse were varied.

2)Of course, increasing the delay is not the best way of decreasing the bunch density in the tracks. The same effect can be obtained by shortening the high voltage pulse. In the present experiment this was not an important matter.

[1] J. W. Cronin, Nucl. Instr. and Meth. 20, 143 (1963); C. T. Coffin et al, Nucl. Instr. and Meth. 20, 156 (1963).

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UNIVERSAL INSTABILITY IN A POTASSIUM PLASMA

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IT has been shown by a number of authors [1-6] that a plasma with an inhomogeneous density distribution in a magnetic field can be unstable against the so-called universal instability. The instability can develop in a low-density plasma (mean free path greater than the dimensions of the system) and in a dense plasma.

The instability leads to the excitation of waves that are essentially perpendicular to the magnetic field but with a finite component along the field; the characteristic frequencies are given by

$$\omega = k_y (cT/eH)\, n'/n, \tag{1}$$

where k_y is the component of the wave vector perpendicular to the magnetic field, T is the temperature in energy units, H is the magnetic field, n is the plasma density and n′ is the density gradient.

In a bounded plasma, in which k_y is determined by the circumference of the plasma cylinder, only those frequencies will be excited for which $m\lambda = 2\pi R$, where λ is the wavelength and R is the radius of the plasma cylinder. The growth rate is inversely proportional to k_z for small densities and k_z^2 for high densities (k_z is the component of the wave vector parallel to the magnetic field). [6] It then follows that long wavelengths are the most unstable.

We have carried out experiments in a device in which a plasma is produced by thermal ionization of potassium vapor on a tungsten plate heated to 2000°K. In this device the plasma forms a cylinder bounded at the ends by hot plates. The magnetic field is along the axis of the cylinder. The plasma density is a maximum at the center and falls off in the radial direction. The plasma