Fyzikálny časopis 18 (1968), No. 2

THE SPARK CHAMBER WITH A SMALL ADMIXTURE OF AIR IN THE GAS FILLING

PAVEL POVINEC, ŠTEFAN ŠÁRÓ, VIERA SRKALOVÁ, Bratislava

INTRODUCTION

Spark chambers are very often used in experiments of high-energy and cosmic ray physics now. These experiments require long-lasting operation of the detection device. One of the most significant parameters for stability of work of spark chambers is the gas filling. It is not possible, however, to keep the gas filling quite constant because of the release of different gases absorbed on the surface and some impurities which can penetrate into the spark chamber during the operation. Therefore it is important to know how the operating characteristics are changed in the course of long experiments.

EXPERIMENTAL ARRANGEMENT

A spark chamber with glass electrodes and with glass walls was used [1, 2]. It had ten electrodes (gap length of 7 mm) and its capacity was about 500 pF.

A high voltage pulse was applied to the spark chamber after there had passed a cosmic-ray charged particle approximately normal to the electrodes of the chamber. The electronic system of the triggering spark chamber is described in a previous paper [1]. The high voltage pulse was of negative exponential form. The rise time of the pulse applied to the chamber was less than 10^{-7} s. The total delay time between the instant of the passage of the particle and that of application of the high voltage pulse was .4 μs. When pulses with the duration of .5 μs were applied to the chamber, good results were obtained. Pulses with a duration exceeding 1 μs caused an increase in the number of spurious discharges, arose as a consequence of non-homogenities of the electric field, caused for example by damage of the electrodes after discharges or by end effect. The pulses of the duration of .1 μs decreased the efficiency and the light intensity of sparks.

The positive voltage of 50 V was applied to the cathodes of the chamber to provide a *clearing* field.

Some tests have been made with technical argon and with a mixture of argon + alcohol at atmospheric pressure. In the gas filling there was an admixture of .5 % air. The addition of ethyl alcohol vapours (resulting in an almost saturated mixture) has a quenching effect and reduces spurious discharges. The number of spurious discharges with the addition of alcohol decreased by about 20 % and the light intensity of sparks increased. The efficiency in this case was not greater than about 87 %.

When the high voltage pulse is applied to the electrodes, electron avalanches begin to develop. Although the electron avalanches began to develop in all gaps along the ionizing particle path, some avalanches did not develop into streamers. The plates are quickly discharged below the threshold voltage and the electric field intensity decreases due to the strong electric current flowing in the streamers, which have been developed before. The ionizing particle is then registered only in some gaps. A picture of a cosmic-ray particle in this chamber is shown in Fig. 1.

From Fig. 1 it can be seen that the light intensity of sparks is not the same in all gaps. The light intensity of the discharge columns depends on the filling gas of the chamber. Using only an argon + air (.5 %) mixture as the gas filling a rather varying light intensity of the sparks was obtained. These

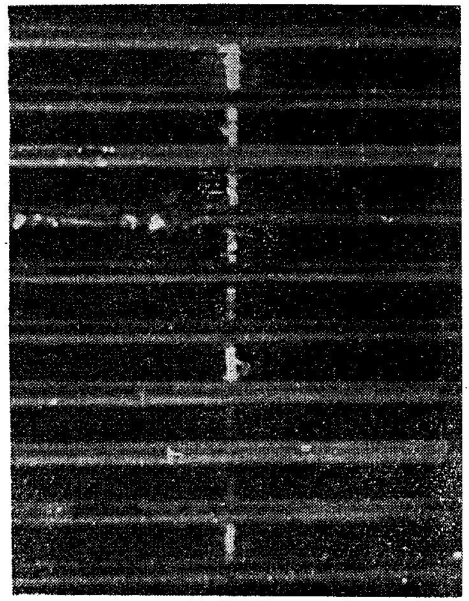

Fig. 1. Typical photograph of a cosmic-ray track.

results can be explained as follows. The developing of streamers is not the same in all discharge gaps (e. g. because of the statistical nature of the electron avalanches). In some gaps streamers are developed faster than in others and the energy storage in a discharged capacitor is not distributed for all gaps equally.

THE INFLUENCE OF ADDITION AIR IN THE GAS FILLING

It is known that the operating characteristics of spark chambers are gradually changed during long experiments.

This effect is essentially due to a change in the composition of the gas filling. The change is caused by the relase of different gases absorbed on the surface and by the release of organic vapour from the walls of the chamber. The influence of air in argon filling, which can penetrate into the chamber during the operation, was investigated.

It is known [6, 7] that the addition of air reduces the efficiency apparently due to the electro-negative ion formation. To reach the maximum efficiency the spark chamber must be evacuated down to .01 torr at least.

The present inpurities can contain contaminations by electro-negative gases. The electro-negative gases easily capture electrons freed by the ionizing particle and form negative ions. The time rate of the change of electron density, n_e, may be written as

$$\frac{dn_e}{dt} = -hn_e\frac{v}{\lambda}, \tag{1}$$

where h is the probability of capture per collision, v is the mean electron velocity and λ is the collision mean free path of electrons.

Although the electrons are intercepted (lost by attachment) and form negative oxygen ions, they initiate a discharge when the value of X/p is about 90 V/cm . torr (X = field strenght in V/cm; p = pressure in torr), since the binding energy of the electrons is rather low ($\sim$2 eV) [3]. When the high voltage pulse is applied to the electrodes the captured electrons are detached from negative oxygen ions through collisions with gas molecules and they can initiate electron-photon avalanches. This is possible in spark chambers filled with air mixture, where the value of X/p lies between 80 and 100 V/cm . torr [4]. But in spark chambers filled with rare gases (generally at X/p — 30 V/ /cm . torr) it seems likely that electrons are not detached from negative oxygen ions. If there is an admixture of an electro-negative gas, electrons are lost by interceptions and they cannot develop electron avalanches.

The attachment time of electrons may be written as

$$T_a = \frac{\lambda}{hv} \tag{2}$$

and the drift velocity of electrons may be expressed by the following equation:

$$w = \frac{3}{4}\frac{Xe\lambda}{mv}. \tag{3}$$

The values of attachment probability h were computed using equation

$$\frac{h_{air}}{h_{mix}} = 1 + \frac{1 - f_{air}}{f_{air}} \cdot \frac{\lambda_{air}}{\lambda_{mix}}, \tag{4}$$

where f_{air} is the mole fraction of air present and λ_{air}, λ_{mix} are the electron collision mean free path in air and in mixture, resp. [3]. The values of h_{air}, λ_{air}, λ_{mix} were taken from [3]. The equations (2), (3), (4), and drift velocities obtained by T. E. **Bortner** et al. [5] were used for computation of T_a. Fig. 2 shows the computed values of T_a for argon-air mixtures. The strong dependence of T_a on the admixture of air can be seen. When the delay time of high voltage pulse is shorter than about 5 . 10^{-5} s the contamination of air of the order .2 % is allowable.

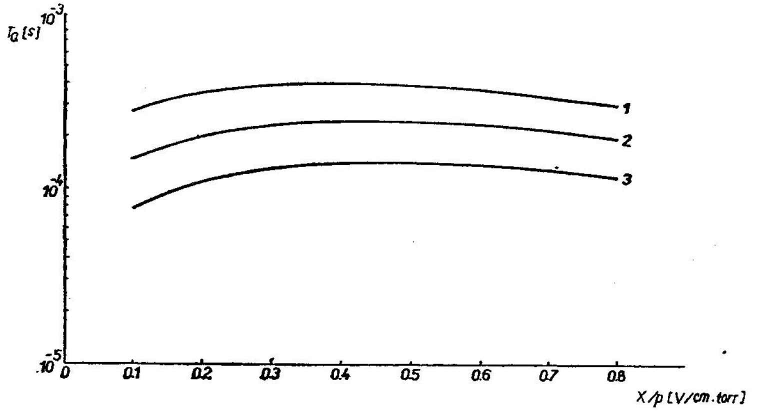

Fig. 2. The attachment time of electrons vs. X/p for argon-air mixtures. 1 — argon + + .05 % air; 2 — argon + .1 % air; 3 — argon + .2 % air.

If clearing voltage is applied to the electrodes, the electrons are swept out of the gaps. Taking into account only this process, the memory half-

---

[1] The memory half-time is the time during which the efficiency per single gap drops to 50 %.

time[1]) can be estimated approximately as follows (the polarity of the clearing voltage is opposite to that of the high voltage pulse): $T_m \sim d/w$, where d is the distance between the electrodes and w is the drift velocity of electrons. Fig. 3 shows the computed memory half-time of the spark chamber (gap length $d = .7$ cm) for argon-air mixtures. The drift velocities of argon-air mixtures given by T. E. Bortner et al. have been used. The change of the memory time is caused by the admixture of air which augments the electron drift velocity [5]. It seems reasonable that the operating characteristics of spark chambers are gradually changed during long experiments due to the strong dependence of the drift velocity on the impurities contained in the gas filling of the chamber. The electron drift velocities deduced from measurement with spark chambers (e. g. from the results obtained by J. W. Cronin et al. [6] in pure neon) are four to six times larger than those obtained with the classical gas discharge techniques. This poor agreement can be explained by the presence of small impurities in the chamber because the purity of the gas filling is not so high as in classical gas discharge experiments.

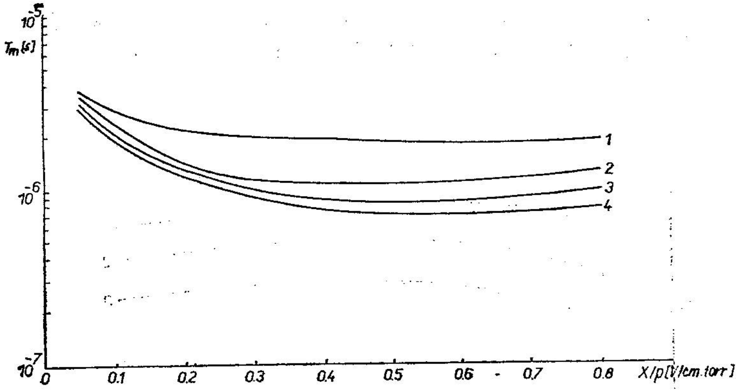

Fig. 3. The computed memory half-time of the spark chamber with gap length of .7 cm for argon-air mixtures. 1 — argon; 2 — argon + .05 % air; 3 — argon + .1 % air; 4 — argon + .2 % air.

THE ACCURACY OF TRACK LOCATION IN SPARK CHAMBER

Under some conditions, the discharge has a tendency to follow the trajectory of an ionizing particle in the gas filling of the spark chamber. It will be seen that the accuracy of track location becomes progressively worse with increasing track angle (the angle between the path of the particle and the direction of the applied electric field).

The tracks for particles crossing normally were analyzed. In the microscope UIM-21 the centres of sparks were measured and the line approximating the trpaicle path was calculated by the least squares method. Then the horizontal deviations of the centres of sparks Δ from this line were calculated. In Fig. 4 a histogram of deviations Δ [mm] of 415 sparks is shown. It can be seen that the full width at half-amplitude is of the order of .6 mm. Only 6 % of the sparks have values of $|\Delta|$ greater than 1.1 mm and 3 % of the sparks have values of $|\Delta| > 2$ mm. From the measured deviations a standard error δ can be determined. For 90 % of deviations the standard error is .26 mm. Displacements greater than 5 mm were not observed.

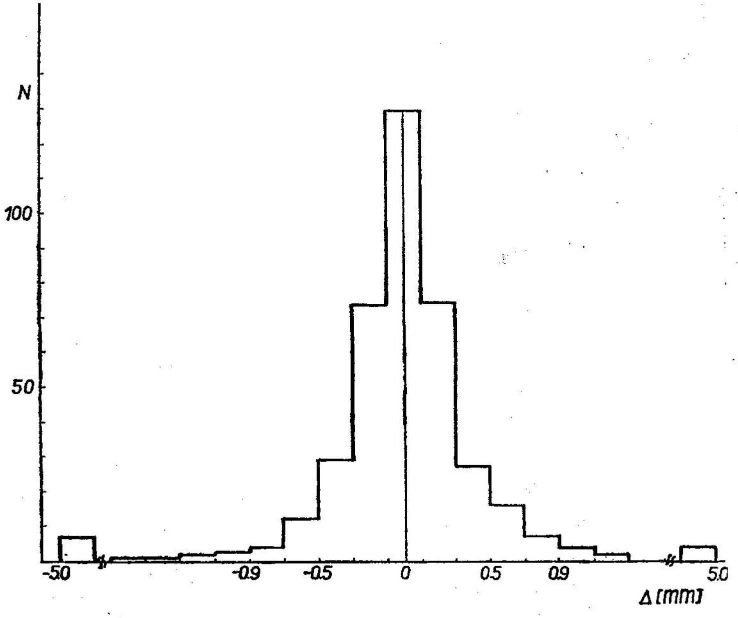

Fig. 4. Histogram of the measured values of Δ.

The basic contributions to the Δ value can be caused by the scattering of particles in the electrodes of the spark chamber (up to 2/3 of the value), hence they are included in these calculations besides deviations of Δ caused in consequence of non-accurate track location of the spark discharge.

The histogram shown in Fig. 4 may be approximated by the analytical function $N = N_0 \exp(\varkappa|\Delta|)$, $\varkappa = 4.4$. In Fig. 5 ln N is shown as a function of $|\Delta|$ and it is seen that the experimental points lie on the line.

Observed deviations of sparks can be explained by the secondary photoionization and by production of knock-on electrons. The transition from an electron avalanche to a streamer occurs when Raether's condition $\alpha x \geqslant k$ is fulfilled, where α is the first Townsend coefficient, x is the distance from the place of the electron avalanche beginning to the positive electrode and k is a constant at the given gap length. The streamers develop most probably near the cathode, because there Raether's condition is fulfilled best. Photons are released from the basic electron avalanche and they can initiate ionization on the cathode. For photo-electrons formed in this way Raether condition is fulfilled and therefore the discharge can be developed in another direction.

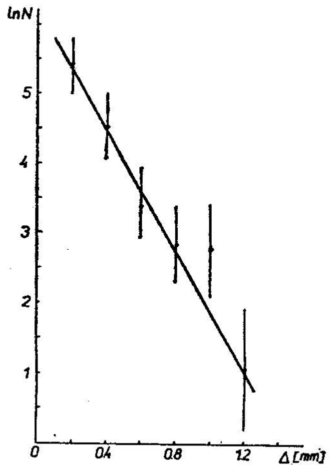

Fig. 5. The linear dependence of ln N as a function of $|\Delta|$.

Greater displacements are caused by knock-on electrons. Knock-on electrons are produced in the gas filling and in the electrodes of the chamber. Very often two sparks were observed near each other, at distances of up to 5 mm. Only one of the sparks, the one near the track, is plotted in Fig. 4.

The spark chamber was tested also with particles crossing the spark chamber under the angle of incidence of about 20°. We found out that the discharges usually developed in the direction of the electric field intensity. Very often we could observe *break* sparks — one part of the spark follows the track of the particle, the other follows the direction of the field intensity. The standard error was .35 mm.

CONCLUSIONS

On the basis of the performed measurements it is possible to conclude that in a spark chamber with a small admixture of air (.5 %) in the gas filling good results can be obtained, too. The addition of air in the gas filling has a large effect on the operating characteristics of the spark chamber due to the attachment of electrons by oxygen molecules and the strong dependence of the drift velocity of electrons on the admixture of air in the spark chamber. It is possible to reach a high efficiency for single tracks even by a greater addition of air in the gas filling. The harmful influence of air can then be reduced by making the delay time of the high voltage pulse shorter. The accuracy of track location of an ionizing particle is the same as in spark chambers with a pure gas filling.

REFERENCES

[1] Šáró Š., Povinec P., Srkalová V., Nuclear Instruments and Methods *50* (1967), 11.

[2] Šáró Š., Povinec P., Srkalová V., Acta F. R. N. Univ. Comenianae Physica (to be published).

[3] Loeb L. B., *Basic Processes of Gaseous Electronics*, Berkeley — Los Angeles 1955.

[4] Дайон М. И. Князев В. М, Марикян Г. А., Приб. и техника эксп. *10* (1965), 54.

[5] Bortner T. E., Hurst G. S., Stone W. G., Rev. Sci. Instrum. *28* (1957), 103.

[6] Cronin J. W., Renninger G., Rev. Sci. Instrum. *32* (1961), 496.

[7] Bayukov Yu. D., Leksin G. A., Suchkov D. A., Telenkov V. V., Nuclear Instruments and Methods *20* (1963), 198.

Received August 29th, 1967

Katedra jadrovej fyziky
Prírodovedeckej fakulty UK,
Bratislava