# ON THE SHOWER EFFICIENCY OF SPARK CHAMBERS POSSESSING A LARGE "MEMORY"

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(Presented by M. I. DAION)

In contrast to chambers filled with neon, air and air-argon spark chambers [1–4] have a large "memory." This property is very valuable in some cases, for example, if the control pulse is considerably delayed for physical or technical reasons. An example is the experimental installation in which the spark chamber is combined with an ionization calorimeter and is controlled by the pulse from the calorimeter.

An important shortcoming of air and air-argon chambers is the low recording efficiency of several particles, which is manifested, in particular, when a single charged particle crosses a few gaps of a spark chamber: a breakdown does not occur in all the gaps. In order that sparks form in each gap, it is necessary to "decouple" the gaps by means of resistances or inductances.

In the present work an attempt is made to create an air-argon chamber capable of recording several particles. For this purpose one of the electrodes of each gap was insulated from the working gas by a dielectric layer (glass, ebonite), which limits the discharge current and thereby prevents a rapid drop of the potential on the chamber plates [5].

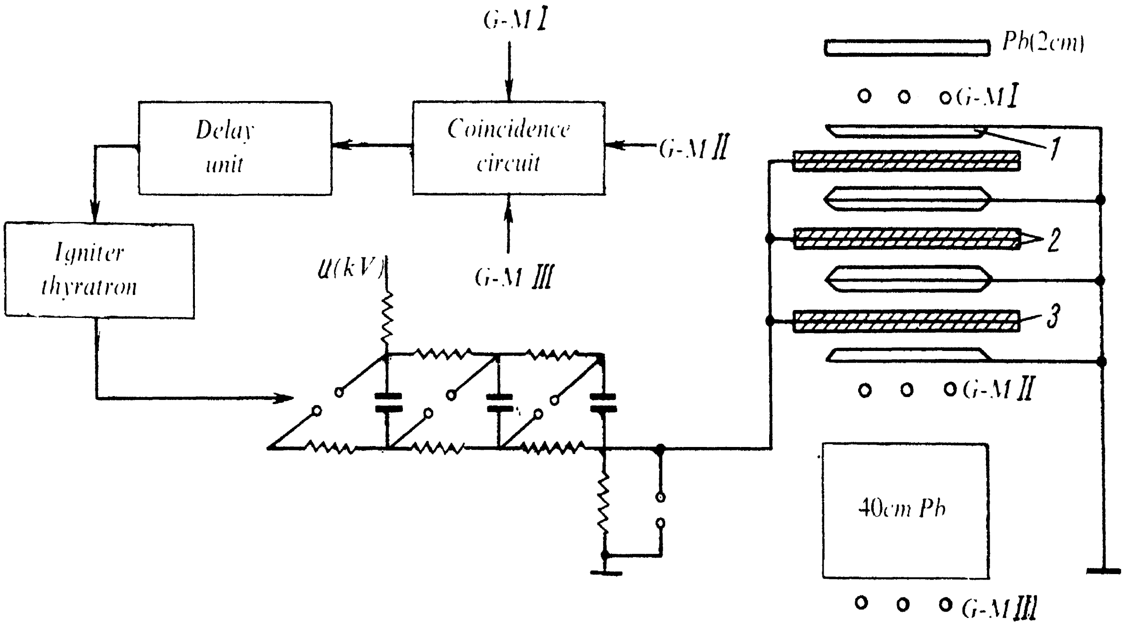


Fig. 1. Circuit of a chamber with six discharge gaps: 1 – metal electrode (Al); 2 – glass; 3 – metal foil.

Fig. 1 gives the circuit diagram of a chamber consisting of six discharge gaps [5]: the working area of each electrode is 100 $cm^2$, the interelectrode distance is 5 mm. The chamber was filled with the mixture

$$\text{air} + \text{Ar}(70\%) + \text{alcohol vapor}$$

to a total pressure of 1 atm. A voltage of 12–14 kV was applied to the igniter and two or three sections of it were switched on. The output capacitance of the igniter was about 3.000 farad. The chamber was triggered by 2–400 $\mu$sec-delayed pulses from triple coincidences of discharges in a telescope of Geiger-Müller counters. Under these conditions (measurements were also performed for other parameters of the high-voltage pulse) upon the passage of one particle, bright sparks located close to the trajectory are created as a rule in all six gaps (Fig. 2).

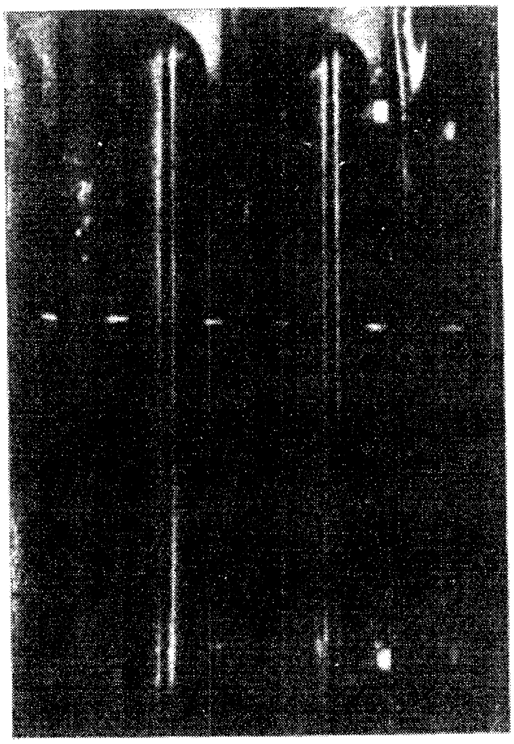

Fig. 2. Photograph of a particle track in a spark chamber.

Thus, owing to the dielectric the individual gaps are decoupled. The accuracy of localizing sparks for trajectories passing near the vertical was determined by the method of deviations [2, 4]: the spark coordinates $x_1, x_2, \ldots, x_6$ in each gap were measured and for each trajectory the deviations $\Delta_1 = x_2 + x_5 - 2x_3$, $\Delta_2 = x_2 + x_6 - 2x_4$ were calculated (see Fig. 3).

It is obvious that the distributions of $\Delta_1$ and $\Delta_2$ are identical to that of $\Delta$. If we denote the rms deviation of each spark from the trajectory by $\delta_x$, then

$$\sqrt{\overline{\Delta^2}} = \sqrt{6}\delta_x; \quad \delta_x = \sqrt{\frac{\overline{\Delta^2}}{6}}. \tag{1}$$

The histograms of Fig. 3 give the $\Delta$-distributions for two values of the high-voltage pulse delay: $\tau_3 = 2$ and $400$ $\mu$sec. Most of the cases group about small deviations $\Delta < 1$ mm, but there are also small distribution "tails." For a quantitative estimation of the deviations, the rms-values of $\Delta$ for 90% and 95% of the cases involved in the histograms were calculated. Hence, the $\delta_x$-values of interest (given in the table) were determined from formula (1). By increasing the delay from 2 to 400 $\mu$sec, the rms-value of $\delta_x$ somewhat increases in accordance with the expected increase due to diffusion of oxygen molecules (0.07 mm during 400 $\mu$sec). Some decrease in the recording efficiency is observed as the delay increases, which cannot be attributed to recombination of ions, to charge carriers leaving by diffusion

| Filling | Delay $\tau$, $\mu$sec | $u$, kV | $\delta_x$, mm* for 90% of the trajectories | $\delta_x$, mm* for 95% of the trajectories | $\eta$**, % |
|---|---|---|---|---|---|
| 74% Ar + 21% air + 5% alcohol | 2 | 37.5 | 0.13±0.01 | 0.21±0.02 | 99±4 |
| | | 31.5 | 0.11±0.01 | 0.17±0.02 | 96±5 |
| | 20 | 37.5 | 0.12±0.01 | 0.16±0.02 | 98±4 |
| | 50 | 37.5 | 0.13±0.01 | 0.15±0.02 | 98±5 |
| | 100 | 39.0 | 0.20±0.01 | 0.26±0.02 | 95±3 |
| | 200 | 39.0 | 0.19±0.02 | 0.28±0.03 | 90±4 |
| | 300 | 39.0 | 0.21±0.03 | 0.49±0.08 | 89±6 |
| | 400 | 39.0 | 0.22±0.01 | 0.41±0.02 | 89±3 |
| 94% Ar + 4% $O_2$ + 5% alcohol | 400 | 39.0 | 0.16±0.02 | 0.25±0.02 | 90±4 |
| 93% Ar + 2% $O_2$ + 5% alcohol | 400 | 39.0 | 0.39±0.04 | 0.56±0.05 | 90±4 |
| | 2 | 39.0 | 0.18±0.02 | 0.27±0.02 | 98±5 |

* The rms deviations $\delta_x$ are given with the statistical error. The measurement error is 0.03 mm.

** $\eta$ is the recording efficiency of a single particle in one gap. It is given with the statistical error.



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to the plates, or to the purifying effect of the pulse front. Apparently, as a result of collisions with air and alcohol molecules, part of the negative ions eventually transforms into heavier slow molecular aggregates which reduces the probability of electron stripping in the electric field of the high-voltage pulse.

Besides an air-argon mixture, mixtures of

$$Ar + O_2 + \text{alcohol vapor}$$

were also investigated.

The corresponding results are given in the Table (see the bottom three lines).

The efficiency of the chamber and the localization accuracy of the sparks are maintained if the percentage of oxygen remains the same as in the air-argon mixture, i.e., the chamber's "memory" is determined by the amount of oxygen in the working mixture.

Of great interest is the question of the accuracy for inclined trajectories. The rms deviation of sparks for an angle of 25° was found to be $\delta_x = 0.37 \pm 0.06$ mm. This result shows that not all negative "centers" appearing on the path of a particle initiate sparks with the same probability. As a rule, sparks are formed only in a small region of the spark gap; most likely this region is adjacent to the negative electrode.

Let us consider this problem in greater detail. The process of spark formation can be divided into three stages: a) detachment of an electron from a negative oxygen ion; b) development of an electron avalanche; c) development of the avalanche into a conducting streamer channel which shorts both electrodes.

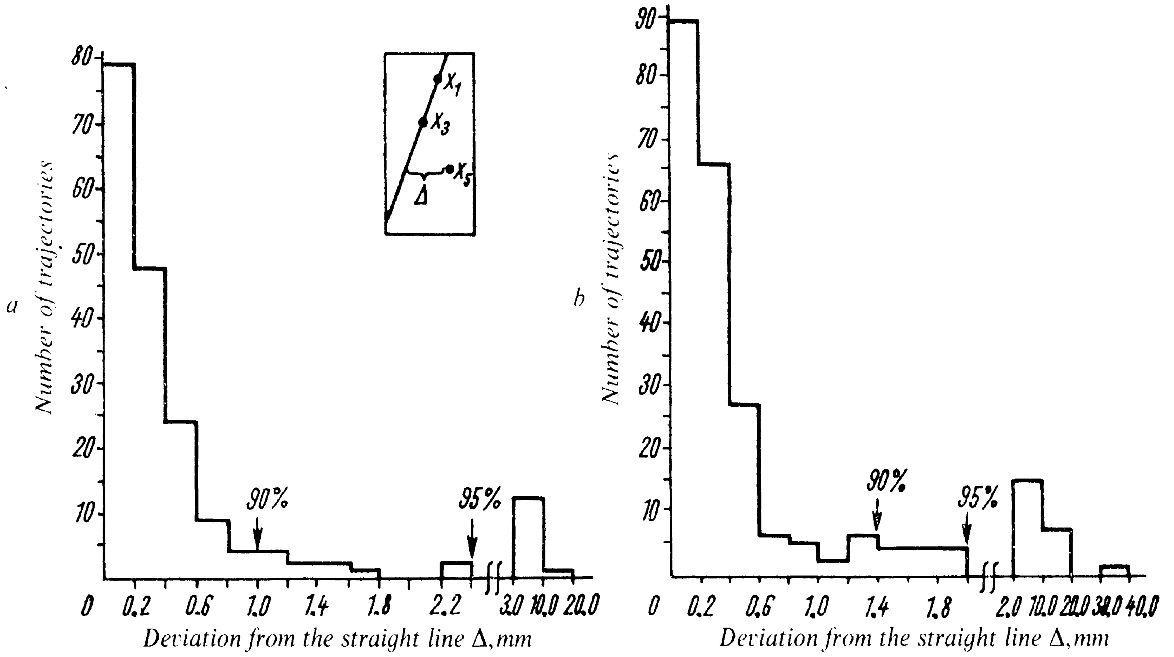


Fig. 3. Distribution of Δ for two values of the high-voltage pulse delay:
$a - \tau_d = 2\ \mu$sec; $b - \tau_d = 400\ \mu$sec.

Let us denote the durations of each stage by $T_a$, $T_b$, and $T_c$, and the fluctuations of these quantities by $t_a$, $t_b$, and $t_c$, respectively.

If the place of formation of a spark breakdown were determined by the fluctuations $t_a$ or $t_b$, then the rms deviation $\delta_x$ would be considerably larger than that experimentally observed (0.37 mm).

Hence we conclude that the time $T_c$ depends on the place of formation of the avalanche and it has the smallest value for avalanches initiated by electrons appearing near the negative electrode.

The question now arises: does a dielectric have a decoupling effect between sparks in one gap and can the chamber record several particles? The preliminary data we are presenting were partly obtained in the above described chamber, whereas the major portion was obtained in a larger chamber (9 gaps with a height of 7 mm each, electrode area $20 \times 30\ cm^2$, 2 mm thick ebonite dielectric, igniter output capacitance of about 4.000 farad, voltage of 50 kV, 20 $\mu$H inductance $L$ connected in place of the resistance $R$). Cases of 2 and 3 particles passing through the chamber were chosen. Usually, two or three trajectories are respectively observed (Fig. 4), but the number of sparks in each trajectory is less than that for single trajectories. It was found that upon the passage of two particles, about 75 % of the sparks appearing in a single trajectory are observed in each of the two trajectories, and upon the passage of three particles – approximately 65 %. The spark localization accuracy apparently decreases somewhat (the data have not been processed). As the number of particles passing through the chamber increases, the average number of sparks per trajectory decreases, but the total number of sparks increases, which in particular indicates the relatively important role of fluctuations during spark formation.

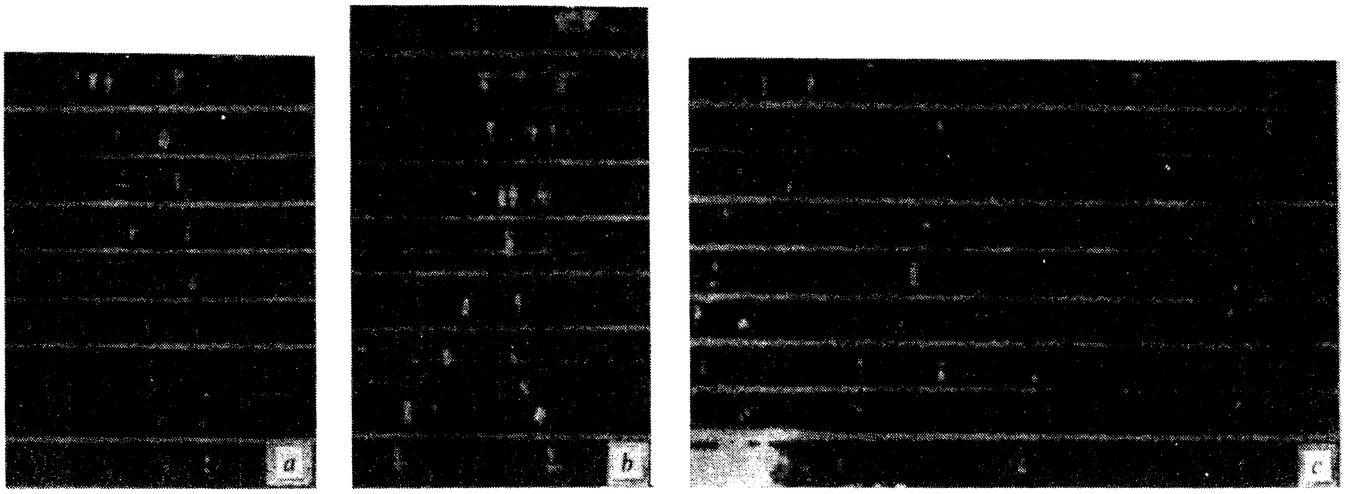

Fig. 4. Spark distributions upon the passage of two ($a$, $b$) or three particles ($c$).

Thus, our preliminary data show that the air-argon chamber with a dielectric has a relatively high shower efficiency. The same chamber without a dielectric yields a low recording efficiency, even for single particles.

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