THE REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 32, NUMBER 5 MAY, 1961

A 14×14×7-in. Thin Plate Spark Chamber

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(Received March 6, 1961)

A Lucite wall spark chamber with 0.012-in. aluminum electrodes, active dimensions 14×14×7 in., has been constructed and tested both with cosmic rays and a particle beam. The gap efficiency is nearly 100% and the time resolution ~1 μsec. Construction methods and chamber characteristics are presented.

INTRODUCTION

A SPARK chamber with moderately thin electrodes to minimize background interactions has been constructed for use in particle accelerator experiments. In tests with cosmic rays and with a beam at the Cosmotron the chamber performed satsifactorily. In this paper we will discuss the characteristics of this chamber, along with some experimental results obtained with smaller test chambers.

CHAMBER CONSTRUCTION

The chamber is a set of parallel electrodes, made of 0.012-in. aluminum. These electrodes are supported and insulated from each other by spacers which are Lucite frames; the electrodes and Lucite frames are bonded together in a vacuum-tight joint with epoxy resin. The Lucite spacers then also serve as the vacuum wall, and no outside vacuum tank is necessary. Tests with small chambers had shown that this method of keeping the sharp electrode edges away from the neon filling gas completely eliminates sparking from these edges, even with foil as thin as 1 mil. The electrodes can be ended either inside the wall or outside in the air, with no sparking.

In this chamber the electrode spacing is $\frac{3}{8}$ in. and the wall thickness of the Lucite is $\frac{1}{4}$ in. to minimize material. To help support the wall in pumping down to vacuum, the chamber was constructed in sections, each section consisting of six gaps separated by the Lucite frames with an aluminum frame at each end. The sections are gasketed together with O-rings. This sectioning also permits the easy insertion of lead plates for gamma-ray conversion. The sections are held together by bolts between two $\frac{1}{4}$-in. end plates. These end plates are milled down to $\frac{1}{16}$ in. over the chamber. The active area of the chamber is 14×14 in. and the active length approximately 7 in. for three sections. A photograph of the chamber is shown in Fig. 1.

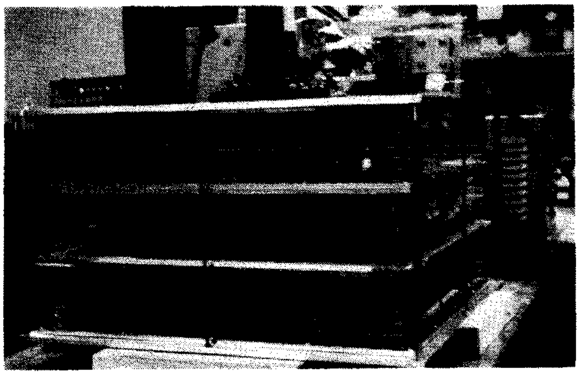

FIG. 1. Lucite wall spark chamber.

The electrode sheets are cut with tabs sticking out one edge. These tabs serve as the electrical lead-ins, to be connected alternately to high voltage and ground terminals of the pulse generator.

The 12-mil aluminum electrodes are stretched flat by a combination of methods. The most important method is bonding the chamber together at lower than normal temperature. The large temperature coefficient of expansion of Lucite (three times that of aluminum) pulls the electrodes flat on returning to normal room temperature. A 10°C temperature difference is all that is needed. Large temperature changes, greater than say 20°C or so, should be avoided after the bond is set, to prevent cracking of the epoxy joints. The electrodes which are next to the aluminum supporting frames are stretched, by holding the frames in compression while bonding. Release of this compression after the bond is made then stretches the foils. A third stretching technique, not needed here, is to operate the chamber at 1 lb/in.^{2} or so over atmospheric pressure.

Chambers of comparable dimensions built with the above technique but with very thin foil, 1 mil or so, should probably be constructed with considerably thicker Lucite walls, to even the stress on the foil and prevent wrinkling. This also has the advantage that with thick enough Lucite frames (about 1 in. for the above size chamber) the aluminum supporting frames are not necessary. A chamber of this type has been completed and works very well. With such extremely thin foil some care must be taken not to get too far above normal operating temperature, so that the yield strength of the foil will not be exceeded.

Before assembly the 12-mil aluminum electrodes were cleaned with sodium hydroxide solution. From tests with small chambers this appears necessary with aluminum sheet stock, but such cleaning did not noticeably affect the gap sparking efficiency of very thin aluminum foil chambers. Different methods of cleaning did not change the efficiency of copper foil test chambers, either.

The chamber was pumped down through a set of $\frac{1}{8}$-in. holes drilled through the Lucite wall, one hole per gap. A Lucite manifold was cemented with epoxy to each section. The spaces between sections inside the aluminum frames were pumped through connecting holes through the frames.

It is not necessary to get an excellent vacuum before filling. Test chambers pumped down with a fore-pump worked satisfactorily. With the large chamber, however, a diffusion pump was used and the chamber was pumped for three days, to outgas the Lucite as much as possible. A second pumping down, after taking the chamber to Brookhaven, required just a few hours to approach equilibrium. After pumping, the chamber was filled with neon gas at one atmosphere pressure.

HIGH VOLTAGE PULSE

Each section of the chamber, six gaps connected in parallel, is pulsed from a supply run at 8–15 kv, with a pulse length around 0.1 μsec, using a standard RLC pulse forming circuit with an Amperex 6279 hydrogen thyratron (a modified 5C22). Since the total capacity of a section is about 900 $\mu\mu$f, the capacity C of the pulse forming network is considerably larger, 4000 $\mu\mu$f. The rise time of the pulse at the chamber is estimated $\sim 5\times 10^{-8}$ sec. Small increases in this rise time ($\sim 10^{-8}$ sec), made by adding series resistors, did not affect the chamber sparking efficiency; however, an increase of the rise time to $\sim 10^{-7}$ sec did markedly decrease it, perhaps a factor of 2. Other modifications of pulse shape or length appear to have little effect on chamber efficiency.

Each 6279 is fired by a pulse from an EFP 60 blocking oscillator circuit.[1] A 400-v pulse on the grid fires the 6279 in about 0.1 μsec. The required current to the grid is around 400 ma, an amount which the EFP 60 circuit can deliver. Delays in the phototubes and coincidence circuitry add to this firing delay, giving a minimum total delay of the high voltage pulse from the particle traversal time of 0.2 to 0.3 μsec.

A photograph of the high voltage pulser attached to the chamber is shown in Fig. 2.

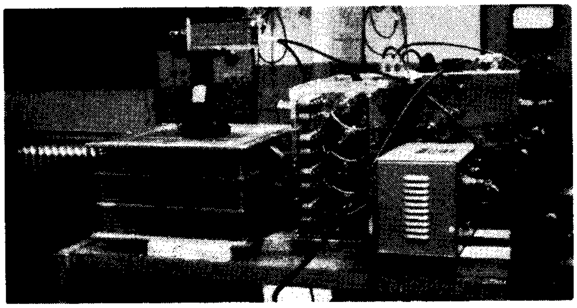

FIG. 2. High voltage pulser connected to spark chamber.

OPTICAL SYSTEM

The sparks are photographed on one film with four views; two at right angles for accurate measurements, and two at 54°, the latter to resolve possible ambiguities in the right angle views. To be able to photograph between the plates all the way to the back of the chamber, spherical field lenses are placed as close as possible to the Lucite walls on the two sides of the chamber being observed, and the camera is put at their focal point. (Two plane mirrors are required for each of the four views, with the use of a single camera.) Photographing the chamber with the camera at the focal point of a spherical lens gives a picture in which the magnification is independent of the position of the track in the chamber, so angles measured on the film give directly the projected angles of the track. The field lenses, 17 in. in diameter, were made of Lucite, cut planoconvex on a lathe with a radius of curvature of 37 in. giving a focal length of 75 in. Aberrations in their fabrication, and inherent spherical aberration, each corresponded to angular deviations of less than 1 mrad, or a position error of less than $\frac{1}{2}$ mm in real space. If the camera is operated with an $f/11$ aperture, the circle of confusion corresponding to the 14-in. depth of field in the chamber is also $\frac{1}{2}$ mm in real space. Enough light is generated by the spark so pictures of tracks taken with this f number were quite satisfactory, using either Isopan Record or Tri-X Pan film. On these rather fast films, one can still easily resolve lines 25 μ apart, corresponding to a real space separation of 1 mm with this optical system.

SPARK CHAMBER CHARACTERISTICS

Two (single view) photographs of cosmic-ray tracks taken with the spark chamber are shown in Figs. 3(a) and 3(b). The two central blanks are due to the aluminum support frames. Occasionally other gaps will not fire; the gap efficiency is about 95% for tracks normal to the plates, under the standard conditions discussed above. Tracks at large angles to the normal have a somewhat smaller gap efficiency. The efficiency also drops as the number of tracks increases. Showers of 20–30 tracks through the chamber appeared to have a gap efficiency under 50%. The sparks are mostly 1–2 mm in width, although some of the dimmer ones are narrower than this. They tend to follow the track direction only out to 20° or so, after that the sparking usually inclines toward the normal to the plates.

Some events obtained using a parasite 1 Bev/c π^- beam at the Cosmotron are shown in Figs. 4(a) and 4(b). The two views on the left are the 90° stereo views which see the entire chamber. The two on the right, with 54° stereo angle, miss viewing the first few gaps and about half of the rear part of the chamber.

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[1] C. T. Coffin, R. L. Garwin, S. Penman, L. M. Lederman, and A. M. Sachs, Phys. Rev. **109**, 973 (1958).

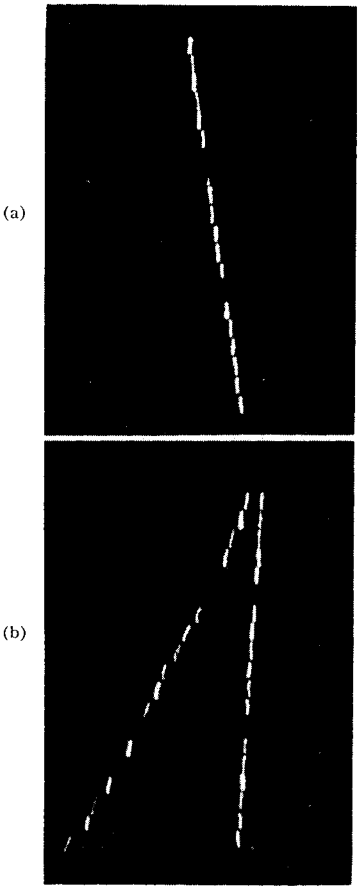

FIG. 3. (a,b) Cosmic-ray tracks, photographed with the arrangement of Fig. 2.

RESOLVING TIME

The gap efficiency of the spark chamber depends on the time delay of the high voltage pulse from the time of particle traversal, and on the magnitude of a dc clearing field applied between the plates. (The clearing field is usually applied opposite in direction to the high voltage pulse, to give it a faster rise.) A set of visual estimates of the gap efficiency, taken with different delays and clearing voltages, is given in Table I. The gap efficiency dependences given in the table for the large spark chamber are not quite the same as those obtained with a smaller test chamber with glass walls. The dependence of the efficiency on delay and clearing voltage probably is a function of gas contamination.

TABLE I. Gap efficiency of the spark chamber as a function of the delay of the high voltage pulse and the dc clearing voltage. The chamber is filled with neon at 1 atm pressure. The plate spacing is $\frac{3}{8}$ in.

Delay of high voltage pulse (from particle traversal) μsec	dc clearing voltage 0	100	200	300	400
	Gap efficiency, %				
0.3	95	95	95	95	95
0.45	95	90	40	25	25
0.60	85	50	0	0	0
0.70	85	0	0	0	0

The rapid decrease of chamber gap efficiency with delay with 100 v or so of clearing voltage permits pictures to be taken of desired single events while the chamber is in a background beam of moderately high intensity. For example, the above table would indicate that with a 100-v dc bias single event pictures could be taken in a beam flux of 10^6/sec; i.e., the chamber has a resolving time of less than a microsecond. This resolving time was consistent with results obtained in the test run at the Cosmotron: with a beam of 400–500 particles through the chamber in less than a millisecond, a large fraction of the chamber firings showed just one or two tracks.

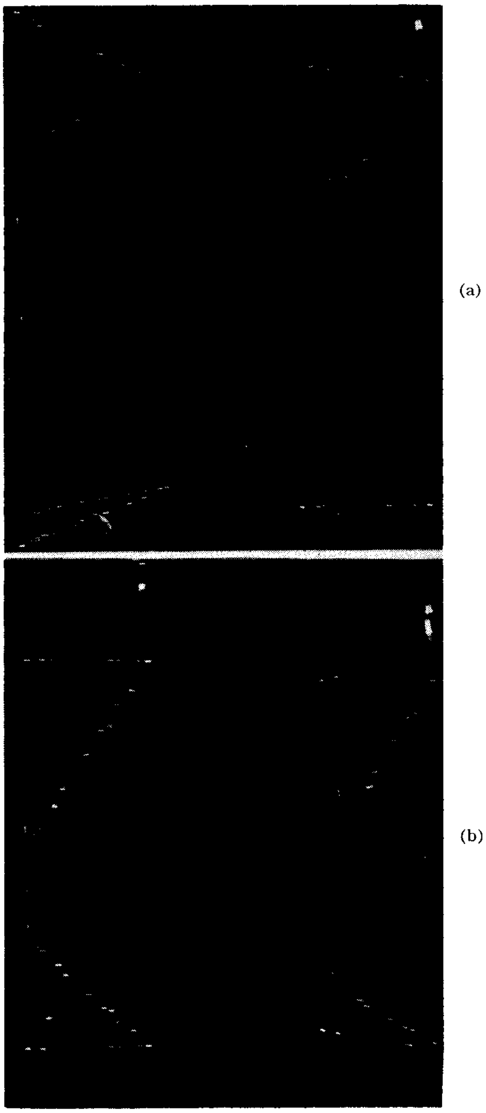

FIG. 4. (a,b) Four views of events obtained in the spark chamber using a 1 Bev/c π^- beam at the Cosmotron. The views on the left of the pictures are taken at 90° angles to each other; those on the right at 54°. The 54° views do not see the entire chamber and are slightly tilted; they are used to resolve possible ambiguities.

EFFECTS OF GAS CONTAMINATION

To test the effect of oxygen on the efficiency of a test chamber, air was admitted in a measured amount. With $\frac{1}{2}$% of air added to the neon, the tracks were as good as with pure neon but the spark color was slightly changed from orange toward the blue of the air spark. With $1\frac{1}{2}$% air the sparking efficiency was still good but the color had changed to blue. With larger amounts of air, the sparking efficiency dropped while the sparking voltage increased.

A large test chamber with Lucite walls, which normally operated satisfactorily, was found to be poisoned (no sparks at all) after it had been heated (in a foil stretching test). Every material used in the chamber construction was examined for this poisoning property, by heating it in a vial connected to a small working test chamber. The materials included Lucite, unhardened epoxy, acetic acid, and Krylon. Of these only Lucite affected the chamber efficiency. The effect seems to depend strongly on the heating, because the large chamber, kept near room temperature, ran on one filling for over four weeks with no marked change in efficiency.

EFFECTS OF VARIATIONS IN GAP SPACING

Two small test chambers, one with gap spacing of $\frac{1}{2}$ in. and one with a spacing of $\frac{7}{16}$ in. were placed on top of one another and pulsed with the same high voltage pulse. Tracks appeared in the $\frac{7}{16}$-in. spacing chamber, never in the other, the closer spaced chamber apparently dumping the voltage before it had risen to the sparking point of the wider spaced chamber—even though the spacings differed by only 15%. When small decoupling resistors were placed in the leads to the two chambers, however, both sparked on the same track with essentially 100% efficiency. So gaps which are parallel but with spacing errors can have their efficiency improved by such decoupling. (Two adjacent gaps, with a common high voltage plate, are obviously not balanced by this procedure. Thus if all the gap spacings were different, decoupling would raise the efficiency to a maximum of 50%.) Usually more serious than variations from gap to gap are the variations within a gap, due to the bowing of thin plates. A barely perceptible bowing, with a $\frac{3}{8}$-in. gap chamber, dropped the efficiency down to near 50% even with decoupling. Stretching the plates flat in this same chamber brought the efficiency up to nearly 100%.

ACKNOWLEDGMENTS

We wish to acknowledge the work of T. C. Coffin, who was responsible for the development of the counters and coincidence circuitry for operation with the 14-in. chamber. We also want to thank L. J. Curtis for his help in construction of the chambers.