SECONDARY DISCHARGE SPARK CHAMBER OPERATION

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ABSTRACT

The double discharge or 3-electrode spark chamber represents an effort to combine the advantages of fine and weak (primary) sparks with the requirements of a simple and efficient computer system.

The basic principle is that the spark occurring in the wake of an ionizing particle is changed into a different type of discharge, the secondary discharge, which is adjusted without losing its spatial position and without dissipation of excessive energy to the requirements of the electronic retrieval system.

It is shown that it is possible to record x and y coordinates from a single spark without excessive pulsing of the detector array in a wire chamber and as a further development one can hold the secondary discharge long enough to act as the sole memory element in the system. This leads to the possibility of retrieving correlated coordinates from multiple events with minimum computer time.

1. INTRODUCTION

As a spark breaks down in the wake of an ionizing particle and right after its decay a conductive channel exists in its place and can lead to the secondary discharge if a proper source of current is available. Henning[1)] used such secondary discharges to single out and intensify for photography those sparks which were accompanied by coincident ones; another example of secondary discharge is the accidental involvement of the clearing field source as current supply subsequent to the occurrence of a spark. In the early years of spark chamber operation this used to occur until the destructive properties of the resulting arc discharges prompted precautions to eliminate the chance of their occurrence.

We found it worthwhile to learn to time and regulate secondary discharges for several reasons, some of these shall be described hereafter.

i) It is possible to extend the memory time of a spark chamber with respect to its total information content or any part thereof without time limitation or loss in spatial resolution, if a certain mode of discharge takes over the plasma-column of every primary spark. Fortunately the power dissipated in this discharge can be much lower than the primary spark and threshold of the detectors*) should be set so that they do not respond to the current of either the primary or secondary discharge. By subdividing one or both planes of each spark chamber deck into wires or other discrete conductors of sufficient resolution, it is now possible to make access to any one of the above described discharge sites or memory elements one by one and intensify the discharge to the level of response of the detectors. Thus the sparks corresponding to multiple events which occurred simultaneously can be read out sequentially, without ambiguity, by any one of the digital or analogue retrieval systems reported on this conference.

ii) In a wire chamber built for digital information retrieval[2] the detection of a secondary discharge of sufficient intensity allows the retrieval of x and y coordinates from a single spark chamber deck if the wire planes corresponding to the pulsed and the ground electrodes are crossed. This means simplification of equipment and computer programme as both wire planes are used as detectors and the same spark yields both coordinate's information--this is one feature the wire chamber did not share previously with other systems.

iii) The effort to minimize the energy and the diameter of the plasma-column in order to achieve best spatial resolution and shortest dead time would cease as one reaches the energy stored in the wire plane capacity[3] or that corresponding to the threshold of the detectors. Certain modes of secondary discharge in combination with isolated charge storage on every wire enable us to decrease the primary spark energy below the above limits. While our secondary discharge spark chamber is in an early developmental stage, a few experiments were performed which lead to encouraging results and these as well as some speculations are described in the following paragraphs.**)

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*) In a standard wire-and-core chamber, the cores are the detectors.

**) The contribution of Drs. Charpak, Schneider and others of this meeting and Professor Heinz Raether, Hamburg, are gratefully acknowledged.

2. TRIODE AND MULTI-ELECTRODE SPARK CHAMBER

In our preliminary experiments the spark chamber consisted of three wire planes, two of which were separated by a distance of 6 mm and the third was at 1 mm from the ground plane.

The electrical connections were somewhat analogous to a triggered spark gap inasmuch as a conventional pulser circuit caused a discharge in the 6 mm gap if a cosmic ray passed through it and this triggered a secondary discharge in the 1 mm gap which was connected to a constant d-c voltage (just below its static breakdown potential). A similar chamber shown in Figs. 1-3 has more than 3 wire planes to yield x and y information from the same spark.

Figure 3 shows the current waveform of a secondary spark. We discontinued this experiment because similar results are avilable from a spark chamber with only two crossed wire planes with somewhat more sophisticated circuitry. Also, the delay of secondary breakdown can be minimized if the shadowing effect of the grounded wire plane is eliminated.

We also built a chamber where the secondary gap was formed by a system of interwoven and insulated wires where the shadowing effect could be eliminated.*)

3. DISTRIBUTED CHARGE STORAGE

Before describing our next experimental model the principle of distributed charge storage should be emphasized. We no longer intend to dump the full charge stored in a spark chamber into the spark - only the charge stored on one single wire. One of the ways to do this is by coupling each wire through a separate capacitor to the primary pulser. This really does not involve a major increase of components as a multiple condenser can be produced by clamping a metal foil over the cable leading away from the spark chamber with proper insulation and cushioning.*)

It is quite possible that this capacitive coupling of the pulse to every wire would find acceptance in other spark chamber systems described on this meeting in conjunction with the details described in the paragraph on the secondary discharge memory chamber.

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*) This geometry could be useful in the glass covered electrode chamber described by Drs. Fukui and Miyamoto.

**) Dr. Krienen (CERN) and Dr. Miller (Harvard) achieved somewhat similar results by using series resistors or inductors on each wire. Dr. Fukui and Miyamoto were the first to show, in their glass covered electrode spark chamber the advantage of independence of multiple spark circuits.

4. WIRE CHAMBER WITH TWO DETECTOR PLANES

Figures 4 and 5 show this chamber which was originally constructed for an experiment in a magnetic field. The long cables leading all spark chamber wires to detector and memory boards several metres away were utilized to act as bleeders and the primary pulse is lead through a coaxial cable to the "clamp-on" condenser described in the previous paragraph.

Basically this is a conventional wire chamber with crossed wire planes but here two discharge circuits are combined which overlap essentially in the path of the spark or sparks and differ (from the conventional chamber circuit) in the role of the bleeder and the fact that a secondary pulser is added.

Usually (a part of) the pulser current has an option to traverse the space through the spark or go down the bleeder if no spark occurred (for lack of efficiency or any other reason). This is valid for the primary current of our system too, but the secondary current always traverses both the spark site or sites and the corresponding "bleeder" leads.

(On figure 4 the primary current flows through Cx - Pt.x,y-Cy and the secondary current through Mx - Point x,y - My.) Every spark chamber wire has its own dumping condenser, bleeder wire (in the cable) and on the "ground" end a detector and memory element: a ferrite core.

At this point I wish to thank Thomas Nunamaker of this University who suggested building the pulser circuit symmetrically in push-pull, so that the spark chamber planes are pulsed in opposite polarity and swing around the memory boards which are on ground potential except for the secondary voltage.

The advantage of this system is that one spark can be utilized to yield both x and y coordinates, a property which only optical (and our previously described magnetic tape) systems had so far. Thus the number of required discharge planes can be decreased and the computer programme somewhat simplified.

5. DISCHARGE MEMORY CHAMBER

Some very preliminary experiments were performed along the lines of the first paragraph of the introduction and we found that the primary discharge can be turned into a very weak discharge which can be held for time periods of 20 μsec and longer without damaging the wires or spreading to their neighbours. Sometimes these secondary discharges took the form of an incipient corona discharge and were visible only as minute spheres on the two wires involved in the discharge and at times they were invisible to the dark-adapted eye.

We are now working on the circuitry required to stabilize with 100% efficiency this discharge form and plan to produce a third intensifying discharge (as Henning did) in order to "readout" the content of such a spark chamber. Two methods of readout are considered: (1) the conventional clocked scanning into x wires while the y wires feed the significant information bits into the computer memory or an equivalent register and (2) an internal discharge controlled wire chamber where both x and y addresses are simultaneously sent out.

References

1. P.G. Henning, Atomkernenergie, 2, 83 (1957)

2. J. Bounin, R.H. Miller, M.J. Neumann and H. Sherrard, "An integrated wire-chamber computer system", presented at this meeting.

3. J. Fischer and G.T. Zorn, Rev. Sci. Instrum. 32, 499 (1961).

Figure captions

Fig. 1 Schematic diagram of multi-electrode spark chamber.

Fig. 2 Arrangement of the wire planes in the multi-electrode spark chamber.

Fig. 3 Typical secondary discharge waveforms.

Fig. 4 Schematic diagram of a wire chamber with two detector planes.

Fig. 5 Arrangement of the wire planes in the two-electrode spark chamber.

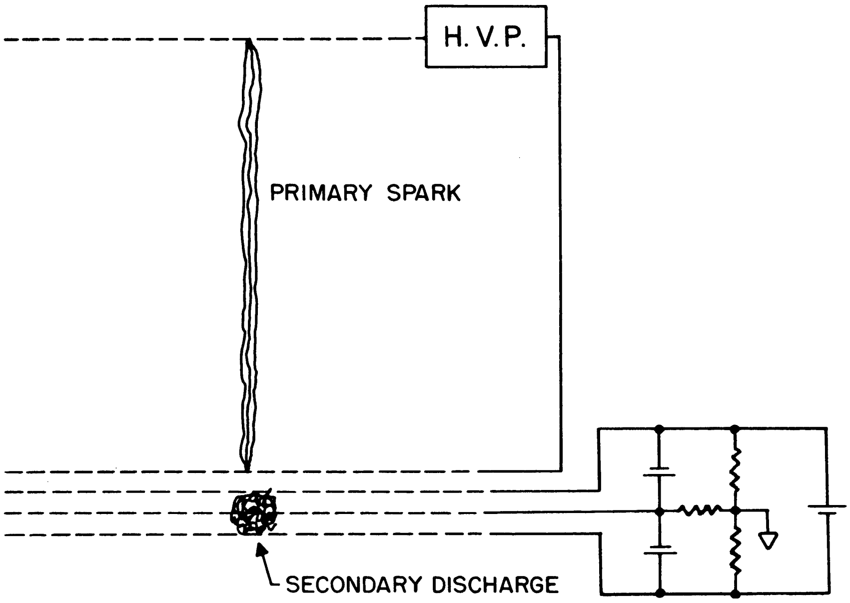

H. V. P.
PRIMARY SPARK
SECONDARY DISCHARGE

Fig. 1

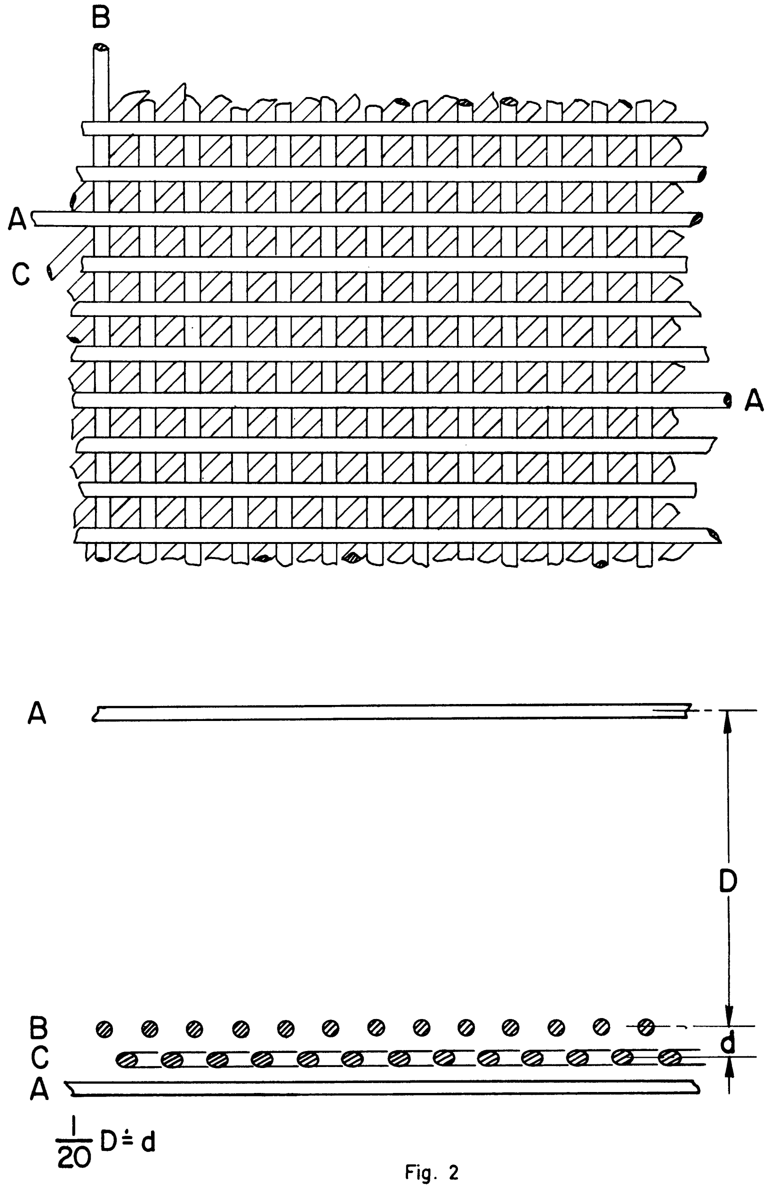

B
A
C
A
A
D
B
C
A
d
$\frac{1}{20}D \doteq d$

Fig. 2

a)

b)

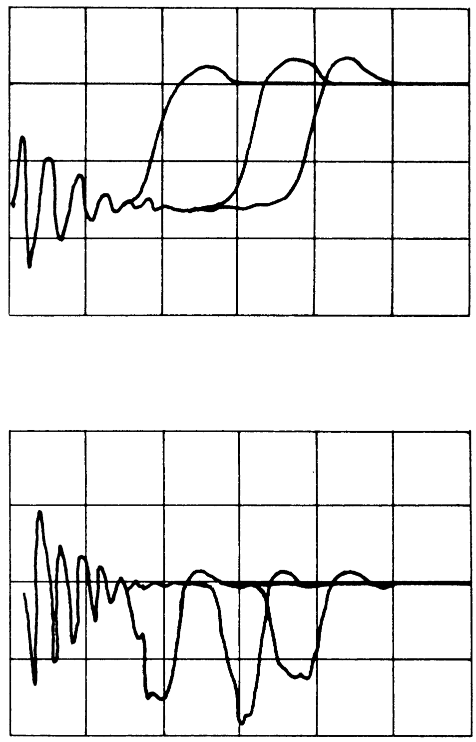


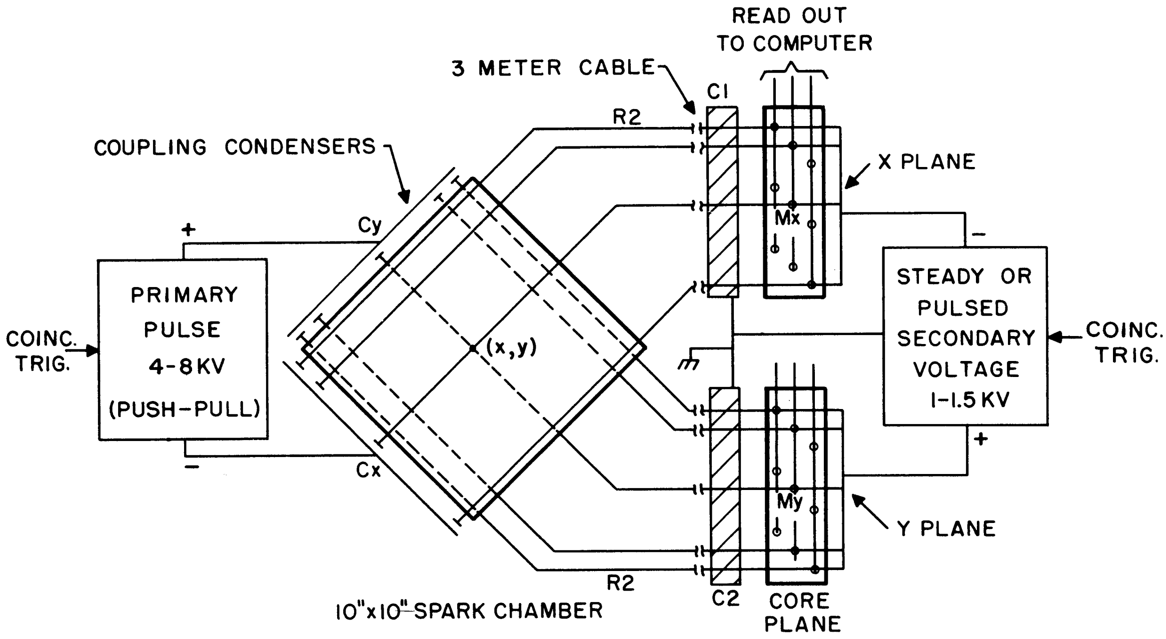
Fig. 3

TYPICAL SECONDARY DISCHARGE WAVEFORMS:

(a) SECONDARY VOLTAGE - NEGATIVE POLE
500 v/div., 1 usec/div.

(b) SECONDARY CURRENT - NEGATIVE POLE
10 amp/div., 1 usec/div.

PRIMARY VOLTAGE - 7KV
SECONDARY VOLTAGE - 1250V



Cx,Cy — CLAMPED-ON CONDENSER: APPROX. 1pf PER WIRE
C1,C2 — " " " " 6pf " "
R2 — LEAD WIRE RESISTANCE: APPROX. 10 Ω PER WIRE

Fig. 4

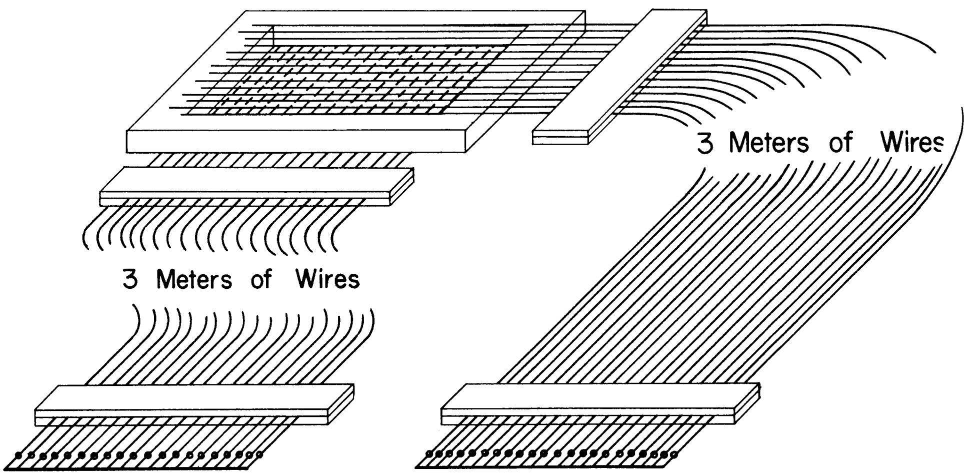


Fig. 5

DISCUSSION

KRIENEN: What gas mixture did you use ?

NEUMANN: Neon with 10% helium, and not more than a trace of alcohol.

SALVINI: In which sense do you think you have high multiplicity ?

NEUMANN: Anybody can have multiple tracks if he understands that X1 X2 X3 and Y1 Y2 Y3 correlate according to the one, two and three. Usually it is a computer or the scanner who has to decide this, you almost always have only two orthogonal projections, not three. So there is a basic ambiguity in this two-dimensional type of reproduction. However, if you take this spark as a circuit element and push a current through it, then you decide unambiguously where that spark was. Say you try to observe a shower and you have 15 various parts in it, then you can locate this much quicker than if you have to put back the sophisticated computer programme on top of it.

SALVINI: But your development is quite independent of the fact that it may be difficult to have 15 sparks corresponding to 15 particles, I mean the physical problem of having more than one track.

NEUMANN: It is independent. I am trying to do this work because I think that we were spoiled. The first spark chambers were also light intensifiers and we pushed a lot of energy into a spark, and I think that with the electronics that we have you can really get much weaker sparks. If you consider a physical instrument like this the noise ratio is a first requirement, then I think we should go down and be modest with our current so we have to amplify the current some place to get our detectors going. I think the first place to amplify is ionic amplification inside the spark chamber, that way I think that we can take a little bit of the burden and complications of further circuitry and computer programme upon ourselves. Let me put it this way. Everybody felt sorry for the first spark chamber. The poor thing has so much information that the computer has to help to get it out fast. We have come to the time when we can be sorry for the computer and try to tell the spark chamber to help a little bit. We can do better spark chambers with less money, rather than build more complicated electronic equipment.