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Technical Report No. 20

THE USE OF IMAGE INTENSIFIERS WITH STREAMER CHAMBERS

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ORA Project 03106

under contract with:

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
CONTRACT NO. Nonr-1224(23)
WASHINGTON, D. C.

administered through:

OFFICE OF RESEARCH ADMINISTRATION ANN ARBOR

September 1965

This report is also a paper to be presented at the Third Symposium on Photoelectronic Image Devices, Imperial College, London, September 1965.

The Use Of Image Intensifiers With Streamer Chambers

Spark chambers with their characteristic good spatial and time resolutions, have recently enjoyed great popularity as research tools in high-energy physics. Their extensive developments in recent years have employed a large family of novel techniques including digitized wire chambers and sonic chambers.(1) However, a spark chamber is in general anisotropic. Sparks in a conventional parallel-plate chamber, for instance, will not follow the true trajectory of an ionizing particle at angles much greater than 30° with respect to the electric field.

A streamer chamber, on the other hand, possesses several unique features. It usually consists of a volume of neon and/or helium gas near one atmosphere pressure confined between two parallel electrodes. Upon the arrival of a high voltage pulse, following passage of a particle, free electrons produced by ionization along the trajectory of a charged particle will develop into streamers which grow towards the electrodes at a rate of about 10^8 cm. per second.(2) If the voltage is abruptly cut off before the streamers have established a spark channel between the plates, then these "frozen" streamers will give rise to a three dimensional visual representation of the trajectory of the particle. When these streamers are limited to one or two millimeters length, so that their dimensions parallel to and perpendicular to the electric field are comparable in size, the chamber displays the paths of the charged particles faithfully in three dimensions. Furthermore, since each track is virtually electrically decoupled from any adjacent tracks present and reduces the chamber voltage a negligible amount, the chamber is expected to posses extremely high multiple track efficiency, and should be a potentially valuable tool for studying interactions <u>within</u> its active volume.

Fairly extensive and promising investigations on the streamer chamber and its associated elaborate ultra-high voltage pulsing techniques have been conducted both in the Soviet Union (2,3,4) and at CERN.(5,6) However, the intrinsic low light output of the streamer mechanism limits the usefullness of the chamber as a practical research tool in this form. For instance, streamers of two or three millimeters are visible to the dark adapted eye but may require a f/1.5 lens and ASA 10,000 film to record them photographically, and the resultant limited depth of field seriously reduces the use of the chamber in nuclear physics research. At the University of Michigan, we have constructed a very simple Marx generator and a streamer chamber with an active volume of 9" X 6" X $2\frac{1}{4}$". Streamers of any length down to less than one mm. may be obtained by adjusting the firing delay of a spark gap which shunts the chamber. With the aid of a three stage image intensifier, cosmic ray tracks have been successfully recorded on 35 mm. Kodak Tri-X film. Streamers of 5 mm. have been so recorded comfortably with a front lens opening of f/16 while the much fainter 1 mm. streamers require an opening of f/4.5 or less.

The arrangement of the apparatus is shown in Fig. 1. A coincidence pulse from the counters located above and below the chamber initiates the triggering functions of the avalanch transistor, the EFP60, and the 5D21 tube which delivers a 7 kv pulse to the trigger electrode of the first stage of the Marx generator. The 101 mm. Wollensak lens images onto the first cathode of the tube the direct view of the streamers normal to the electric field together with the end view, which is parallel to the field and is reflected to the lens by means of a mirror. A pair of 76 mm. f/0.87 Super Farron lenses couples the output of the image intensifier to the film with unity magnification, while the demagnification of the entire system is about 10:1.

The simple Marx generator consists of five 2500 pf. capacitors charged in parallel, each being linked to the adjacent ones by about 30,000 ohms of resistance. They are arranged in such a way that when the first gap is triggered they will discharge in series, generating a pulse of nearly five times their initial d.c. voltage. The discharge mechanism can be obviously seen in Fig. 2. Although the generator is operated in a non-pressurized atmosphere, efforts have been made to minimize the stray inductance of the circuit. The flexibility of the generator lies in the fact that gap spacings between stages may be varied through an operating range of 5 to 25 kv. per stage. In order to avoid excessive delay all gaps are adjusted on the verge of breakdown for a specifically desired voltage. However, we have used 20 kv per stage which produces a field gradient about 17 kv per cm. in the chamber volume for the operation described below.

As shown in Fig. 3, the high voltage electrode of the chamber is a 12" X 9" X 1/8" aluminum plate. A plexiglass frame is cemented between the electrode and a glass plate for gas confinement. A gauze-like aluminum window screen backed by an aluminum frame is placed behind the glass to serve as the ground electrode. This arrangement provides a uniform field in the active volume and permits the two normal views of the streamers to be seen and photographed. Glass with a transparent conductive coating such as stannous chloride has been tried as the ground electrode, but the surface resistance leads to non-uniform fields and severe burning of the coating, in addition to poorer light transmission. When the gap between the last stage of the Marx generator and the 3/8" copper rod breaks down, a 100 kv pulse with a rise-time of about 10 nanoseconds is delivered to the chamber. The voltage is then abruptly cut off when a short circuiting spark is formed in the shunting spark gap. The duration of the pulse and hence the length of the streamers can be conveniently selected by varying the shunting gap spacing which has a typical value of 3/4". To minimize statistical fluctuations the shunting gap is triggered by a pulse from the first stage of the Marx generator. It has been observed that any slight imperfection on the plexiglass frame of the chamber tends to initiate arcing along the surface and careful polishing is needed to prevent such extraneous background. A 25 ohm resistance is inserted between the high voltage electrodes of the shunting gap and the chamber to insure a more effective voltage cut-off should there occur competitive conduction paths, such as breakdown along the insulator.

The image intensifier tube we have used is an electrostatically focused RCA C73491 three-stage tube with a one inch S-20 cathode and a one inch P11 phospher anode. The off-axis resolution and pincushion distortion are apparent in the photographs. During the course of our investigation the image tube has been operating with 50 kv total accelerating voltage, about 12 kv on the first stage and 19 kv on each of the last two stages. This corresponds to a gain of about 30,000. At 50 kv, this tube shows an axial resolution of about 15 line pairs per mm. Operating the system under these conditions, a series of cosmic ray tracks have been photographed. The chamber has been filled with neon with 14.5 per cent helium at atmospheric pressure. When filled with pure helium, both streamer density and light output are inferior to the neon mixture. Figure 4 is an overexposed picture of a track with full-length streamers. It serves to illustrate the field of view covered by the image tube and the extent of distortion involved. The outlines of the front of the chamber and its side window as an image in the mirror have been sketched on the 35 mm. negetives of the subsequent photographs for orientation. The image tube has not been gated and the camera shutter always remains open. With the chamber firing at a rate of about 3 to 5 per minute, the film advancing mechanism has been controlled manually.

Typical interactions and scatterings in or near the chamber at various streamer length settings are illustrated in Figures 5 - 13. They correspond to streamers of approximately 1.5 mm. to 5.5 mm. in 0.5 mm. increments. An estimated 2 X 10^5 photons are liberated in a 1.5 mm. streamer while a 5.5 mm. streamer may release about 3 X 10^7 photons. Suitable f-stops from 4.5 to 16 have been used. It should be noted that in each picture unrelated tracks are superimposed to illustrate the consistancy of streamer length. In Fig. 14 a distribution of streamer lengths from digital measurements of a film sample represent the range of streamer fluctuation at a typical setting. The display of the two normal views of the tracks in each photograph indicate the depth of field achieved. The high multiple track effeciency of the streamer chamber is evidenced by showers produced in some of the pictures, such as Figures 7, 8, 12 and 13.

While streamers of 1 mm. or even less are just as readily attainable, it is doubtful that pressing for minumum streamer length at the expence of less light output is always advantageous. From the practicle point of view, the dark streak at the middle of a 4 mm. streamer track might be as accurate a track definition as the center of the shorter streamers.

It should be pointed out that although the streamer chamber approaches being a genuine isotropic track recording device, particles travelling at very small angles with respect to electric field still tend to be more luminous at any given streamer length. However, such variation is slight over a substantually large angular range. The observed streamer density of about 6 per cm. of track is lower than the 10 per cm. expected. Apparently the 200 nanosecond delay between the arrival of the high voltage pulse and the passage of the particle has allowed some of the ion pairs to recombine. But much of this delay should be reduced by a slight modification of the trigger mechanism of the Marx generator.

The prime limitation of the system is probably the resolution and the distortion intrinsic with the present image tube, however, newer tubes are available with far superior qualities. We may conclude that our brief investigation strongly suggests that a simple streamer chamber-image intensifier system may well be incorporated as a practicle research tool in particle physics.

Acknowledgement

The authors would like to thank Mr. Orman Haas for his helpful discussions and significant technical assistance.

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Figure Captions

Figure 1	Arrangement of apparatus with light-tight walls removed.
Figure 2	A schematic circuit diagram of the Marx generator.
Figure 3	Details of the streamer chamber and the Marx generator.
Figure 4	An overexposed picture of a full length streamer track showing the field of view covered by the image tube and the extent of distortion involved.
Figure 5	Normal views of 1.5 mm streamer tracks photographed with f/4.5.
Figure 6	Normal views of 2.0 mm streamer tracks photographed with f/4.5.
Figure 7	Normal views of 2.5 mm streamer tracks photographed with f/5.6.
Figure 8	Normal views of 3.0 mm streamer tracks photographed with f/5.6.
Figure 9	Normal views of 3.5 mm streamer tracks photographed with f/8.
Figure 10	Normal views of 4.0 mm streamer tracks photographed with f/11.
Figure 11	Normal views of 4.5 mm streamer tracks photographed with f/11.
Figure 12	Normal views of 5 mm streamer tracks photographed with f/16.
Figure 13	Normal views of 5.5 mm streamer tracks photographed with f/16.
Figure 14	Typical fluctuations of streamer length at a given

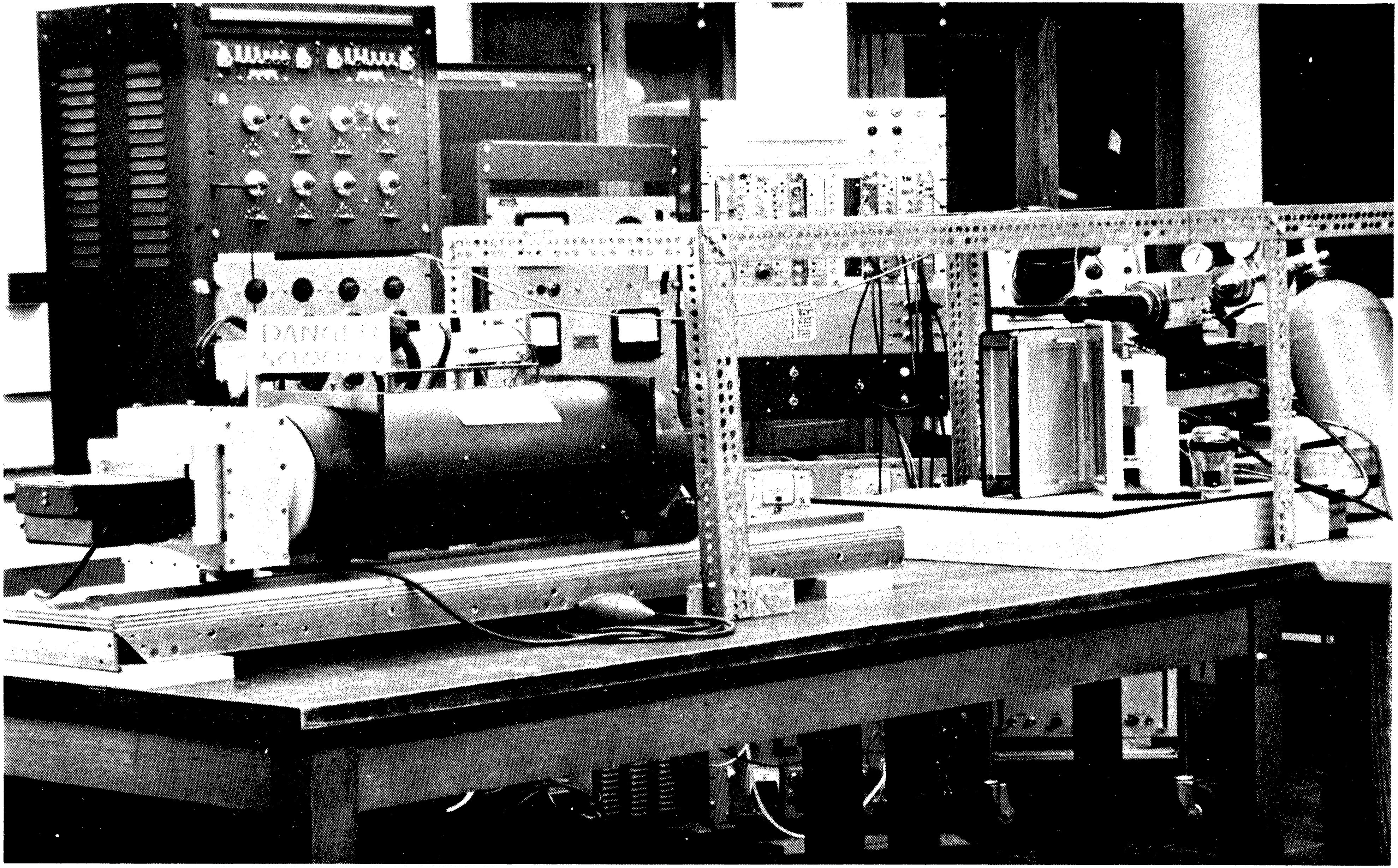


Fig. 1

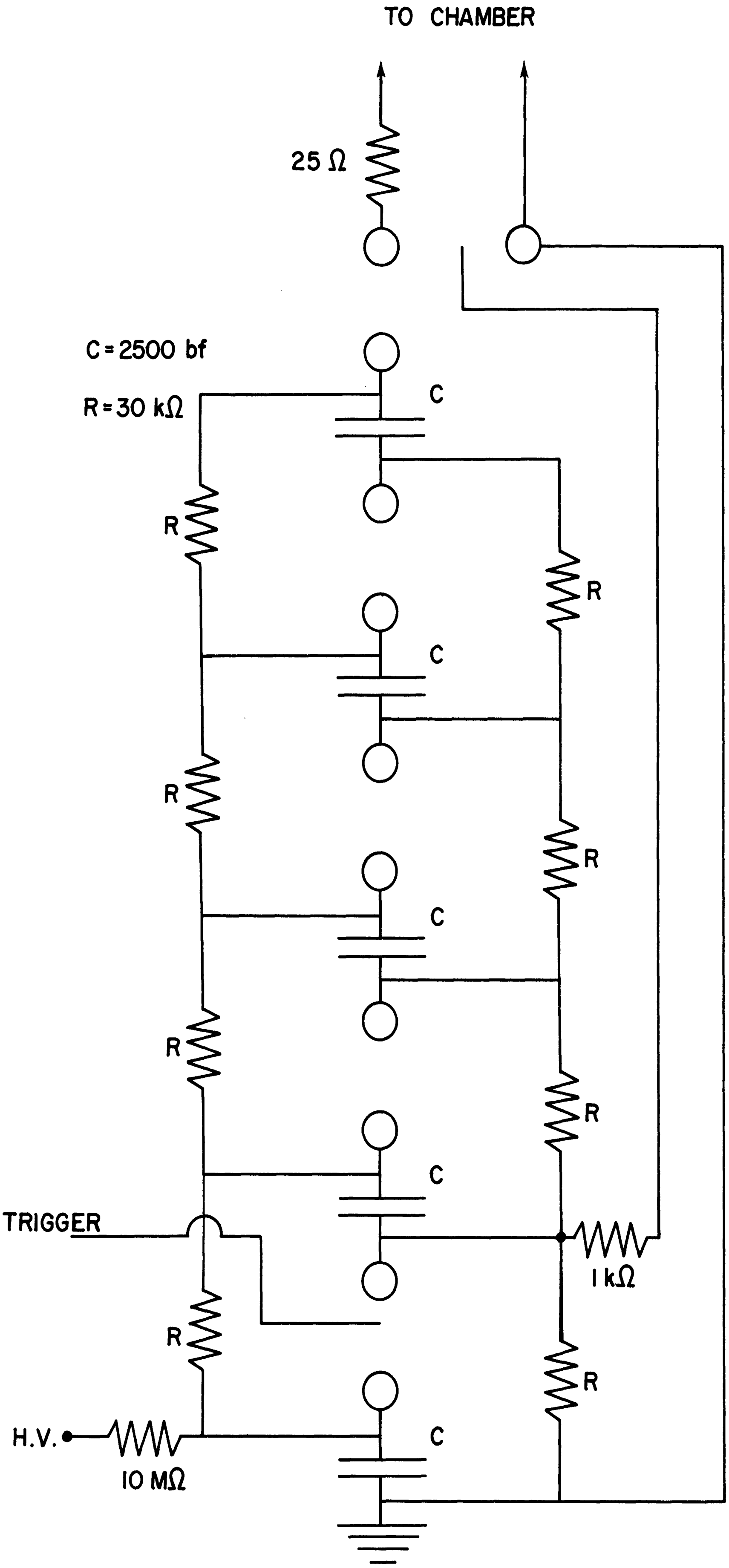


Fig. 2

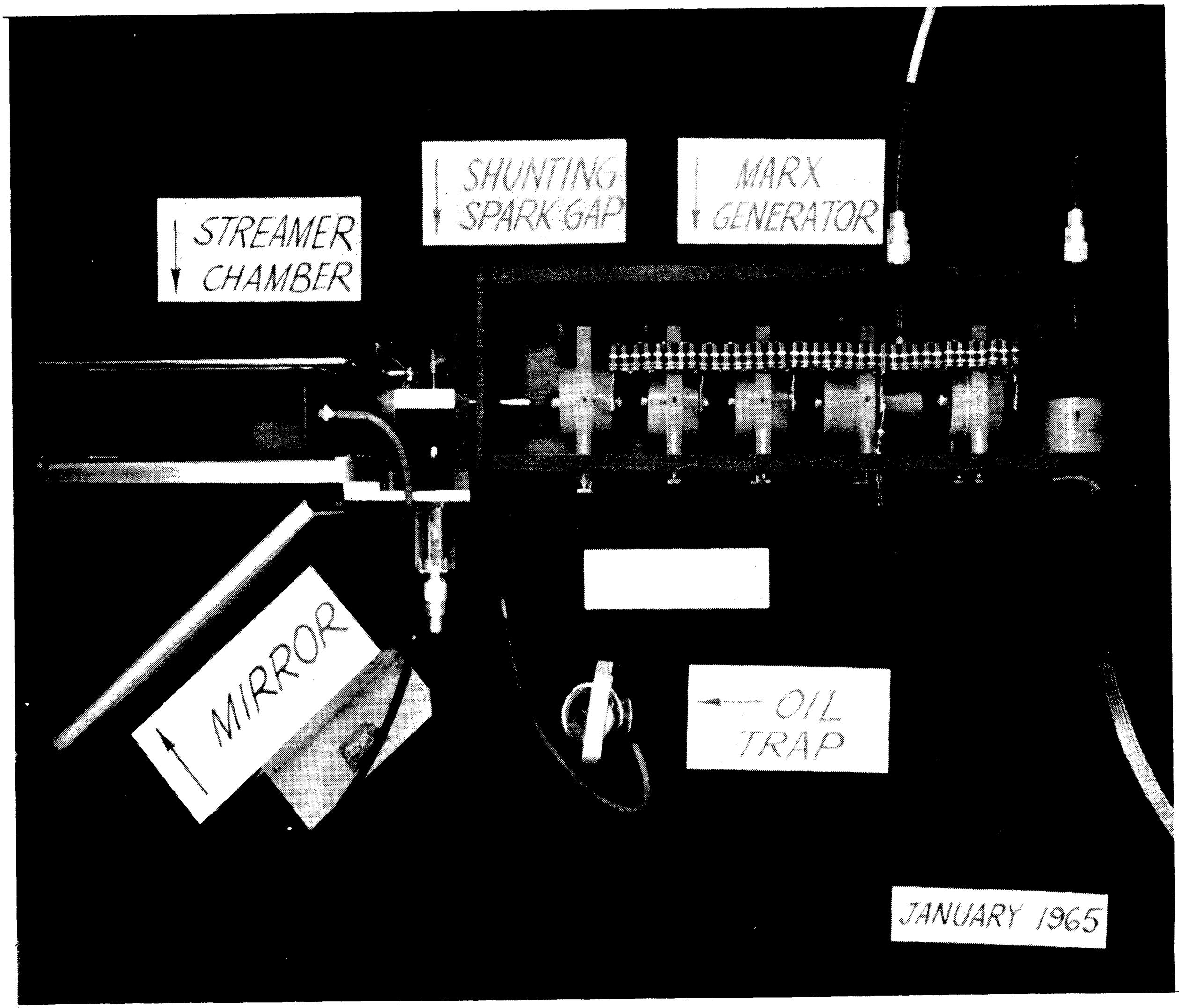

STREAMER CHAMBER
SHUNTING SPARK GAP
MARX GENERATOR
MIRROR
OIL TRAP
JANUARY 1965

Fig. 3

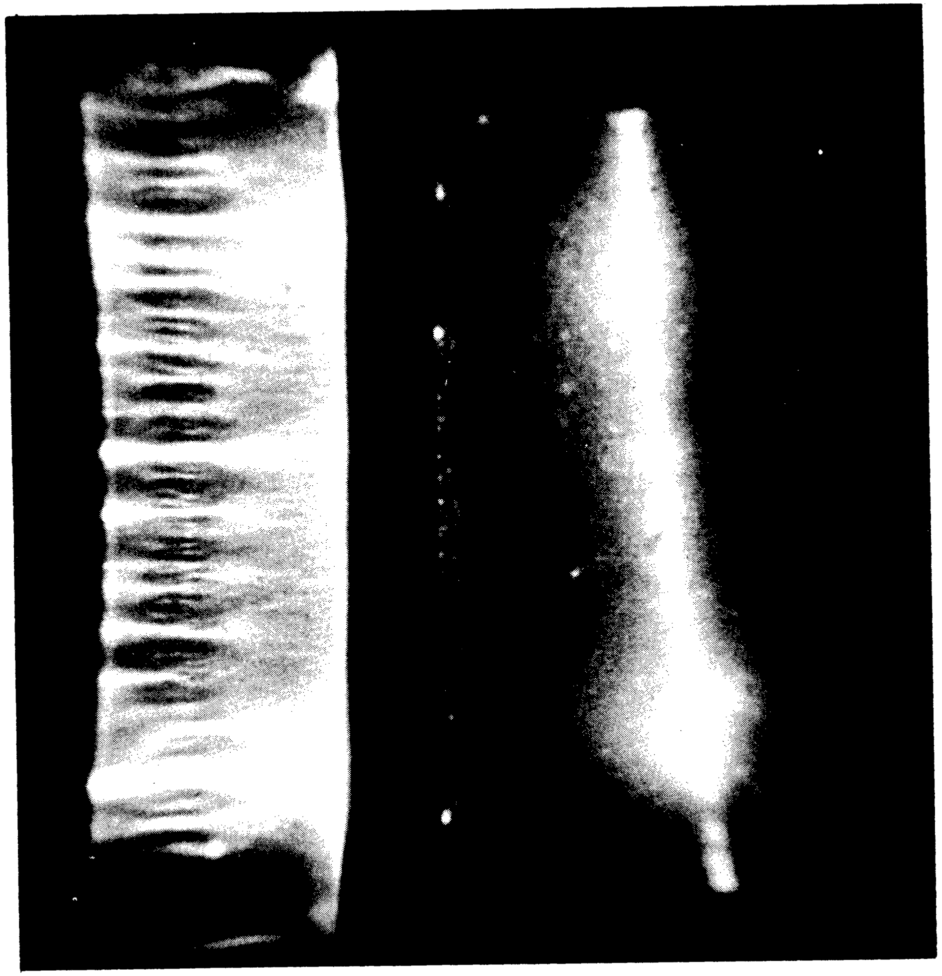


Fig. 4

Fig. 5

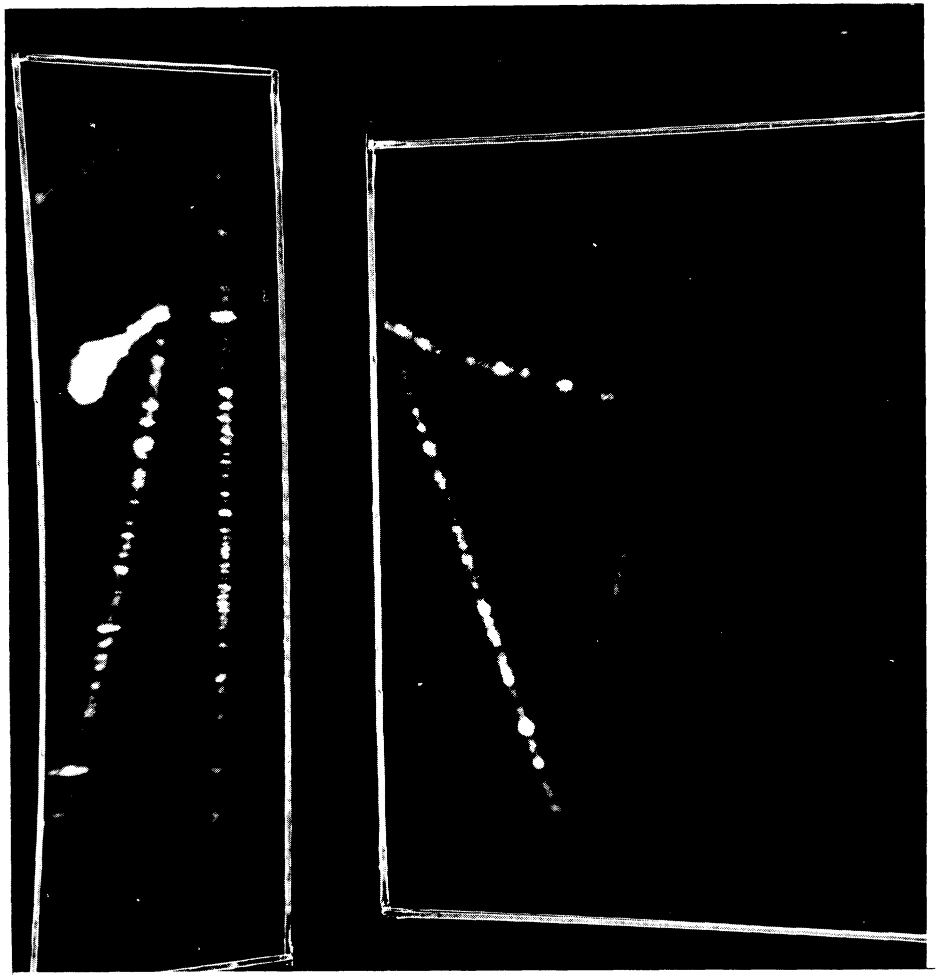


Fig. 6

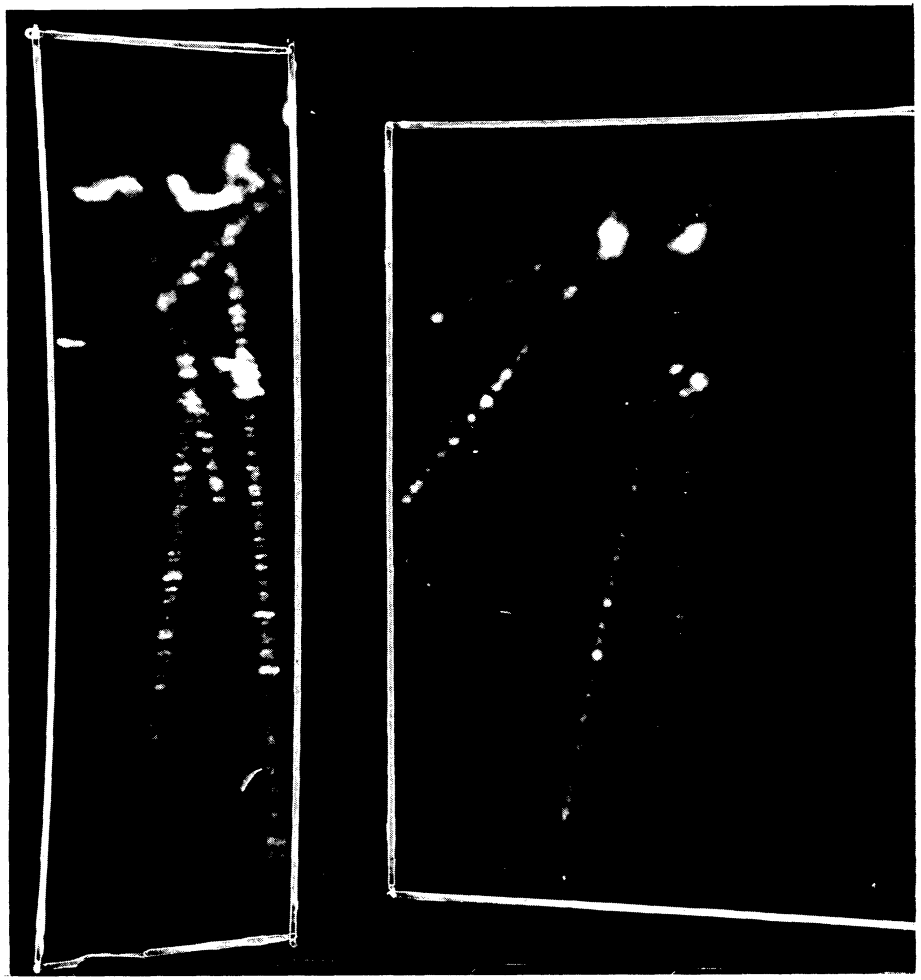


Fig. 7

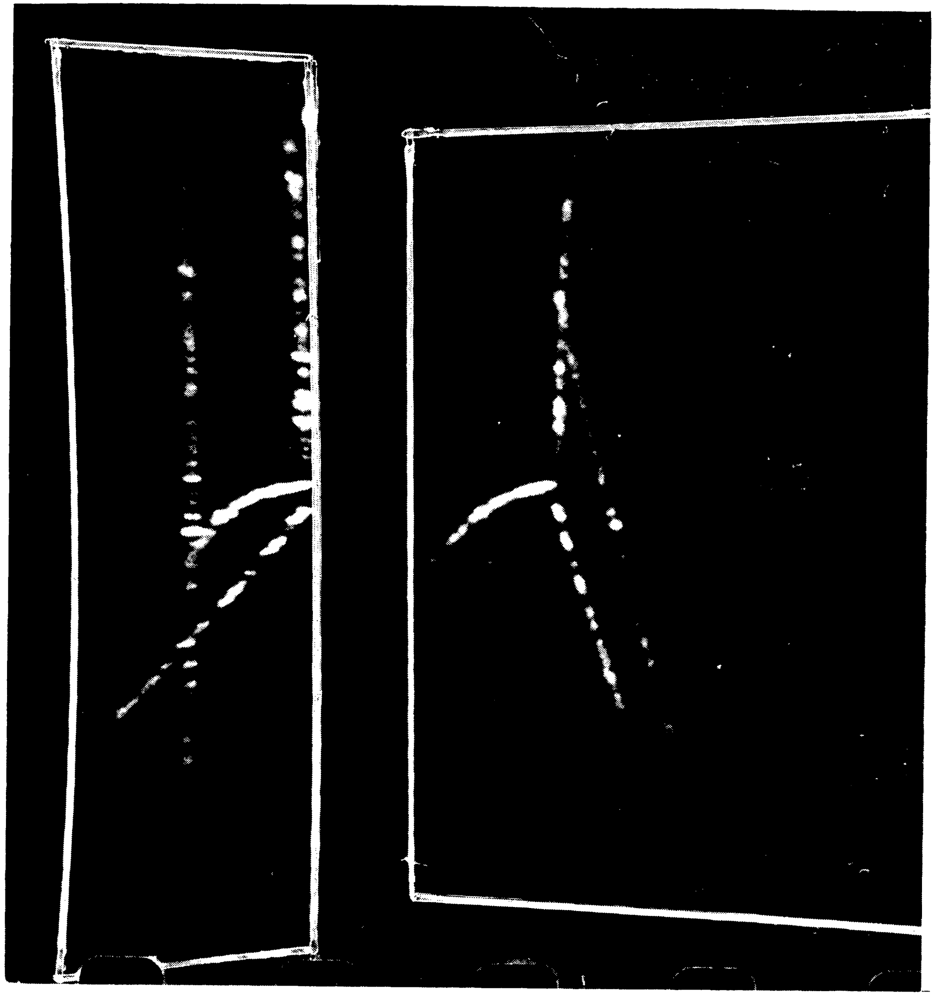


Fig. 8

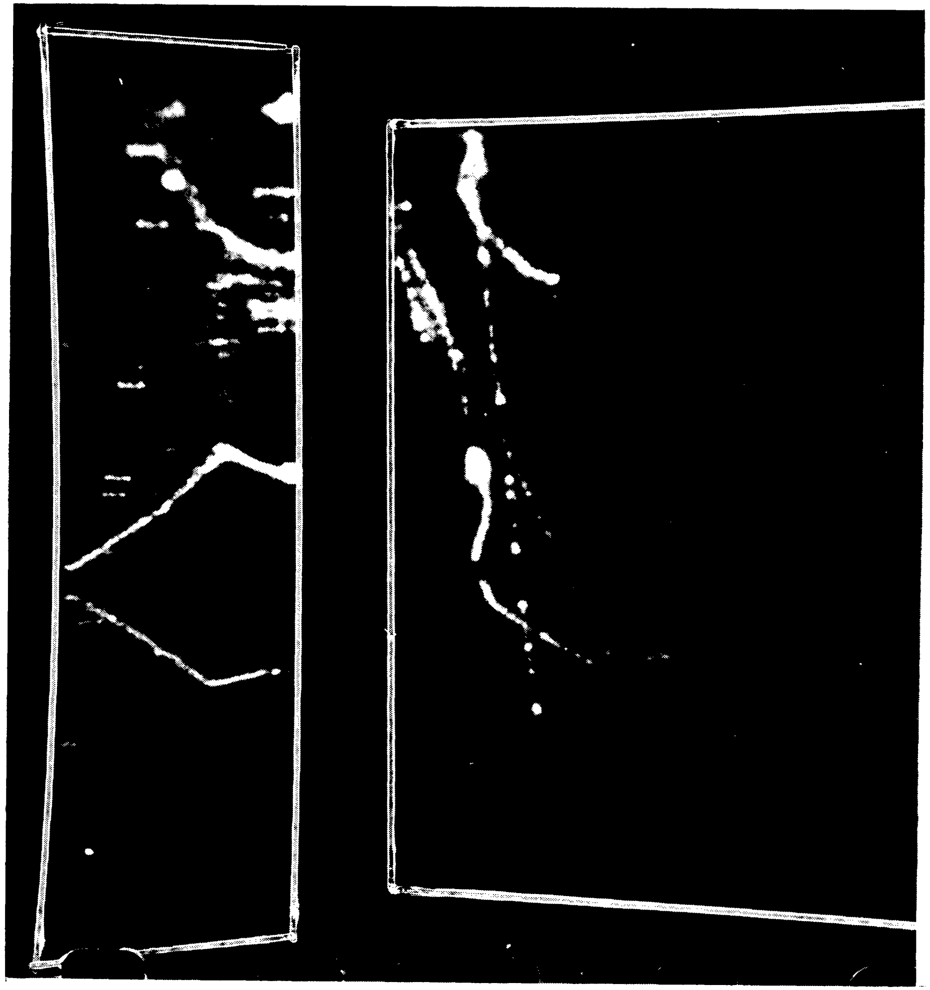


Fig. 9

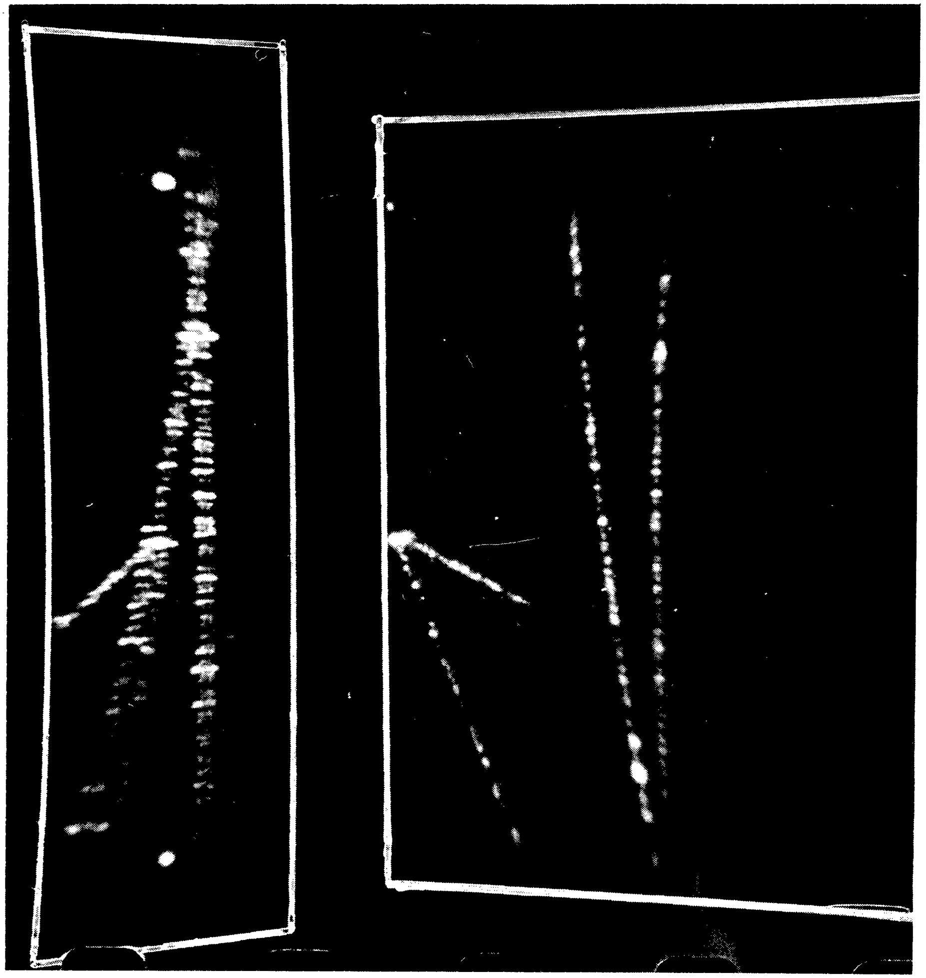


Fig. 10

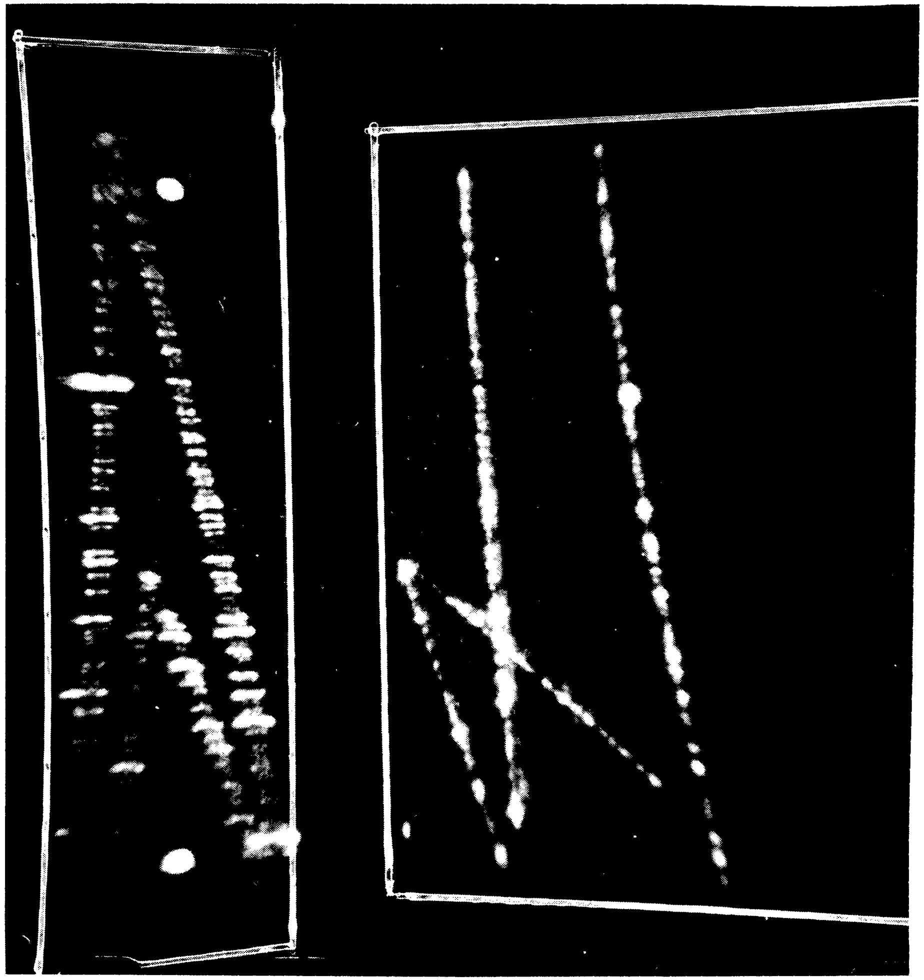


Fig. 11

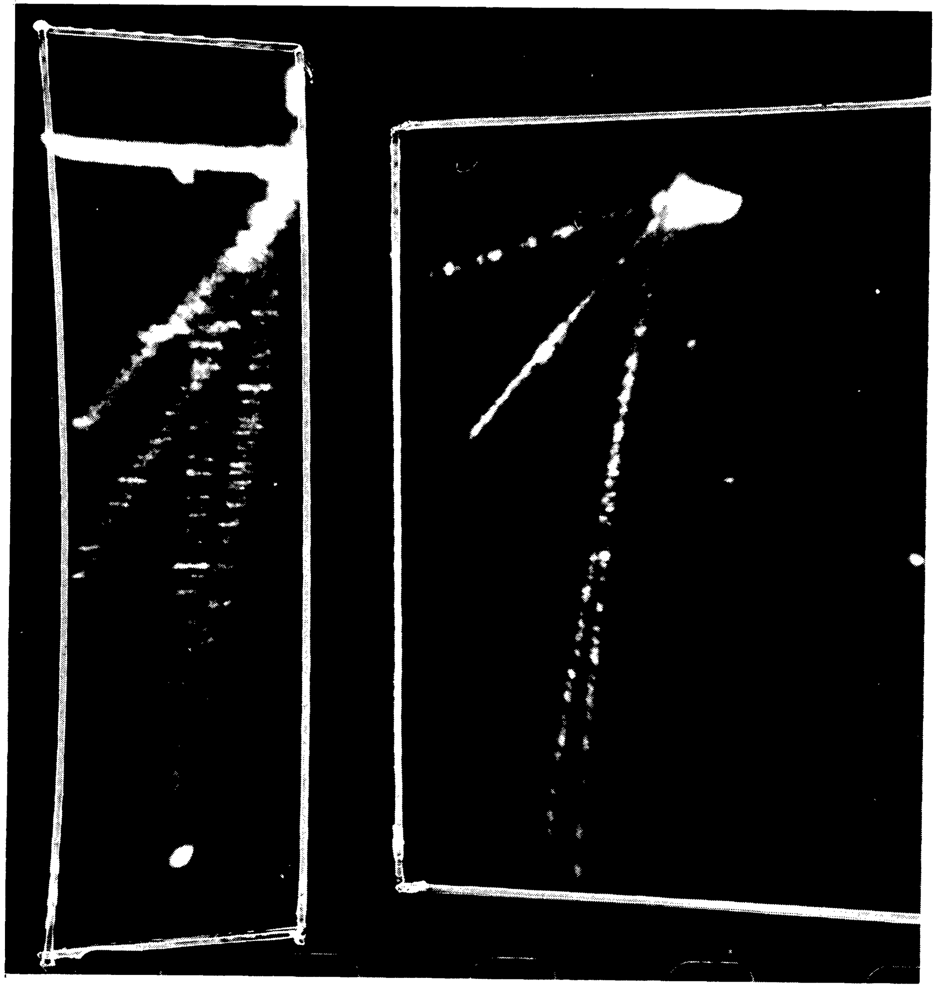


Fig. 12

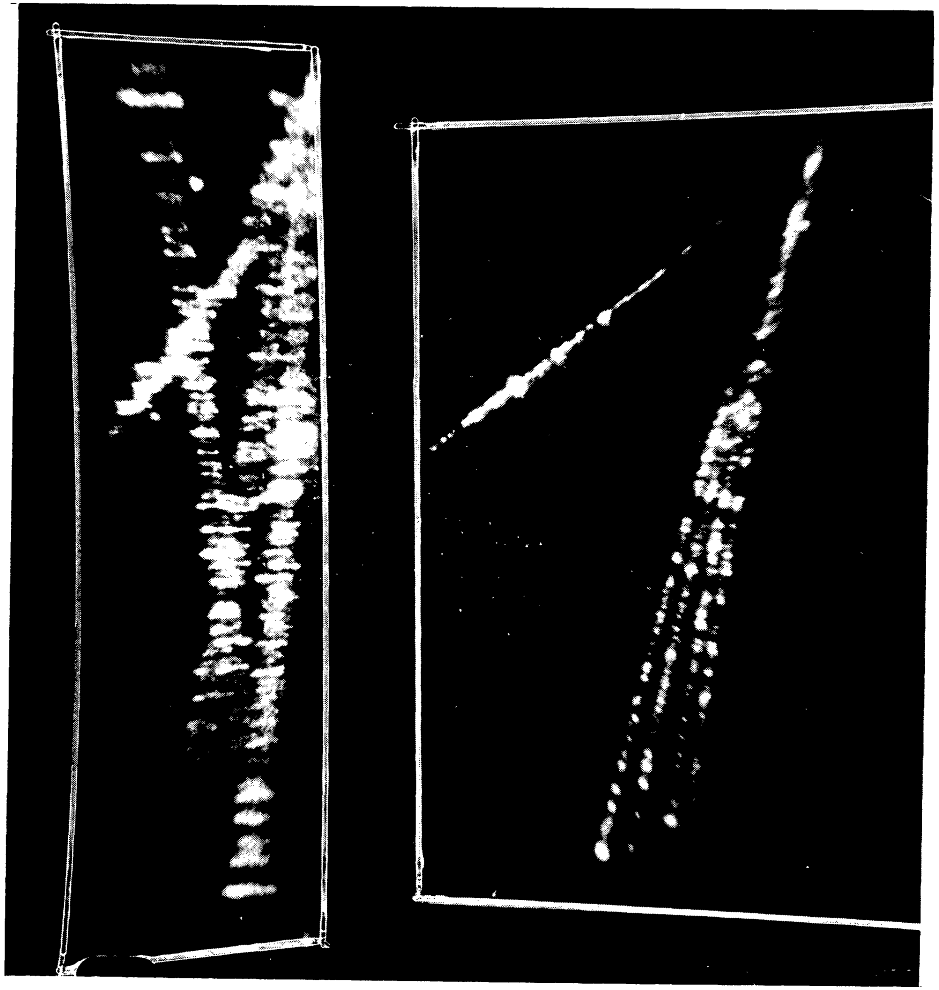
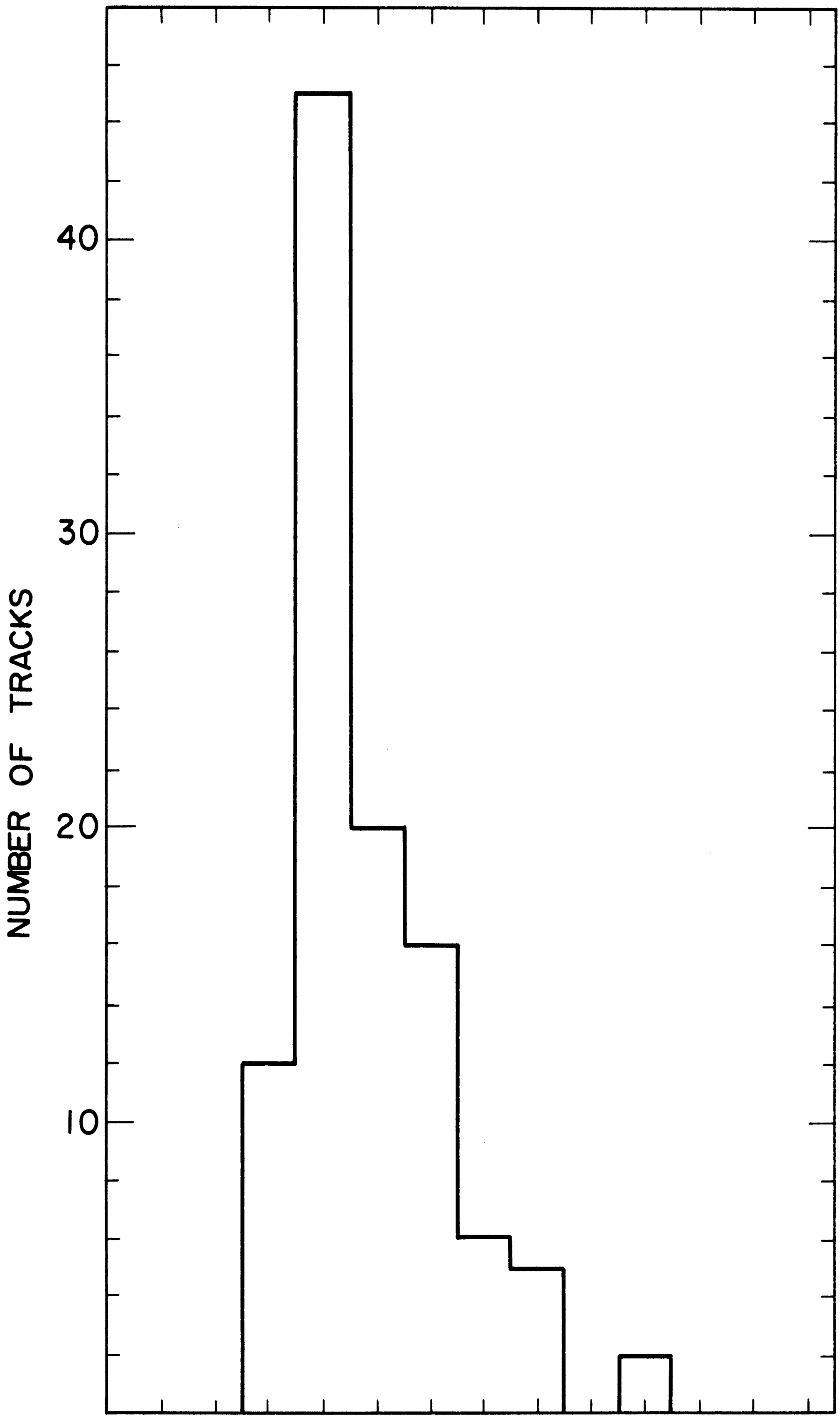


Fig. 13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.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
AVERAGE STREAMER LENGTH (mm.)

Fig. 14