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ELECTROMAGNETIC DELAY LINE READOUT FOR PROPORTIONAL WIRE CHAMBERS*

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ABSTRACT

We describe the use of electromagnetic delay lines to read out the position of ionizing events in multi-wire proportional chambers. The delay line used is a ceramic core (non-magnetic) type with a delay of 80 nanosec/cm. The readout accuracy achieved depends on the wire plane which is read out: for the positive plane which forms the electron avalanche, the accuracy is ± 1 mm. (half the wire spacing). For the negative plane, which records the induced signal produced on a number of adjacent wires by the positive ions, the interpolation property of the delay line permits an accuracy of ± 0.15 mm.

I. INTRODUCTION

Multi-wire proportional chambers are now coming into extensive use in nuclear and elementary particle physics. Their main advantage over wire spark chambers is the ability to record events at high rates whereas the spark chambers are limited by the recovery time of the chamber. The main difficulty with wire proportional chambers so far has been the readout--which in the simplest case is done by using an array of amplifiers and storage logic elements connected to the individual wires. In a previous paper[1)] we showed that a readout scheme using an electromagnetic delay line could be made which was considerably cheaper and simpler than the amplifier array method. The delay line that we used was a ferrite loaded delay line to which the individual wires of the chamber were coupled by coils: the positioning accuracy that we were able to achieve was approximately 3 mm. which was the same as the spacing of the wires. In this paper we discuss a similar readout scheme using a different type of electromagnetic delay line without any ferrite or magnetic material in it. This type of delay line has a number of advantages. The ratio of delay to rise time of a pulse and the delay per unit length are higher than in the ferrite line. Furthermore the dispersion of the signal per unit delay is smaller. The combination of these properties makes it possible to use a readout scheme which achieves a position accuracy better than ± 0.15 mm. and can be used in the presence of magnetic fields of any strength.

II. DELAY LINE CHARACTERISTICS

For this project we have been using a commercially available ceramic core delay line of a type that is well described in the literature.[2)] Fig. 1 shows the construction of the delay line.[3)] The center conductor consists of silver painted longitudinal strips on a ceramic core which is non-magnetic. The outer conductor consists of a copper winding as shown in the figure, made of insulated copper wire 0.09 mm. in diameter with 100 turns/cm. The line is wound in 3 mm. sections with each section overlapping the previous one by 1.5 mm (see Fig. 1 insert). All turns of the winding are in the same direction. This type of delay line has the following characteristics: Delay = 80 nanosec/cm., band pass = 3.6 Mc/sec, attenuation = 1.5 db/microsec delay.

The readout methods described below depend on the high coupling possible through external coils (current coupling) or through external conducting electronics (b) the polarity and wire spacing of the plane which is being read-out. The zero-cross electronics will locate the pulse with a jitter of less than 1 nanosec for pulse amplitudes at the output of the delay line above 400 micro-volt. This corresponds to an output of 10-20 millivolts from the chamber wire. This amplitude is attainable with an Argon-Isobutane (70% Ar: 30% Isobutane) gas mixture with the total number of electrons pairs in the avalanche equal to $\approx 5 \times 10^6$.

The accuracy of spatial distribution depends on the polarity of the plane which is being readout due to the asymmetry in the signals induced on the electron collecting wires or on those that receive the displacement current due to the positive ions. Since the signal produced on the delay line is a composite of the signals from a number of wires adjacent to the source of ionization, interpolation between wires is possible if the amplitude of these pulses falls off monotonically with distance. Fig. 5 shows the electric lines of force. An ionizing event will produce an avalanche on wires a or b depending on whether it occurs in the region AA or BB. The position of the avalanche along the wire has a displacement error which is due mainly to diffusion of the electron trajectory due to scattering collisions in the gas. The displacement current signal induced on the positive ion collecting planes centers on the point perpendicularly opposite to the center of the avalanche, since due to the shape of lines of force there is no 'quantizing' effect.

Our measurements confirm this effect, as shown in Fig. 6, in which we plot the position of the ionizing event measured by the delay line, as a function of the position of a collimated source of 5.9 KeV γ-rays from Fe^{55}. The width of the error bars is the full width at half maximum of the distribution observed from the output of the P.H.A. This is due to source width distribution, straps wrapped around the line (capacitative coupling). Both of these coupling schemes are possible due to the fact that the center conductor of the line is operated as the grounded conductor.

The efficiencies of these coupling methods are shown in Fig. 2.) Fig. (2a) shows the amplitude of the output signal for different rise times of current pulses and various numbers of turns in the coupling coils: Fig. 2b shows the corresponding curves for the capacitative coupling.

An important point to consider is the effect of the external coupling on the delay line characteristics, since we want to maintain an accuracy of timing of the pulses to within 1-1.5 nanoseconds. This loading effect is shown in Fig. 3 for both couplings; it is seen that the capacitative coupling introduces less dispersion and 'ringing' than the coil coupling. Since it is also considerably easier to construct mechanically and electrically, by wrapping plastic with conducting strips etched on it around the delay line, it is the method we prefer to use.

III. PROPORTIONAL CHAMBER MEASUREMENTS

Our measurements were done on chambers with three wire planes: a central plane consisting of wires 25 microns in diameter, spaced by 2 mm. which collected the electrons and whose field gradient produced the avalanches. The positive ion collecting planes were made of wires 100 microns in diameter, spaced by 2 mm. and with the wires oriented at 90° relative to those of the central plane. We collected signals from both the central and the outside planes. The arrangement we used is shown schematically in Fig. 4. For timing purposes we used a zero-cross[4)] method.

The positioning accuracy attainable with this delay line depends on the following: (a) the amplitude of the signals above the noise level of the jitter in electronic timing and diffusion of the electrons in the gas. The difference in position accuracy and interpolation between the two planes is evident. A proportional chamber with this asymmetry is however quite useful in magnetic spectrometer experiments where the position of the particle trajectories in the plane perpendicular to the magnetic field of the deflecting magnet is usually required to the highest accuracy for the momentum determination.

If symmetry in positional accuracy in two coordinates is desired from one chamber the simplest method is to build it with the positive ion collecting planes oriented at $\pm 45^{\circ}$ relative to the central plane and which are then used for the readout.

The width of the signal pulse on the delay line, relative to the velocity of propagation determines the pulse pair resolution for two simultaneously occurring ionizing events. This is shown in Fig. 7. The results are obtained by simultaneously putting two signals on the delay line and then observing the arrival of the signals at one end of the line. The position of A is fixed and B is moved. The two dashed lines indicate the results which would be obtained for a single pulse at position A or B. Interference between the two pulses will cause the measurements to deviate from the straight lines. In the present setup the two pulse resolution is 30 mm., as can be seen from the figure. We are limited here by the simple zero-cross method of finding the pulse center. Measuring the leading edge of the pulse at each end of the delay line and a suitable coding method would improve the two pulse resolution.

IV. CONCLUSIONS

A delay line readout of the type described above has the advantages over the individual amplifier per line scheme of greater simplicity and less expense. It is also more accurate due to the ability to interpolate among wires. The two track resolution as noted above is somewhat poorer, but can be improved.

We should also point out that electromagnetic delay lines of this type can be used for reading out wire spark chambers in magnetic fields. The signals from these chambers--current coupled or capacitatively coupled are large enough so that very little amplification is needed.

Acknowledgements

We would like to thank Ray Fuzesy and Herb Steiner for their help and cooperation in constructing and lending us some of the chambers on which these measurements were made.

FOOTNOTE AND REFERENCES

* This work was done under the auspices of the U. S. Atomic Energy Commission.

1) A. Rindi, V. Perez-Mendez and R. I. Wallace, Nucl. Inst. and Methods 77 (1970) 325.

2) J. Blewett, Proc. IRE 35 (1947) 1580; W. J. Carley, Tele-Tech. and Electronic Industries 13 (1954) 74.

3) 'Mini Lines' manufactured by Columbia Components Corp., 60 Madison Ave., Hempstead, New York 11550.

4) We used type T140/N zero-cross discriminators manufactured by Edgerton, Germeshausen & Grier, Inc., 160 Brookline Ave., Boston, Mass., U.S.A.

FIGURE LEGENDS

Fig. 1. Perspective view of ceramic core delay line.

Fig. 2. Efficiency of coupling from the chamber to the delay line as a function of the input pulse rise time for (a) coils of 50, 75 and 100 turns and (b) copper straps 1 mm. and 2 mm. wide.

Fig. 3. Loading effect of coupling on a 10 cm. delay line for (a) capacitative coupling and (b) coil coupling. The delay lines are loaded with coils or straps, one every two millimeters.

Fig. 4. Block diagram of the electronics used for timing the pulse. The delay line is capacitatively coupled to the chamber and zero-cross discriminators are used to locate the center of the pulse.

Fig. 5. Electric lines of force in the chamber in (a) the view normal to the central wires showing the origin of the quantizing effect and (b) the view parallel to the central wires. To make the lines of force in (b) as parallel as possible flat strips should be used for the negative plane.

Fig. 6. Measurements of the position accuracy for locating ionizing events as read out by the delay line.

Fig. 7. Output pulse separation as a function of the input pulse separation. The dashed lines represent the measured position for a single pulse at A or B.

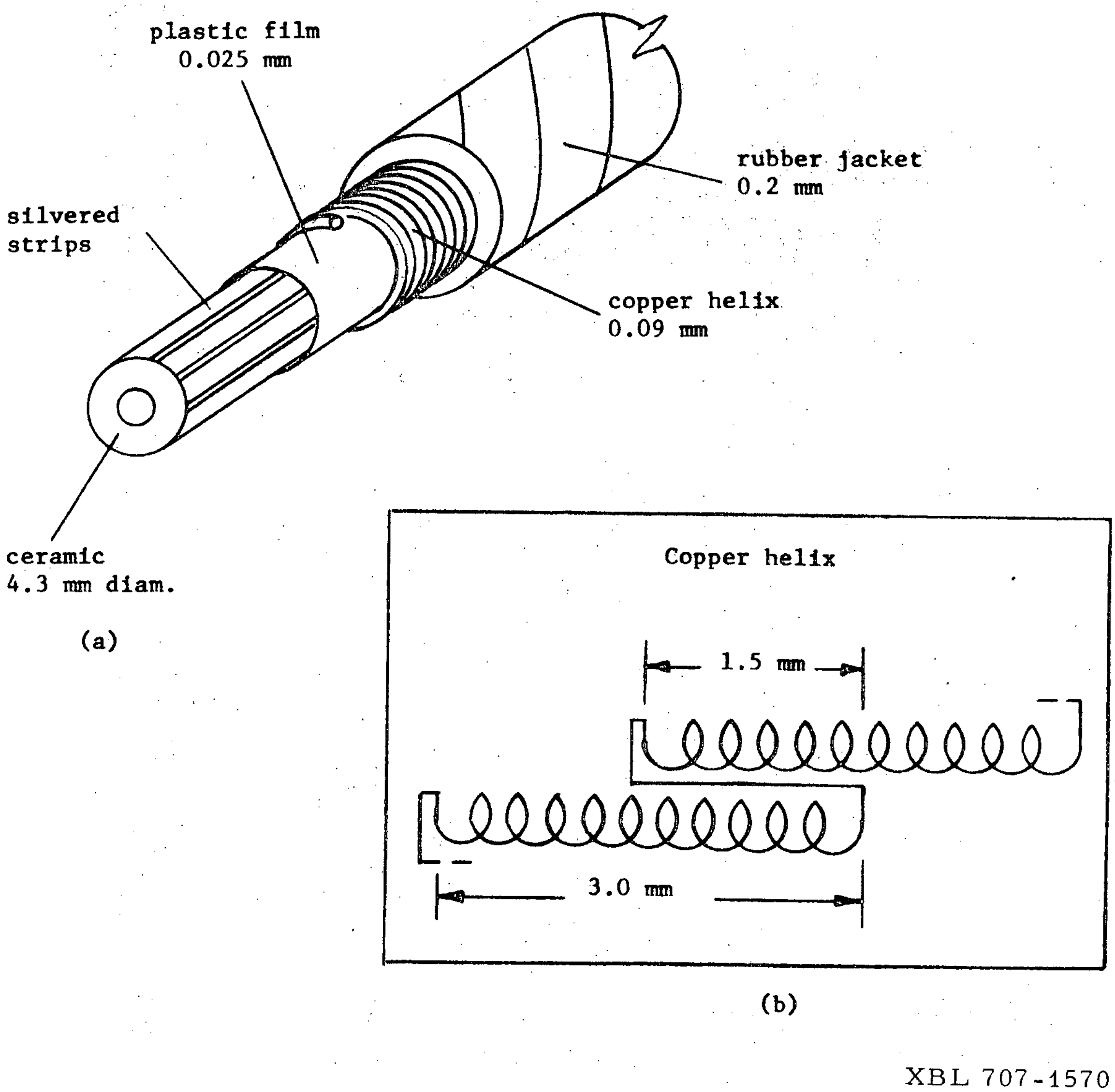
plastic film
0.025 mm
rubber jacket
0.2 mm
silvered
strips
copper helix
0.09 mm
ceramic
4.3 mm diam.
(a)
Copper helix
1.5 mm
3.0 mm
(b)
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Fig. 1

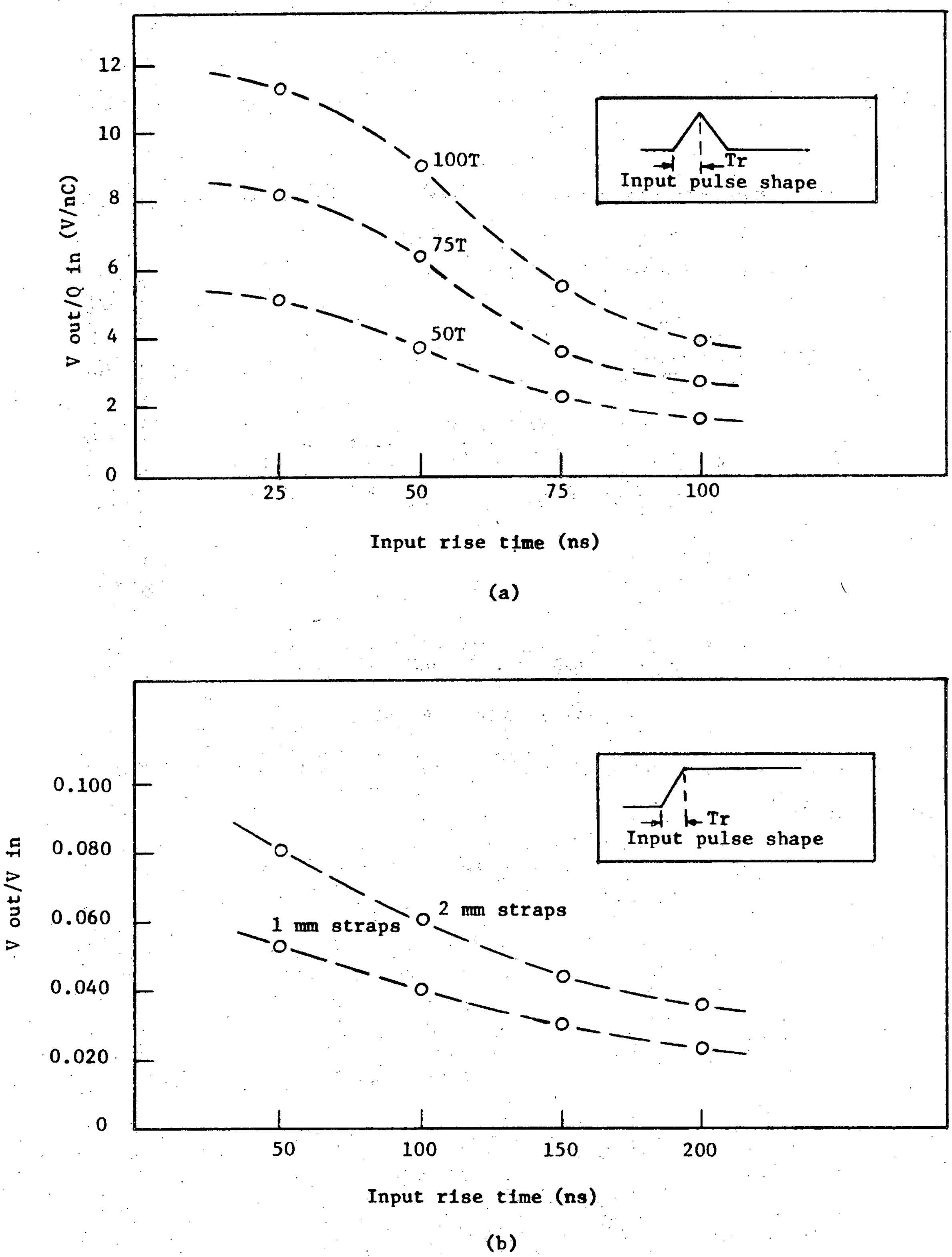

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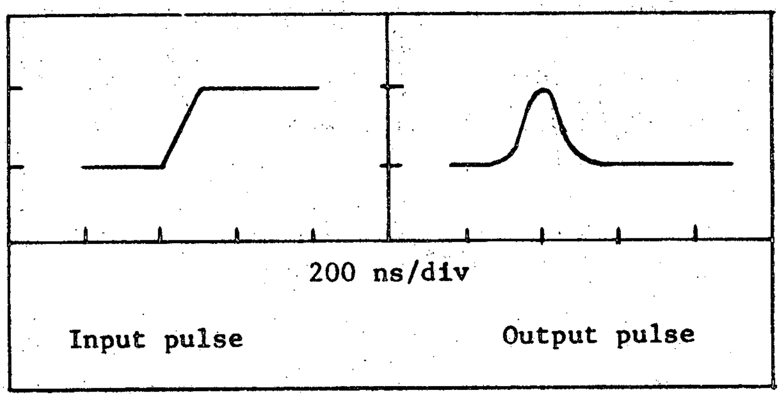
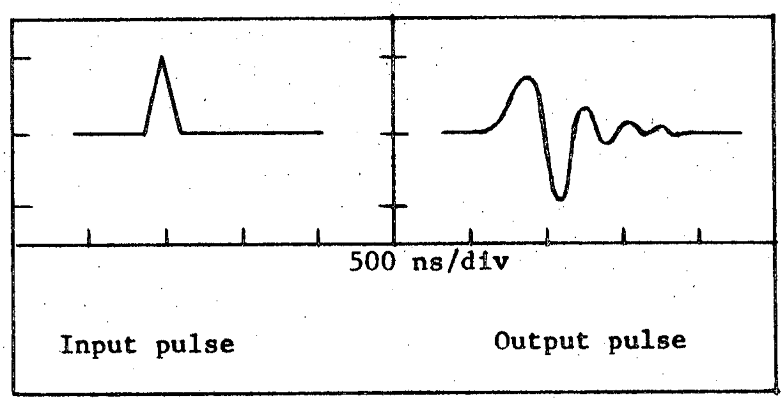
Fig. 2



(a)



(b)

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Fig. 3

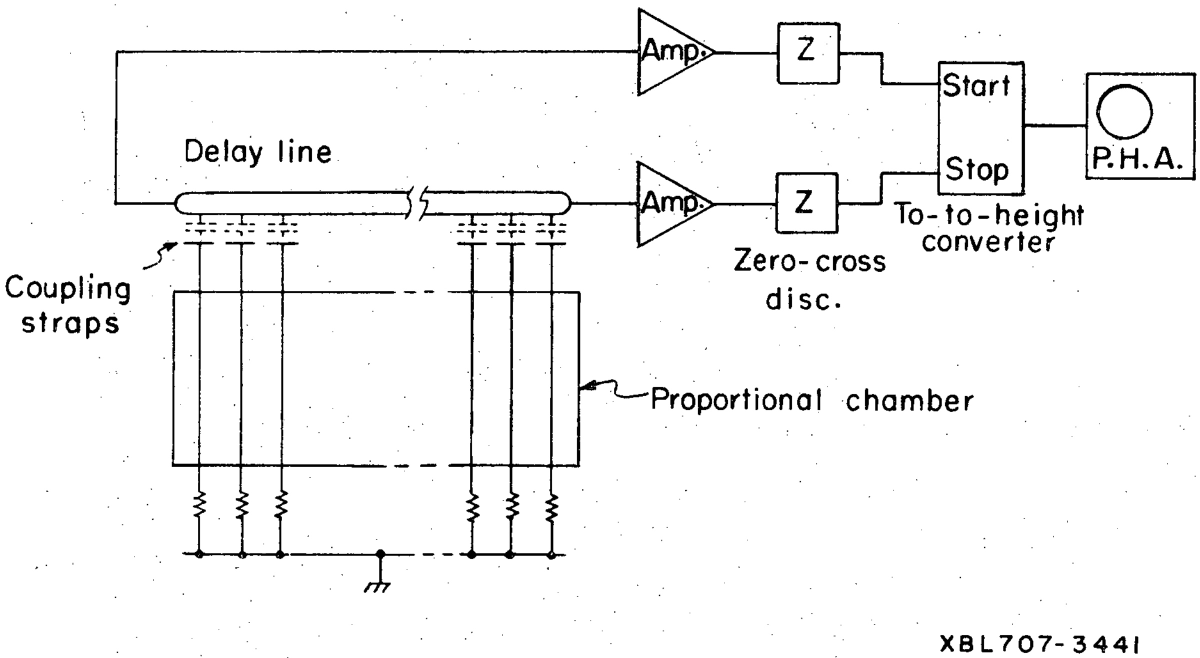
Amp.
Z
Start
Stop
P.H.A.
Delay line
Amp.
Z
To-to-height
converter
Zero-cross
disc.
Coupling
straps
Proportional chamber
XBL707-3441

Fig. 4

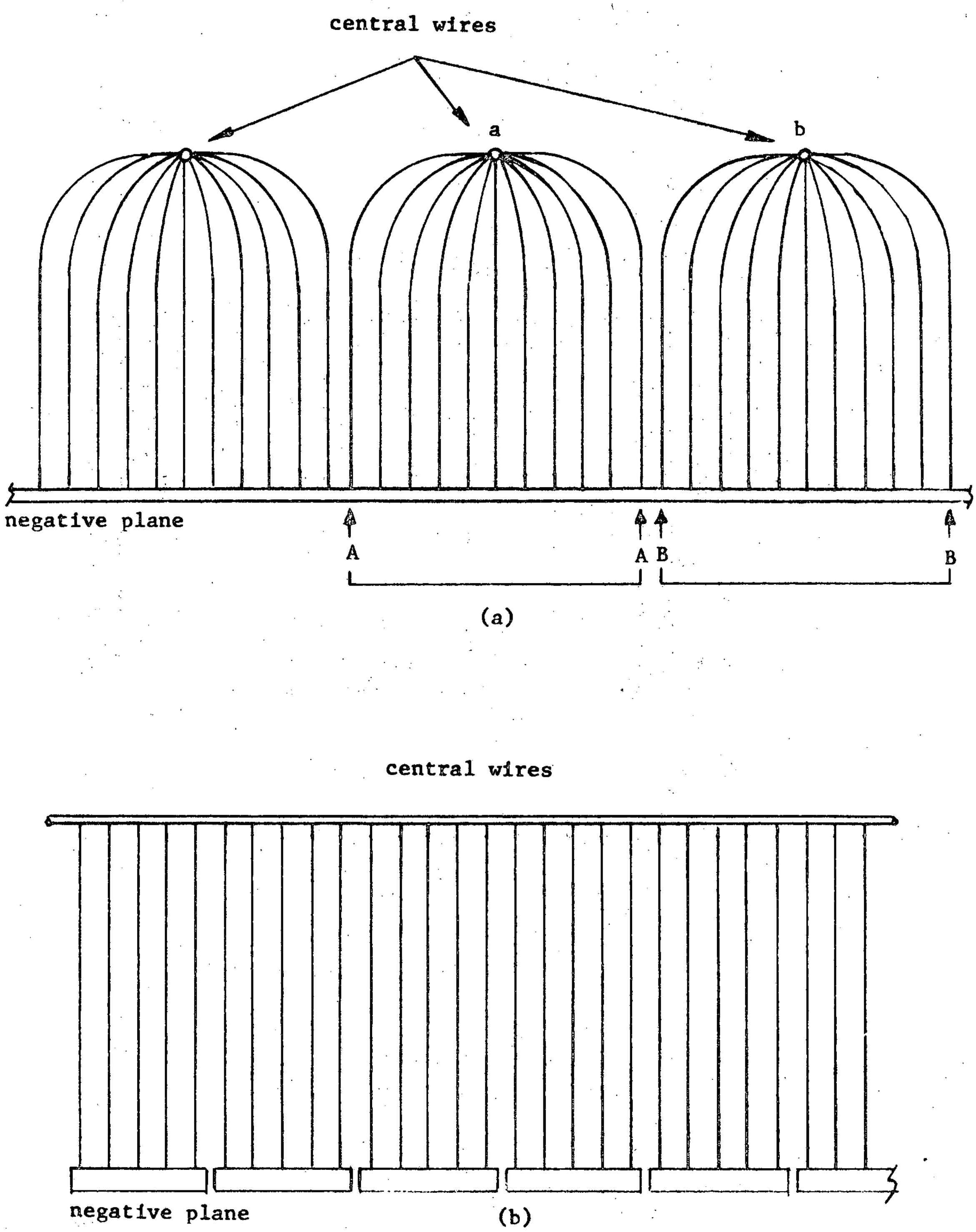

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Fig. 5

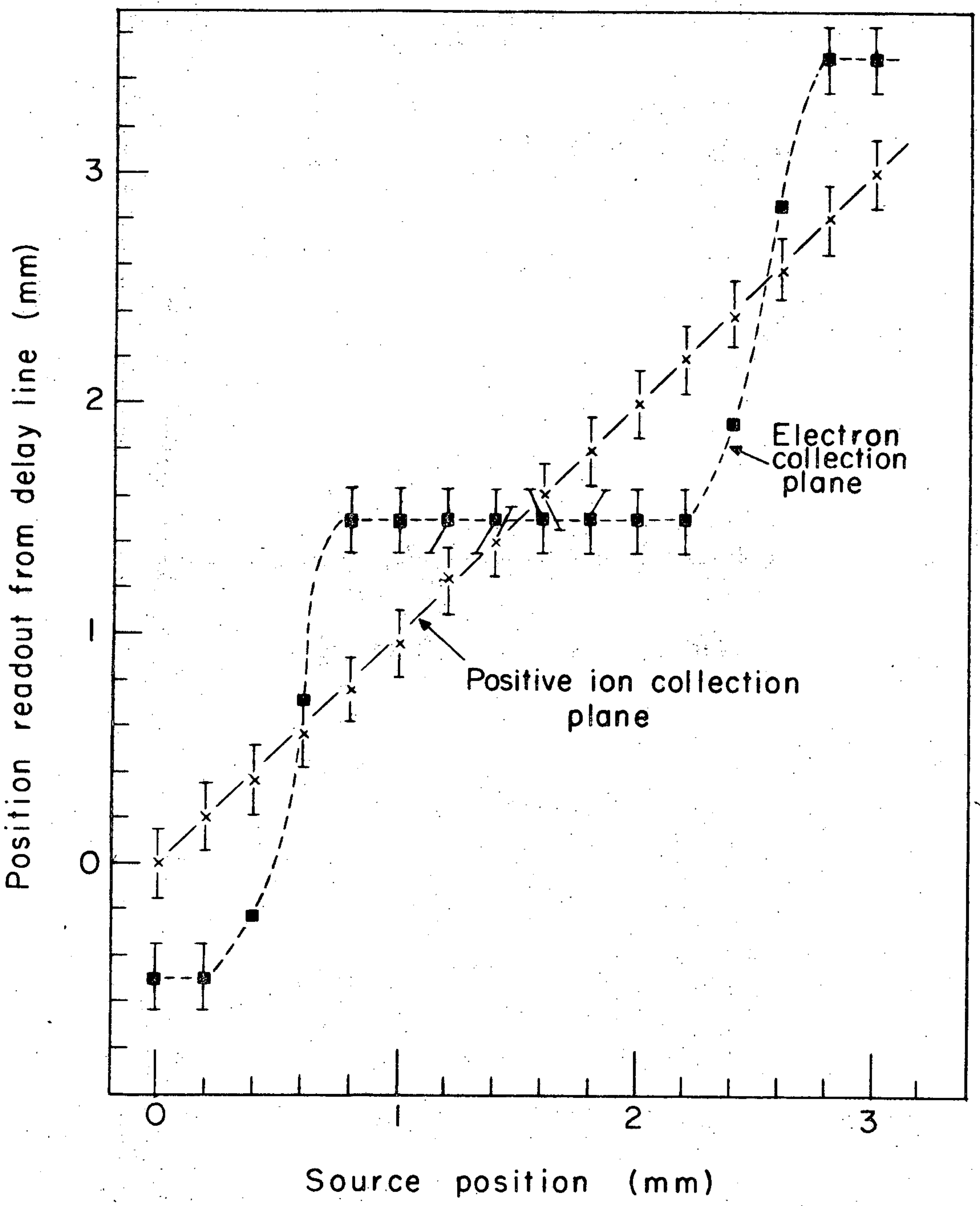

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Fig. 6

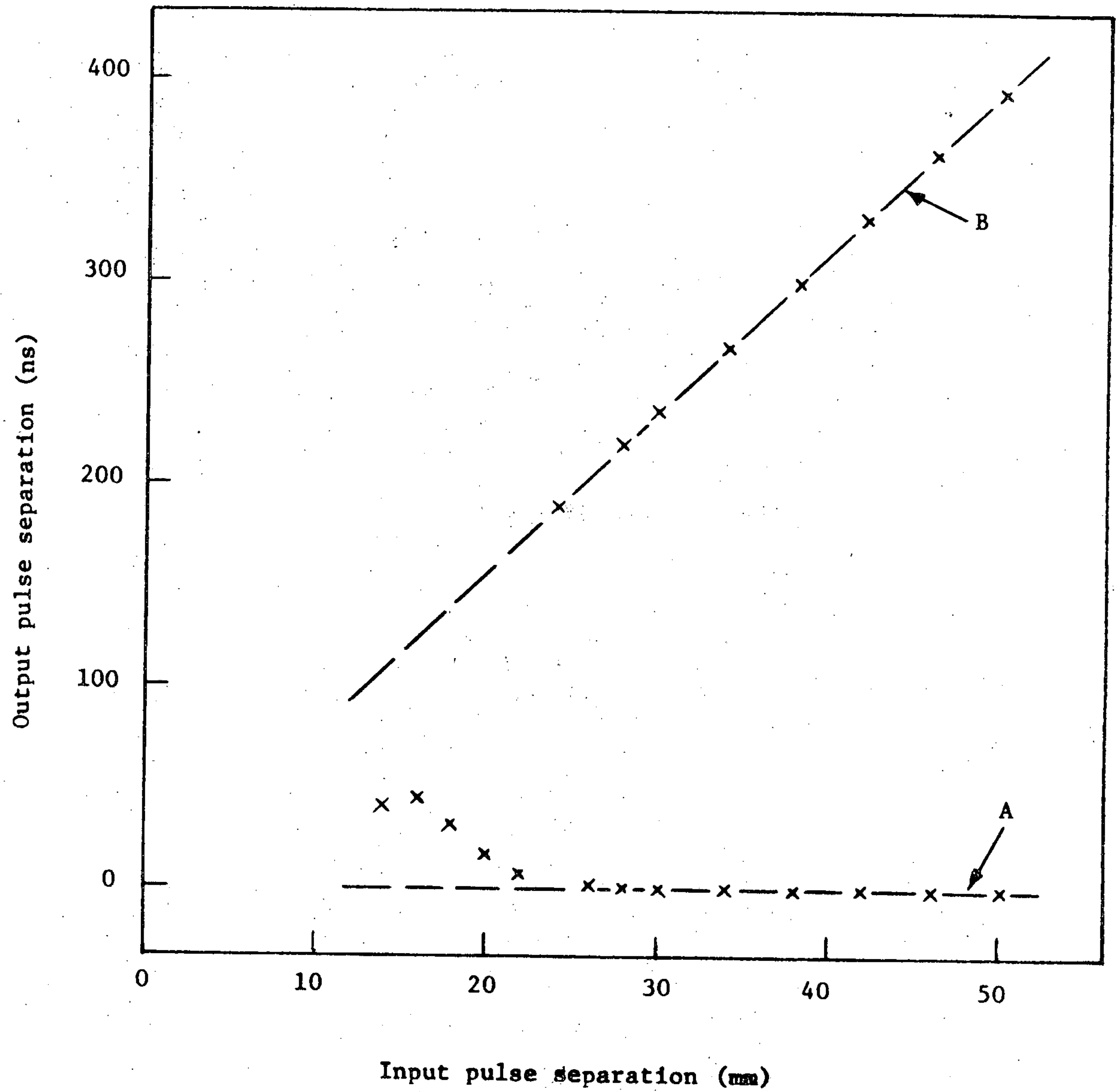

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Fig. 7

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