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Abstract

A scintillation counter hodoscope with 1 mm granularity using fiber optic light guides was designed for use in a 200 GeV secondary hadron beam. Special care was taken to position the scintillators with high accuracy. The efficiency in a beam of 2.5 10^6 particles/sec is 98%.

Introduction

The final stage of the 200 GeV M6E beam line at Fermilab is equipped with five scintillation counter hodoscopes to determine the momentum, angle and position of particles incident on the target. Forward scattered particles are then analyzed by the Single Arm Spectrometer Facility.[1] The unseparated secondary hadron beam is capable of a flux of 10^7 particles/sec in a spot of 5 mm diameter at the final focus. The need to achieve good efficiency for the complete tagging of beam particles imposes a very stringent requirement on the efficiency of any of the five hodoscopes. The hodoscope closest to the target is required to have 1 mm bin size while interposing only minimal material in the beam since small angle scattering in the scintillators will illuminate the spectrometer if set at small angles.

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Two preceding generations of hodoscope design were plagued by low light output from the small scintillators with their complicated structure of rigid lucite light guides. This necessitated the scintillators to be fairly thick along the beam direction without completely curing the efficiency problem. Furthermore, repairs were complicated and always jeopardized the alignment of all the other scintillator elements, which in itself was already difficult to achieve.

For these reasons we improved the design by using flexible fiber optic light guides for good light transmission, efficiency and ease in construction. In addition, the fiber optics eliminated almost all mechanical constraints from the assembly. The use of a novel technique to glue the scintillators precisely into the correct place, yet have them removable for repair, added to the success of this redesign.

The Design

Two rows of scintillators each 3 x 3 x 37 mm^3 (except for the end 2 x 3 x 37 mm^3) are arranged to overlap by 1/3 each and provide 1 mm wide logical bins(Fig. 1). The spacing between the rows and therefore the extension along the beam axis is only 24 mm making the hodoscope very insensitive against angular misalignments. The scintillators (NE102) were ordered machined, polished (0.05 mm tolerances) and annealed to increase the resistance to crazing from Nuclear Enterprises.[2] They were double wrapped with 0.008 mm aluminized mylar foil.

The flexible fiber optics light guides[3] are 60 cm long and consist of randomly arranged high transmission glass fibers sheathed in plastic tubing with epoxy potted, ground and polished ends with metal tips. The transmission is from 0.4 to 2 μ, unaffected by bending and was measured to be 40% using light from a scintillator. These light guides are glued into an adapting lucite piece which is coupled by silicon grease to the 3/4" RCA C31005C phototubes with bialkali cathode. A simple spring and collar mechanism maintains tension on the grease joint. The sockets of the tubes were removed and the flexible leads directly soldered to the printed circuit board containing a conventional HV divider circuit (Fig. 2).

The mechanical assembly of the phototubes is very simple and can be made to fit virtually any experimental situation due to the flexibility of the light guides (Fig. 3). All the usual problems arising from the physical compactness (overconstraining the phototube, light guide, scintillator assembly and introducing too many and sharp bends in the light pipes) are eliminated.

The scintillators are mounted in a frame machined from a block of lucite (Fig. 1). Within one row the scintillators are viewed from alternating sides by the fiber light pipes with the metal terminated end inserted into a hole in the frame and held in place by a set screw. The scintillator is cemented against the end of the light pipe and can be removed together with the light pipe by loosening this set screw. To achieve the desired high accuracy positioning of the scintillators they are glued in place using a gluing jig. This jig is an aluminum block machined on both sides with grooves which accurately fit the scintillators. It is slid into the frame through a fitting hole on one side and butts against the other side for referencing. The prewrapped scintillator is fitted into the groove and glued against the light pipe (Fig. 4).

After all scintillators are in place the jig is removed. For that purpose it consists of three sections held together by screws and two alignment pins. The center piece can be removed directly, opening a recess for the outer pieces to clear the scintillators for removal of the rest of the gluing jig (Fig. 5). This procedure transfers all precision requirements to an easily machinable metal block which can be reused at any time for repairs. None of the positioning depends in an accumulative way on wrapping thickness or the machining tolerances of the scintillators as with many other designs.

Performance

In the M6E beam line at Fermilab we measured an overall efficiency of 98% for single logical elements hit. The flux was $2.5 \cdot 10^6$ minimum ionizing particles/sec within $5 \times 6\ mm^2$. The high voltage on the phototubes was typically 1900 V, adjusted to get full efficiency on single photoelectrons. Using the information from other hodoscopes, the efficiency measurements used only single particles not acompanied by one or more in the same rf bucket. The 2% inefficiency is divided approximately equally between zeros and ambiguous multiple hits, mostly likely from δ-rays. Therefore we estimate at least 4.5 photoelectrons on the average per minimum ionizing particle.

Acknowledgements

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REFERENCES

[1]Fermilab Single Arm Spectrometer Group, Phys. Rev. Lett. 35, 1195 (1975) and Phys. Rev. D to be published.

[2]NE102 scintillators from Nuclear Enterprises, 935 Terminal Way, San Carlos, California 94070.

[3]American Science Center Inc., 5700 Northwest Hwy, Chicago, Ill. 60640.

FIGURE CAPTIONS

Fig. 1: Exploded view of the lucite bloc holding scintillators, light guides and the disassembled gluing jig. Two cross sections show in detail the arrangement of the scintillators.

Fig. 2: The RCA C31005 phototube assembly.

Fig. 3: The finished hodosope assembly with front panel removed.

Fig. 4: The lucite bloc assembled with gluing jig, one scintillator and light pipe.

Fig. 5: The finished assembly of the scintillator array.

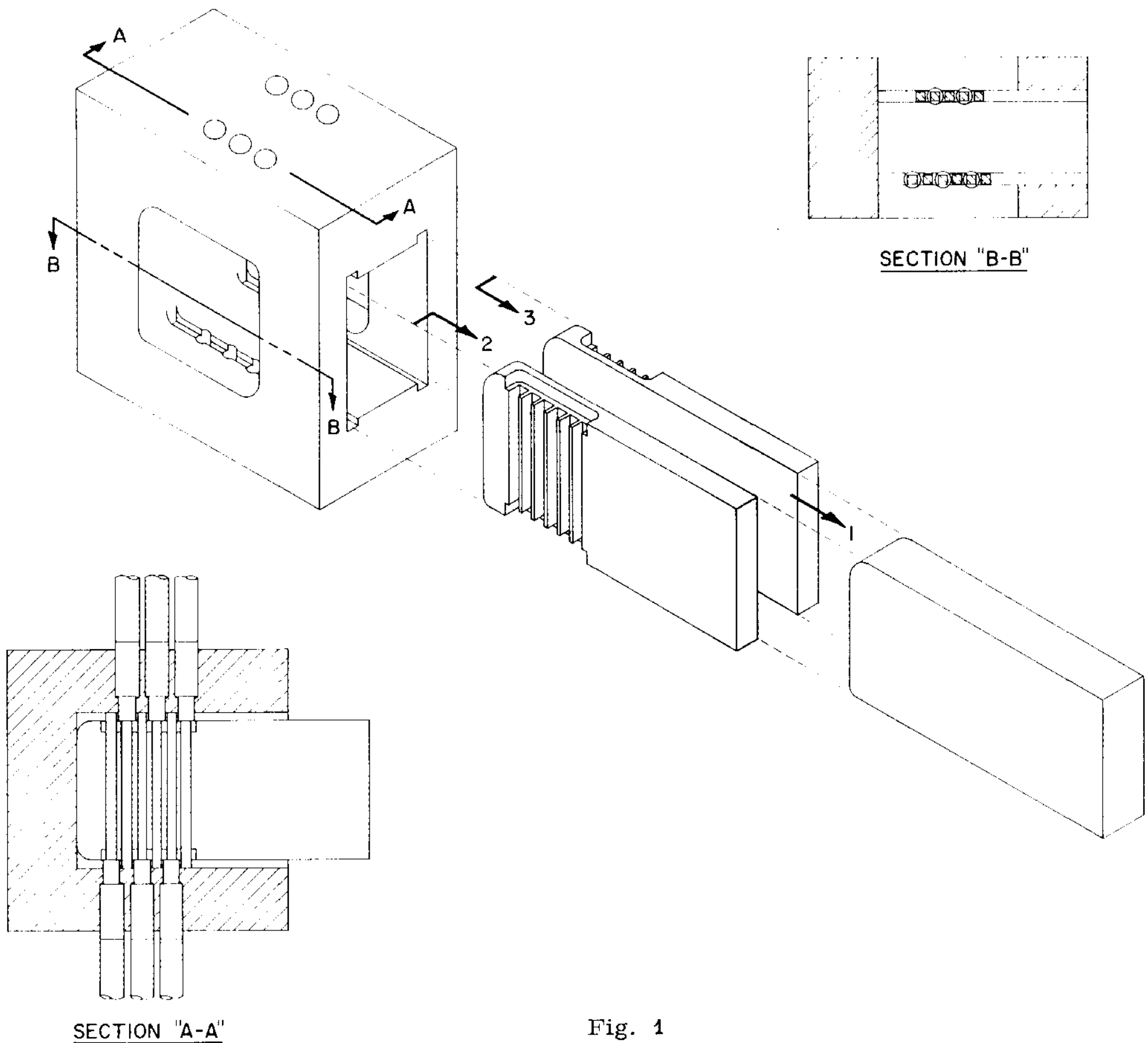

Fig. 1

Fig. 2

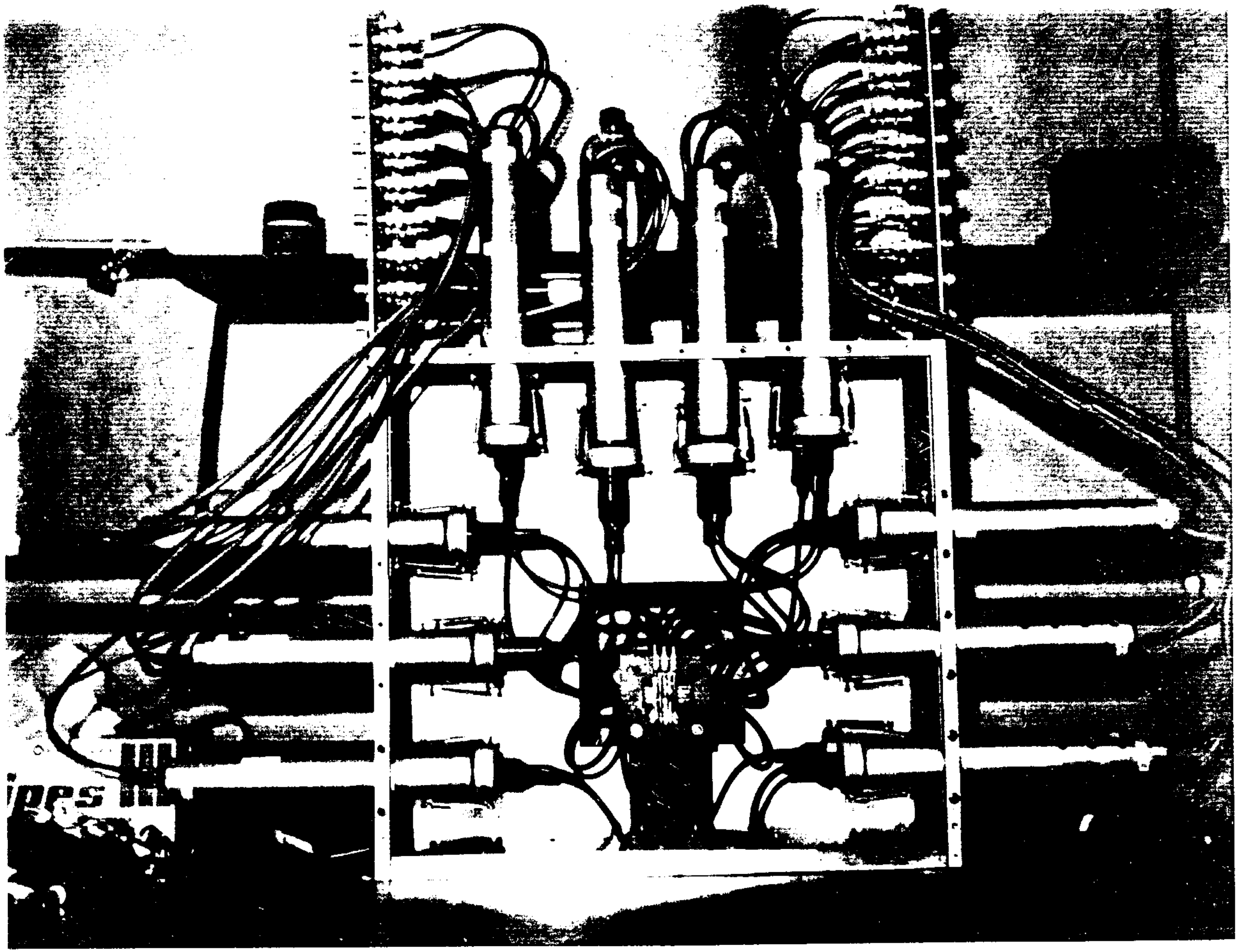

Fig. 3

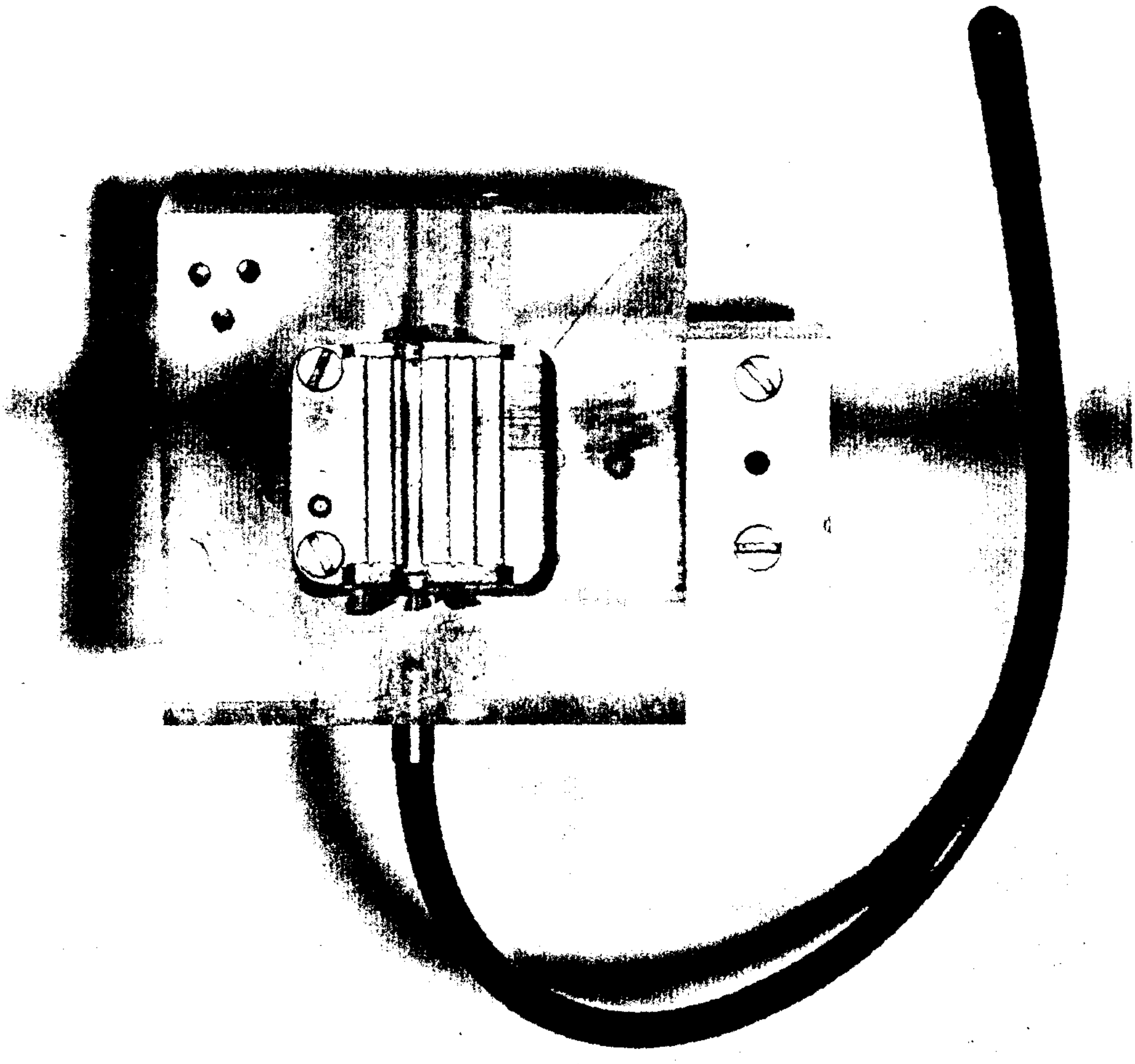

Fig. 4

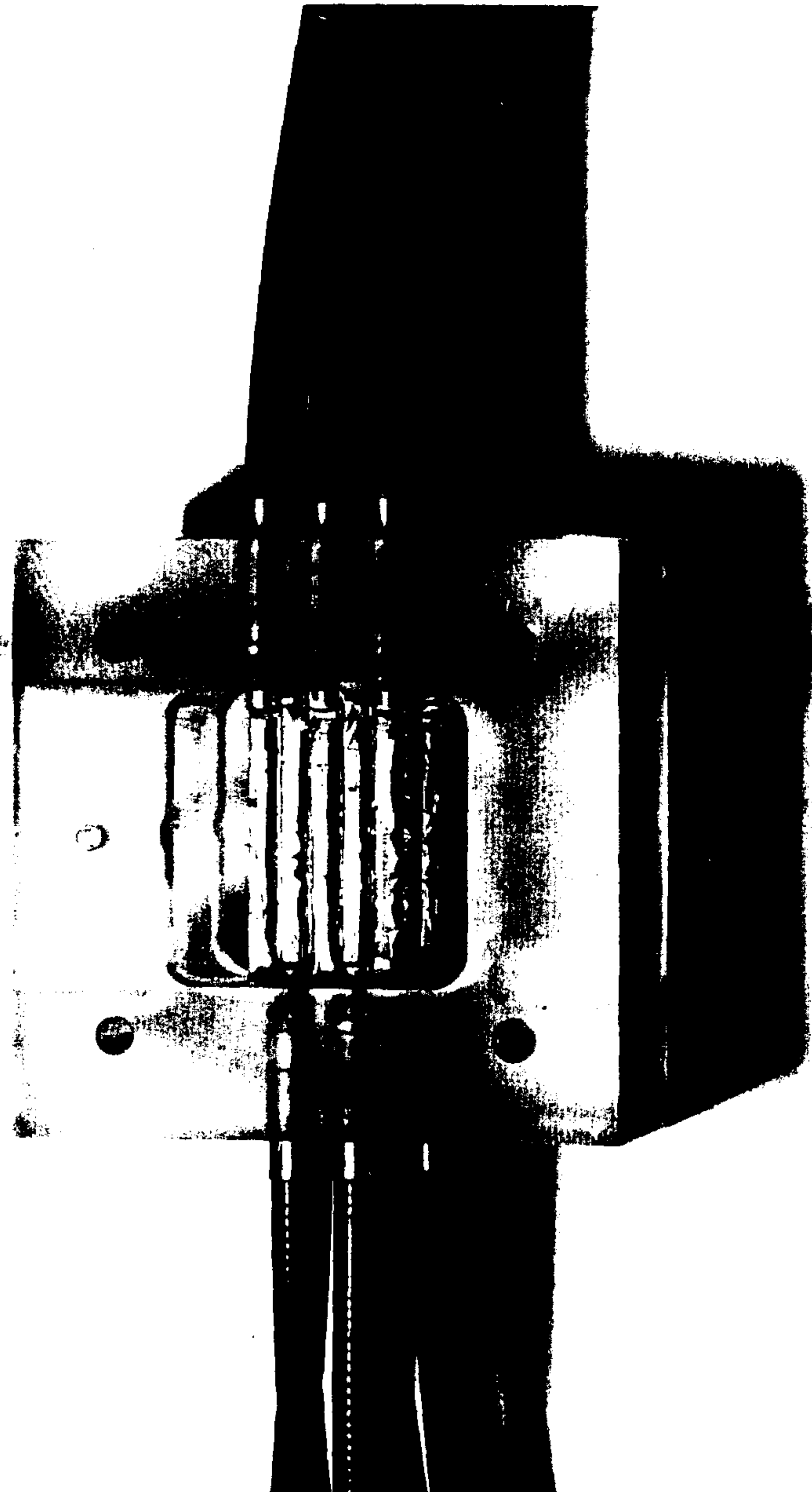

Fig. 5