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A STANDARD BEAM PWC FOR FERMILAB

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As one of its projects the Fermilab Experimental Areas Department has designed and tested a relatively small proportional wire chamber for use in the secondary beam lines. It is intended to supplement the variety of detectors known in the vernacular as "SWICS" that are used to obtain profiles for beam tuning. The new detector, described in this report, operates in the limited proportional mode[1] and allows experimenters to use a standard, lab supported device for associating trajectories of individual beam particles with events triggering their own experiment's apparatus. A completed triple plane module is shown in Figure 1.

I. LAYOUT OF THE SENSE PLANES

There are three types of wire planes that may be combined in almost any configuration and quantity within a module. All three have 1 mm perpendicular spacing between wires and are built such that accurate relative positioning of the planes within a module is automatic. Using the three types of plane the possible measured coordinates occur every 30^{o}.

The "straight" plane has 128 wires (see Figure 2a). Looking at the side of the board to which the wires are attached (the "wire side") with the readout connectors at the bottom, the 64th sense wire from the left is positioned 0.25 mm left of the board center line. If another similar plane is put in the same module with the readout at the top, the distance between the two wires numbered 64 is 0.5 mm. Thus, one-half millimeter effective wire spacing may be achieved by this combination. The perpendicular coordinate may be measured with similar resolution by including boards with readout at the left and right sides. Proper relative alignment is achieved by pinning all sense planes together with four 0.125 inch diameter steel rods which pass through precision holes near the corners of the sensitive areas. The positions of these holes are specified to 0.001" (0.026 mm) relative to the board center line. The board center line targets and the wire placement targets were drawn on the master artwork by a computer controlled plotter (0.007 mm step size).

Artmasters for the two slant planes (figs. 2b and 2c) were prepared in a similar fashion. With the readout at the bottom these planes measure coordinates rotated by $+30^{o}$ and -30^{o} relative to the straight plane. Each slant plane has

64 sense wires with the midline between wires 32 and 33 passing through the module axis. This axis may be determined by surveying the center line targets on the sense planes which are visible in the assembled module.

At either side of the area covered by the 64 or 128 sense wires are placed guard wires which taper the electric field. These were found to be necessary with the six inch long sense wires (but unnecessary in the three inch prototype -- see Appendix) in order to achieve acceptable wire stability at high voltages. The guard wires are made up of a section of two dummy sense wires followed by two or more wires of significantly larger diameter. All are connected to ground.

II. CATHODE PLANES AND CHAMBER ASSEMBLY

The high voltage plane printed circuit artwork is designed so that either wires or aluminum foil may be used as the cathode. If foils are used, the module may be stacked such that only a single foil is used as the upstream cathode for one sense plane and the downstream cathode for another. This arrangement is shown in Figure 3.

If a particular application calls for wire cathodes and/or isolated cathode power supplies for individual sense planes within a module, it will be necessary to insert a cathode-style plane connected to ground between the sense sections. This insures that all fields around all planes are upstream-downstream symmetric. Design of the chamber components is such that it is simple and straightforward to construct a module with any of the above configurations. High voltage is supplied to the cathode through a 100 KΩ current limiting resistor. Test pulses may be applied to the cathode via a lemo style connector which is capacitively coupled to the cathode. The practice of pulsing chamber cathodes and checking for the presence of corresponding pulses in the readout electronics has been found to be quite useful. Not only is readout integrity verified, but the possibility of chamber damage resulting from supplying high voltage while sense wires are unterminated is avoided.

Figure 3 shows a cross section view of a chamber with two sense planes. The various planes are designed in such a way that they may be stacked in almost any orientation. The overall order of the planes is:

Mounting Frame
Window
Spacer
Cathode
Spacer
Sense Plane
Spacer
Cathode
Spacer
.
.
.
Sense Plane
Spacer
Cathode
Spacer
Window
Mounting Frame

Gas ports are in the edges of the mounting frames.

The only restrictions on the configuration of a module, imposed by mechanical clearance requirements, are

1. No two consecutive sense planes may be read out from the same side of the chamber (left, right, top, bottom).
2. If on-the-chamber amplifiers are used, (see below) no two sense planes within a module may be read out on the same side of the chamber; also, sense planes with readout connectors on opposite sides of a module should occur consecutively within the module.
3. No two consecutive cathode planes (or ground planes between subsections) may have their high voltage connections at the same corner.

The chamber is made gas tight with vacuum grease. At assembly each board is cleaned and prepared with a small continuous bead of vacuum grease placed along the line between the locating pins. This method has been tested and found to produce an immeasurably low leak rate (<0.003 SCFH at a pressure of about two inches of pump oil). It has the advantage that chamber disassembly is easy (simply pry the planes apart), and that no costly machining is necessary as would be the case if an O-ring seal were attempted.

III. READOUT CONNECTIONS

The sense plane printed circuit allows two approaches to the problem of mounting the readout electronics. The wires may be brought off the chamber in groups of 32 on shielded ribbon cable (such as 3M 3476 with connectors 3414-7034[2]) and connected to amplifiers located on a mother board a short distance away. Alternatively, amplifiers built to the LeCroy PCOS-III[3] mechanical standard may be inserted directly into connectors on the sense plane. The choice of method should be made by the user based on chamber environment, available electronics, etc. Normally, only one set of connectors would be installed on the board. It should be noted that the chamber parts are designed so that an arbitrarily large number of sense planes can be combined in a single module if the mother board readout scheme is adopted. The only restriction is that no two consecutive sense planes have their readouts on the same side of the module.

IV. MOUNTING

Figure 4 shows a sketch of the chamber frame and the locations of threaded mounting holes. Holes for the chamber clamping bolts are counterbored so that the face of the frame is flat. The four alignment pins may be extended out of the face of the module to facilitate surveying or positioning the chamber on a stand.

The information above is provided so that an experimenter can design a custom mounting arrangement if necessary. In general, however, one can use a modified SWIC stand which supports the chamber and RF shield from the floor. Cable strain reliefs, a cooling fan, and positioning screws are provided on this stand. A full set of prints for fabrication of this stand is on file, and stands of this type are in use with the chambers installed in various beam lines for the 1983-1984 running period.

V. MATERIAL IN THE BEAM

In most respects the chamber has been designed to minimize the amount of matter in the path of the beam. The windows are made of 0.0005" aluminum foil and also serve as RF ground shields and electrostatic balancers for the first and last cathode planes. The sense wires are 0.0004" gold plated tungsten. The cathode planes are 0.0005" aluminum foil. The chamber half-gap (distance between sense wire and cathode) is 0.125". Tests indicate that the chamber parts can be constructed with enough uniformity that satisfactory operation can be achieved with all cathode planes in a module connected together. (As pointed out above, however, this is not a requirement.) This reduces by almost a factor of 3 the number of foils required per sense plane. Thus, in a typical installation having two sense planes in a module, the material in the beam is 0.025" Al, 0.75" gas, and an average of 2×10^{-6} inches of tungsten. This is about 0.002 nuclear collision lengths, or 0.007 radiation lengths.

VI. OPERATIONAL TESTS

The first production-line produced single sense plane chamber module was tested with an 80%/20% $ArCO_2$ gas fill and a Nanometrics[4] PWC amplifier. Sensitivity tests were performed by illuminating the chamber and two scintillator paddles placed behind it with a Ruthenium source. Requiring that the triggering particles pass through the PWC as well as both 0.25" thick plastic scintillators guaranteed that they did not lose a significant fraction of their energy in the wire chamber, and therefore approximated minimum ionizing particles.

For this particular test bench arrangement and amplifier card (a prototype) the lowest threshold current that could be obtained without taking unusual precautions was 1.5 μA. This threshold was used in the tests described below. (See the Appendix for a discussion of the effects of using different thresholds.) Production line amplifiers[4] have been found to be easily operable at a 0.75 μA threshold.

Figure 5a shows the PWC efficiency as a function of operating voltage. The fraction of PWC "hits" in which two or more wires had signals above threshold is shown as figure 5b. The point at which the chamber rent "runs away" is about 2850v. It is clear from this and the figure that the detector has a useful operating range of $\gtrsim$ 200v when coupled to a 1.5 μA discriminator. Operation at the lowest voltage that provides ~100% detection efficiency is recommended since raising the voltage above this point degrades the position resolution of the detector.

VII. ACKNOWLEDGEMENTS

The author wishes to express his gratitude to the other members of the E.A.D. Facilities Support Group for designing, fabricating, and procuring a large number of parts for the detectors, and for covering for him while he worked on this device. Thanks are due to the Research Services Printed Circuit Shop for constructing what must have seemed an endless series of prototypes, and for making their winding machine available for production runs of anode planes. The Design and Drafting Group of the Technical Support Section as well as the Computing Department provided invaluable advice and assistance for creation of the anode

plane art masters. The Fabrication Procurement and Contracts offices took care of the business end of this project.

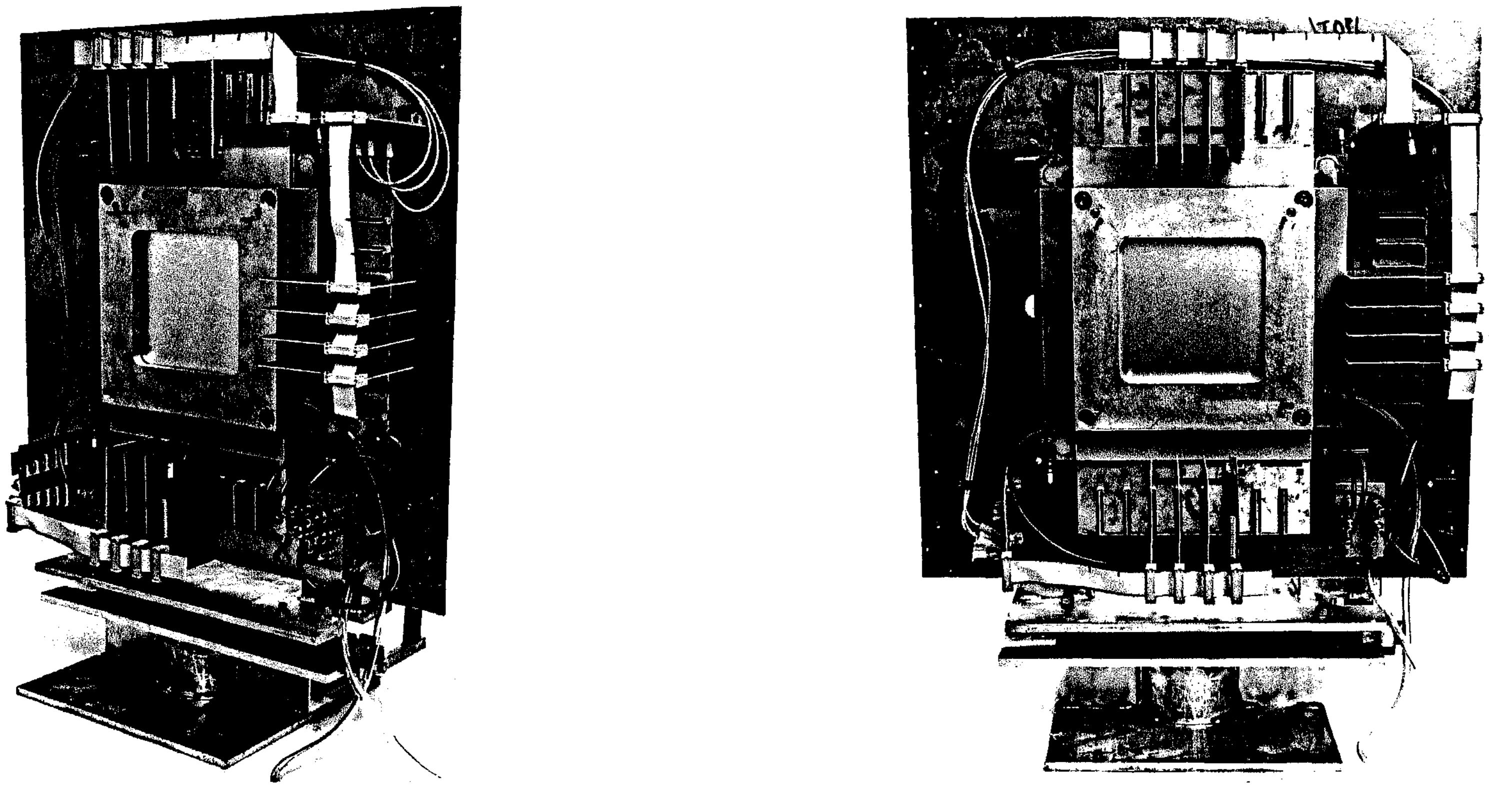

Figure 1

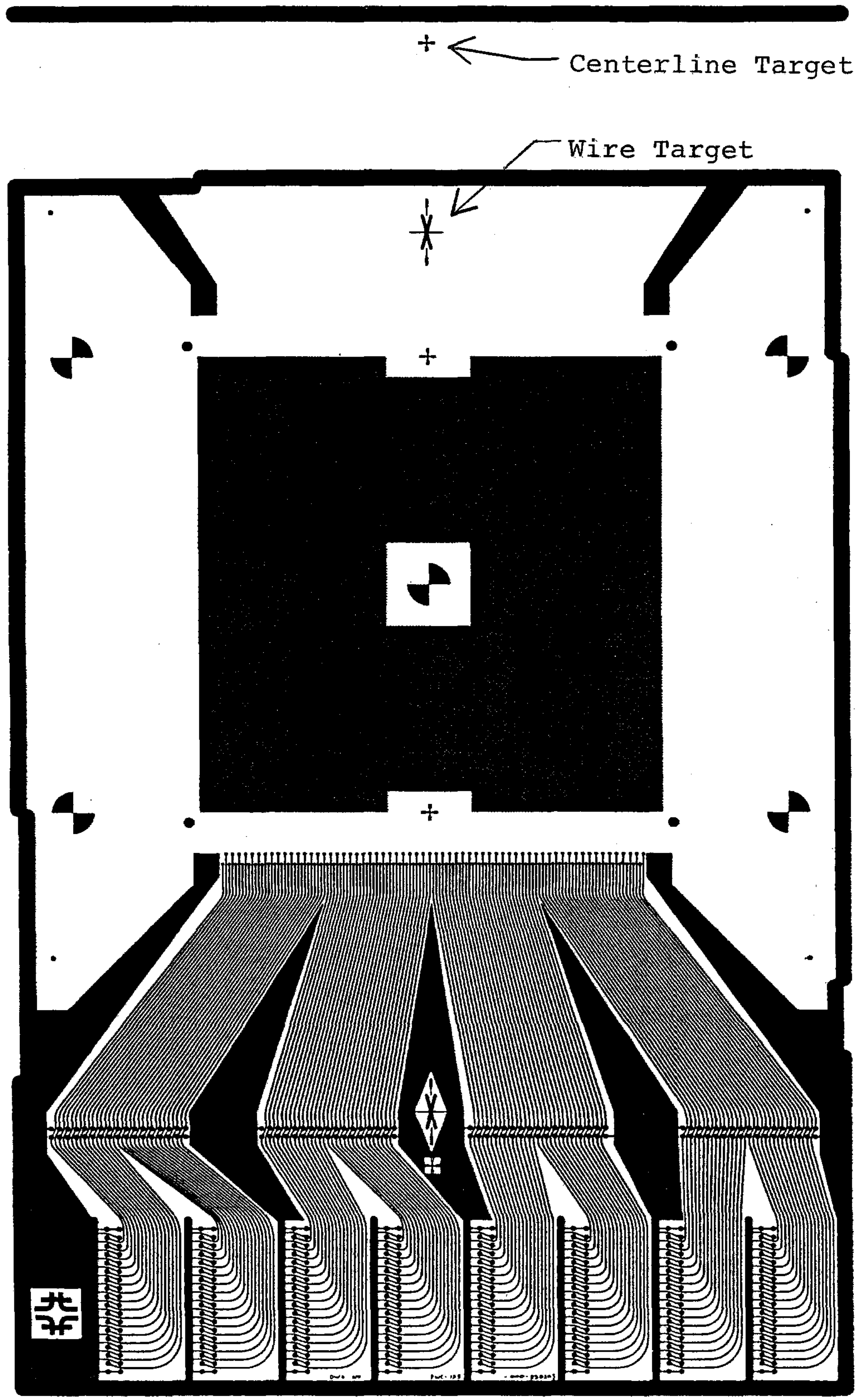

Fig. 2a 0° Sense Plane Artwork

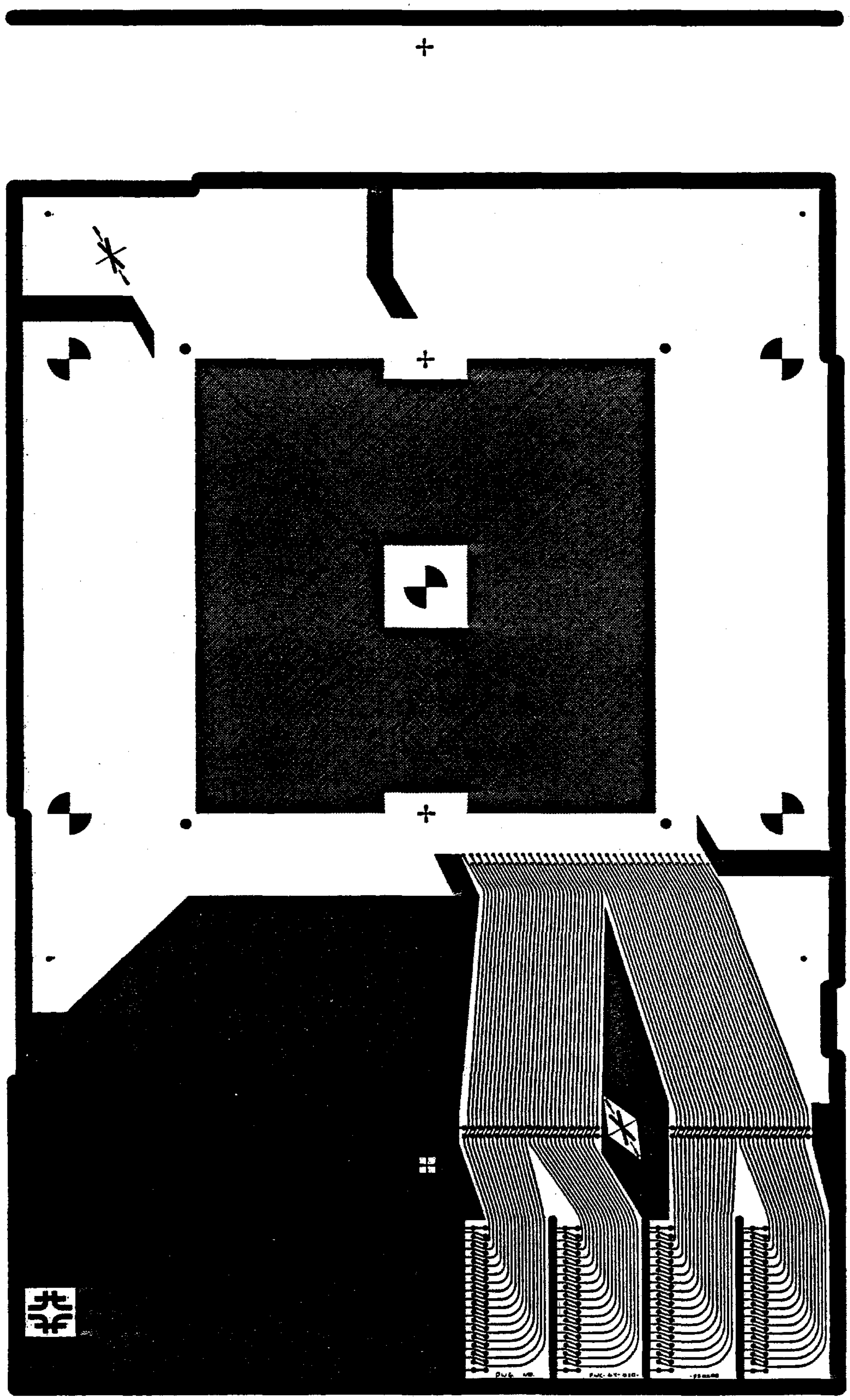

Fig. 2b 30° Sense Plane Artwork

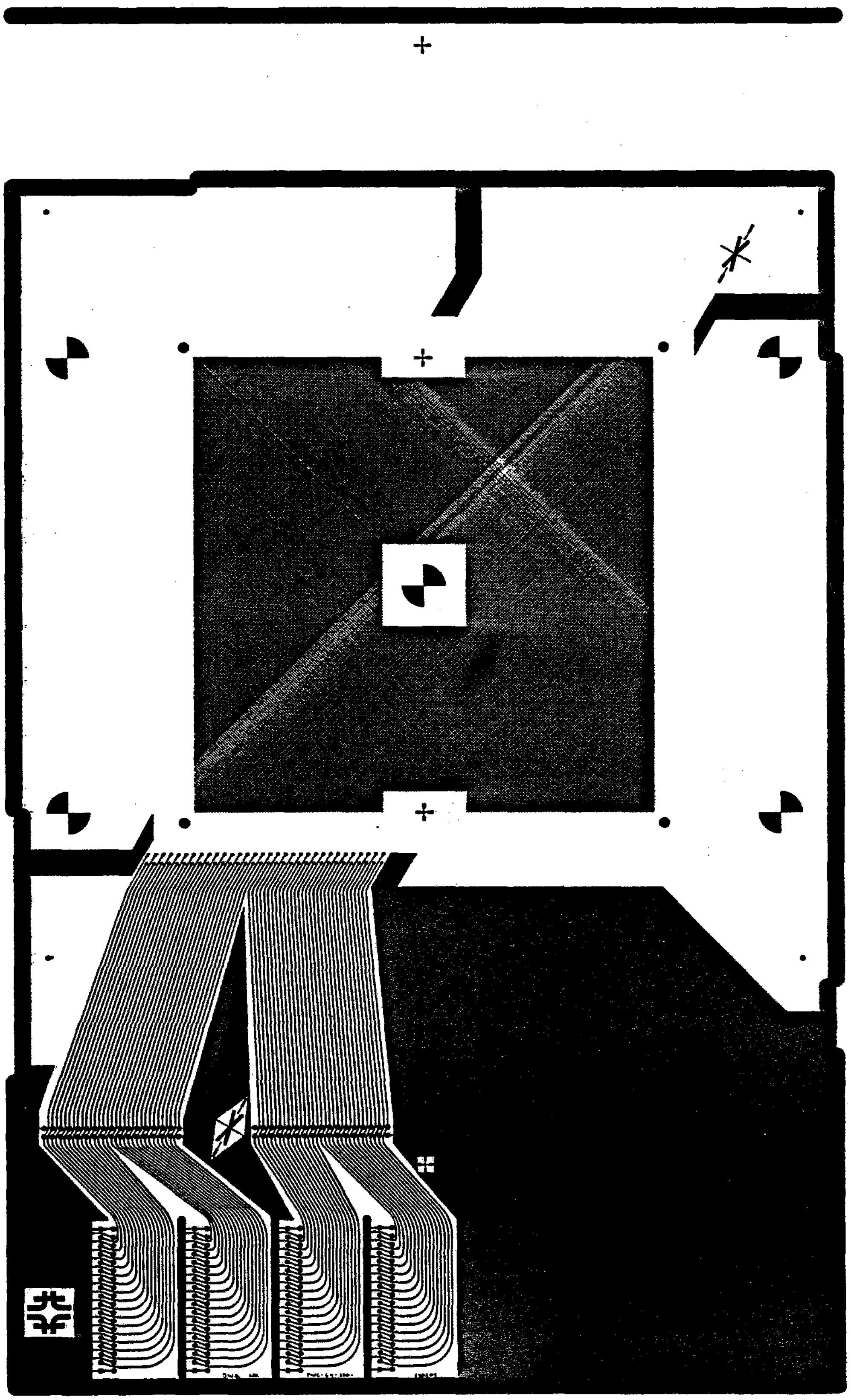

Fig. 2c 330° Sense Plane Artwork

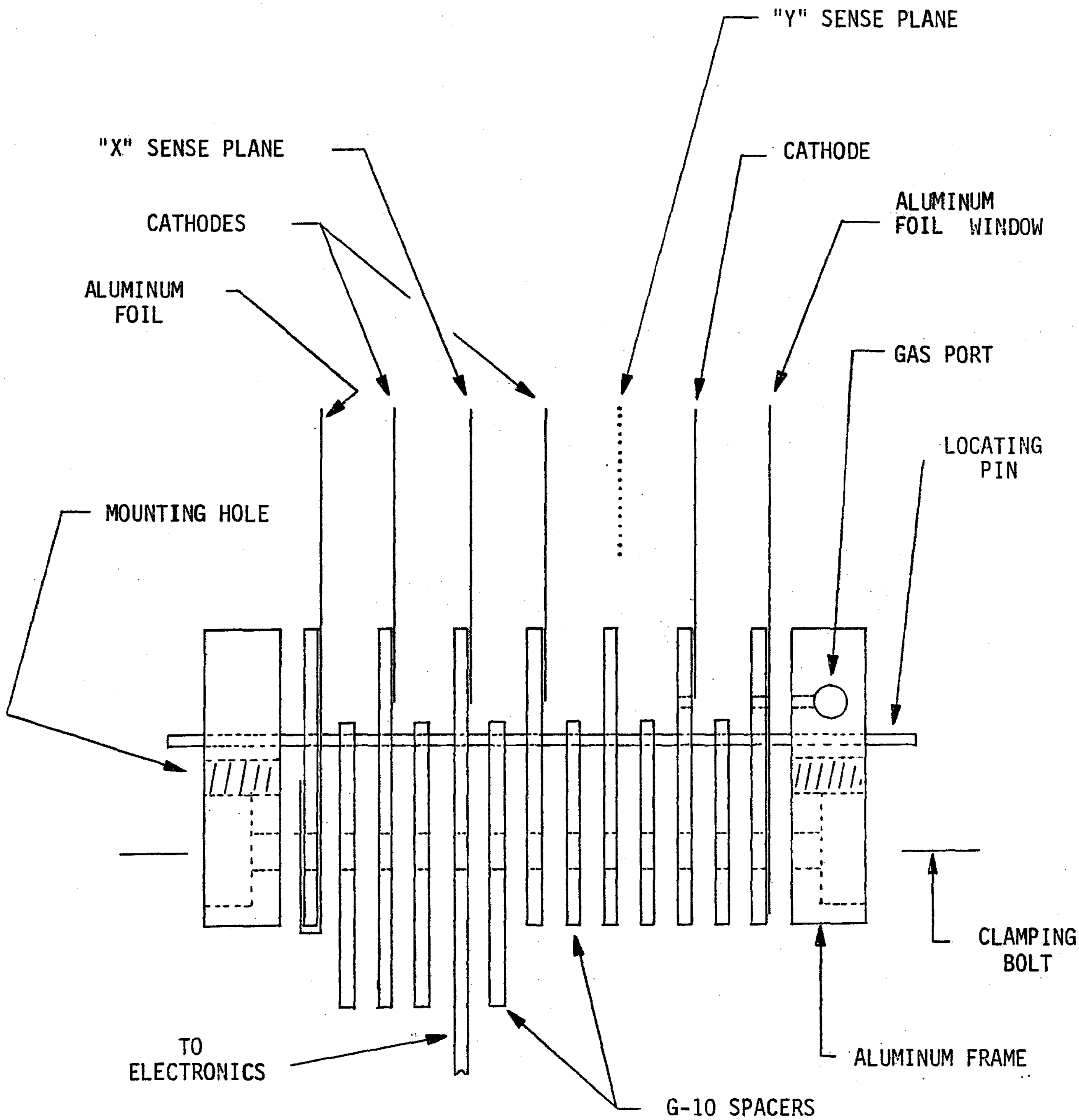

FIGURE 3

Full-size expanded cross-section of part of a module with "X" and "Y" sense planes illustrating how the pieces may be stacked together.

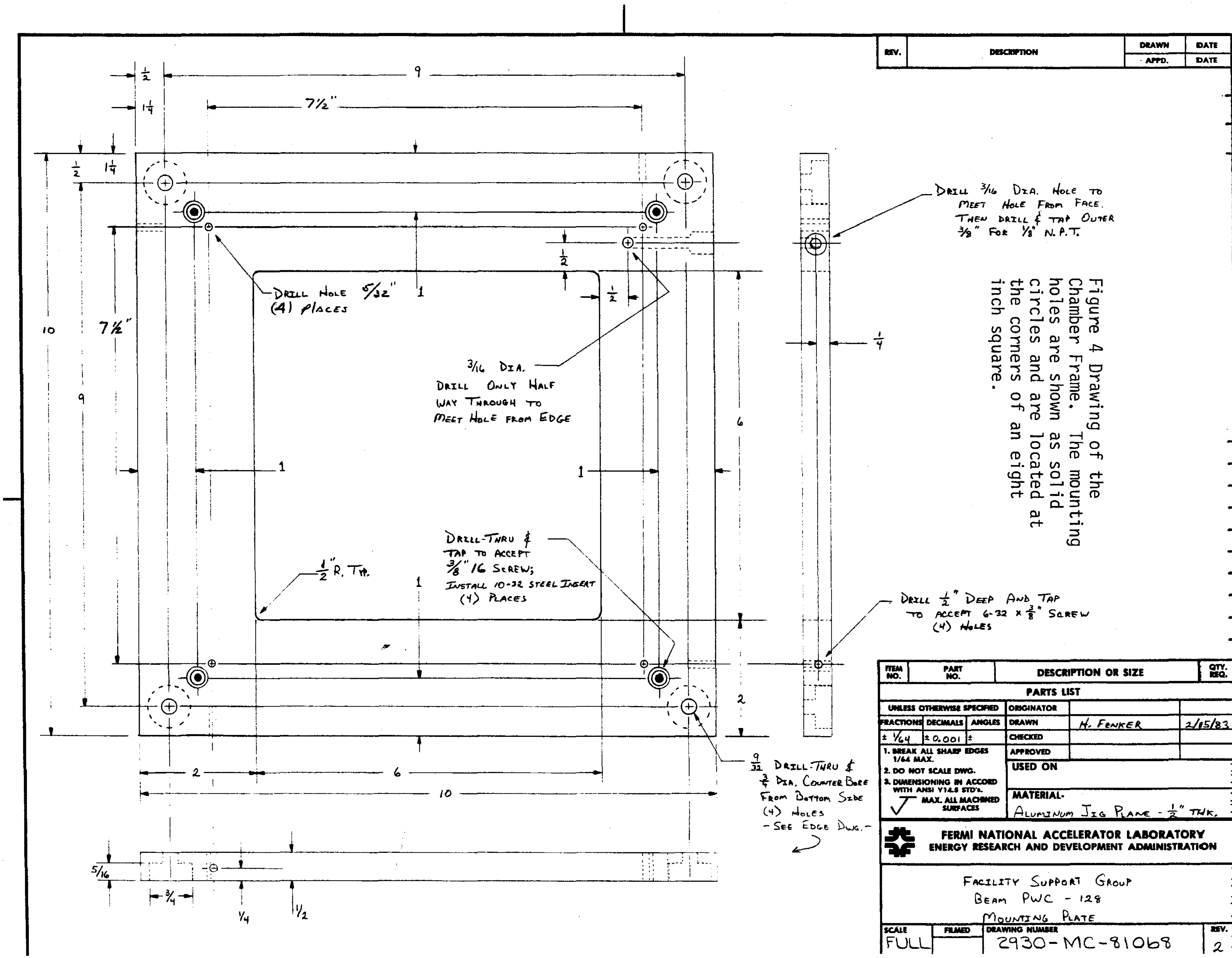

Figure 4 Drawing of the Chamber Frame. The mounting holes are shown as solid circles and are located at the corners of an eight inch square.

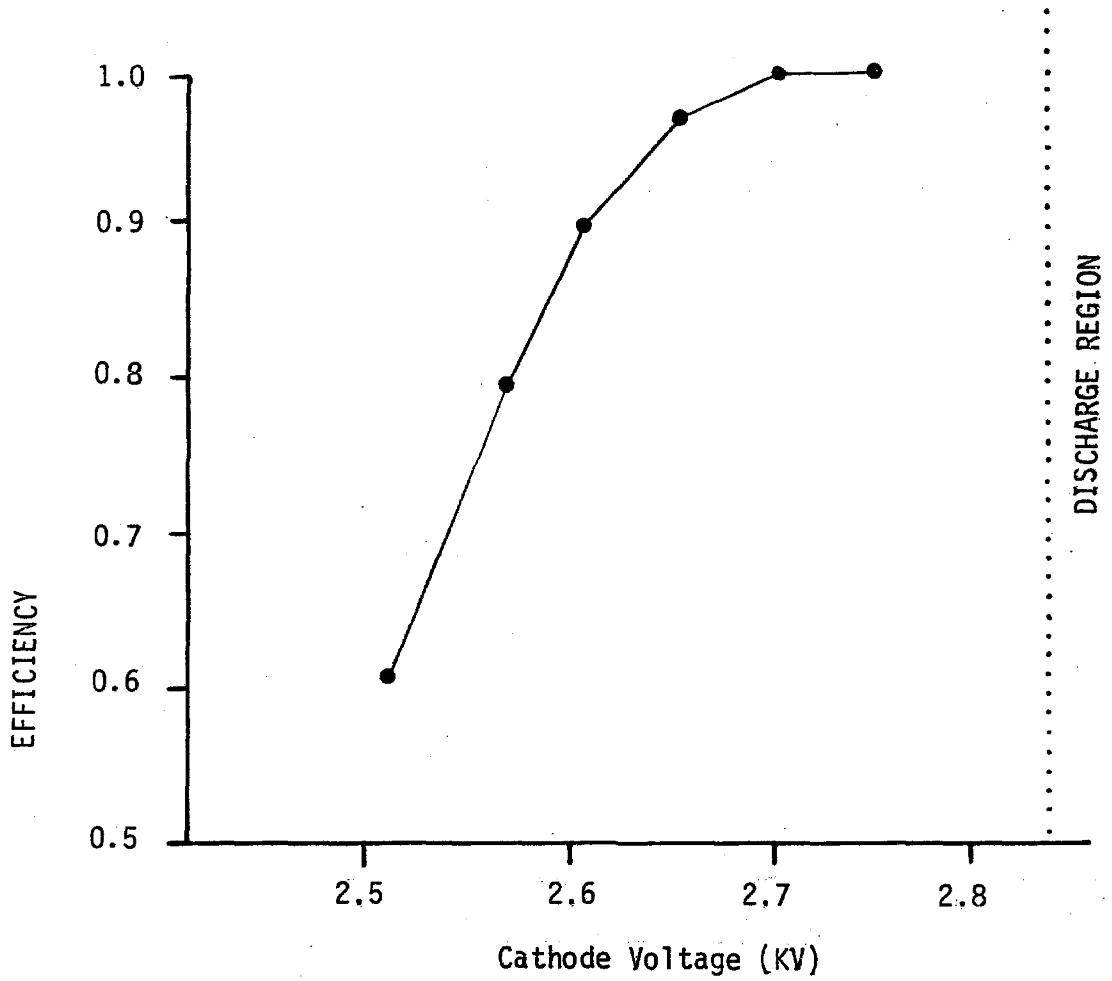

Figure 5a) Production model PWC efficiency vs. operating voltage with I_{th} = 1.5 μA and $ArCO_2$ gas fill.

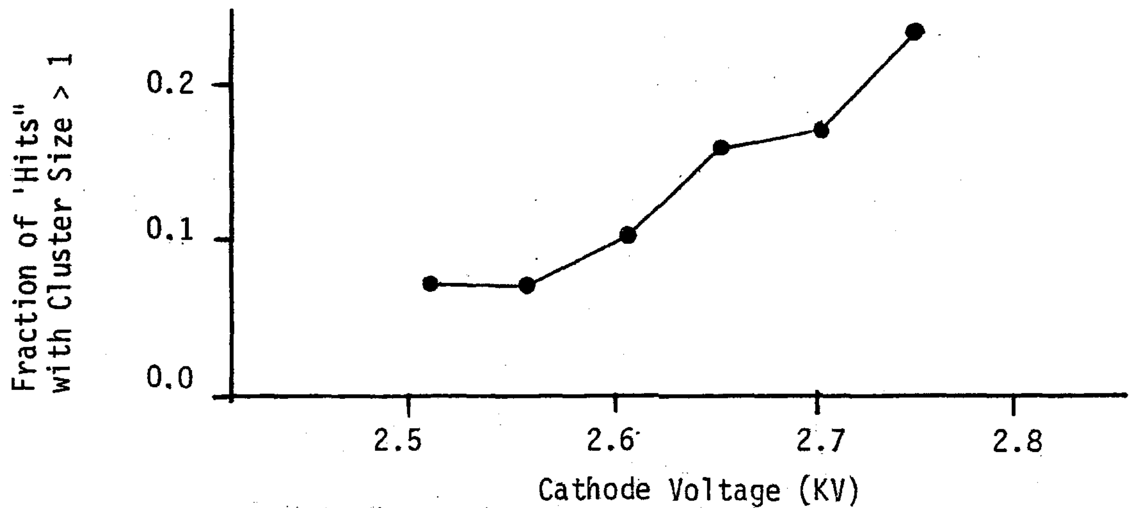

Figure 5b) Fraction of hits in a) involving more than one wire.

APPENDIX

Effects of Variations in Gas Fill And Discriminator Threshold

The test results presented here were obtained on a prototype chamber one half the size of the production model described in this report, as well as on a full size model. The small prototype was wound with 0.0005" diameter sense wires (as opposed to 0.0004" in the production model). In all other respects relevant to chamber operation it is identical to the production model. Wire spacing, half gap, and materials used are the same. Readout electronics were different, however. Three different amplifier / discriminators were tested, and the gas fill was varied. Many precautions were taken to allow operation of the electronics at the lowest possible threshold.

Freon 13B1 (monobromotrifluoromethane) is commonly used as a component in PWC gas mixtures because of its high electronegativity. It reduces the mean free path for electron capture and is therefore believed to reduce the probability of a spark discharge, as well as the effective size of the sensitive region around the anode wires. Although the goal was to produce a detector that would operate in the most simple gas mixture possible, it was felt that tests with other mixtures should be carried out.

Figure A1 shows plateau curves for the production model chamber filled with 80%/20% $ArCO_2$ plus varying amounts of freon. It can be seen that a slightly higher operating voltage is needed when the gas contains freon (about 50v at the 50% efficiency point with 0.4% freon). No significant change in the breakdown voltage was observed when freon was added to the gas.

It was not possible to obtain results on the effect of freon on spark discharge probability. In all chambers of this series tested, the lowest voltage breakdown occurs in the form of a glow discharge associated with mechanical instability of one of the small diameter wires. In the small prototype, (3" wires), this discharge occurs at a voltage sufficiently higher than the knee of the plateau that no attempt was made to suppress it. In the full size (6" wire) units it was found to be necessary to place relatively large diameter "guard wires" at either edge of the sense plane. Satisfactory suppression of the glow discharge was achieved with two different arrangements of guard wires: a) a 0.001" wire followed by an A.W.G. #28 wire, and b) two or more 0.006" wires. In both cases the guard wires continued the spacing of the sense wires. As far as can be determined, spark discharges involving the wires never occurred unless the glow discharge was already taking place.

Tests were also performed with the small chamber filled with "magic gas" (Argon, 20% Isobutane, 4% Methylal, and 0.5% Freon 13B1). In magic gas the minimum glow discharge voltage was increased significantly, and the plateau voltage was reduced. The plateau curves for operation with magic gas and $ArCO_2$ are shown in fig. A2. As can be seen, the use of magic gas reduces the operating voltage needed to obtain 50% detection efficiency by about 75v. This, coupled with the rise in the breakdown voltage of about 300 volts, can increase the operating window by a few hundred volts. Unfortunately, magic gas is relatively dangerous to use, and has been observed by the author to cause a buildup of material on the anodes and cathodes of proportional wire chambers which is detrimental to their efficient operation.

Plateau curves using a range of threshold current settings are shown in fig. A3. It appears that a factor of two reduction in threshold lowers the 50% efficiency point by about 100v. Users of these (or any other) chambers would therefore be advised to use low threshold electronics both to improve the plateau, and to combat rate-dependent space-charge and breakdown effects [5]. For example, artwork for the amplifier/discriminator of ref. 6 is available upon request.

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5. M. Atac, CDF Note 146 (1982)

6. S. Hansen, FNAL TM-1158 (January 1983)

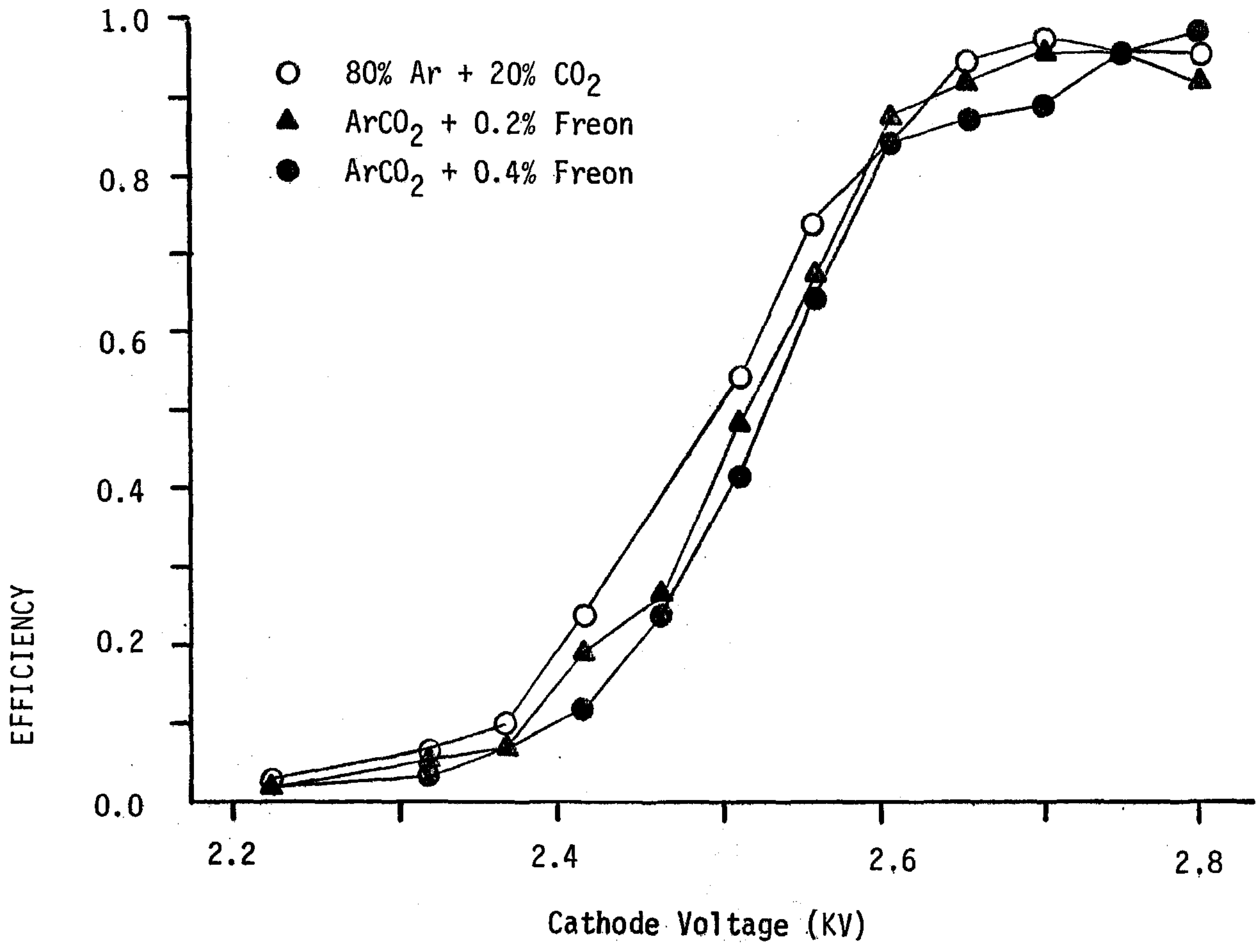

Figure A1. Plateau curves for the production model detector at I_{th} = 1.5 μA with various amounts of Freon added to the $ArCO_2$.

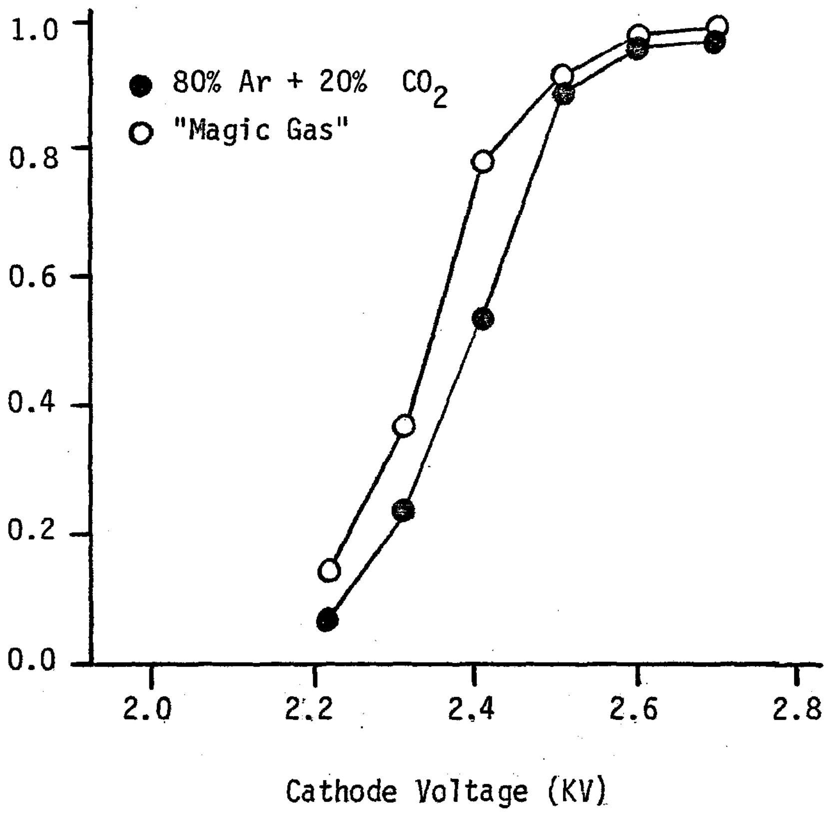

Figure A2. Plateau curves for the small prototype chamber at I_{th} = 1.0 μA using "Magic Gas" (see text) and using 80% Argon + 20% Carbondioxide.

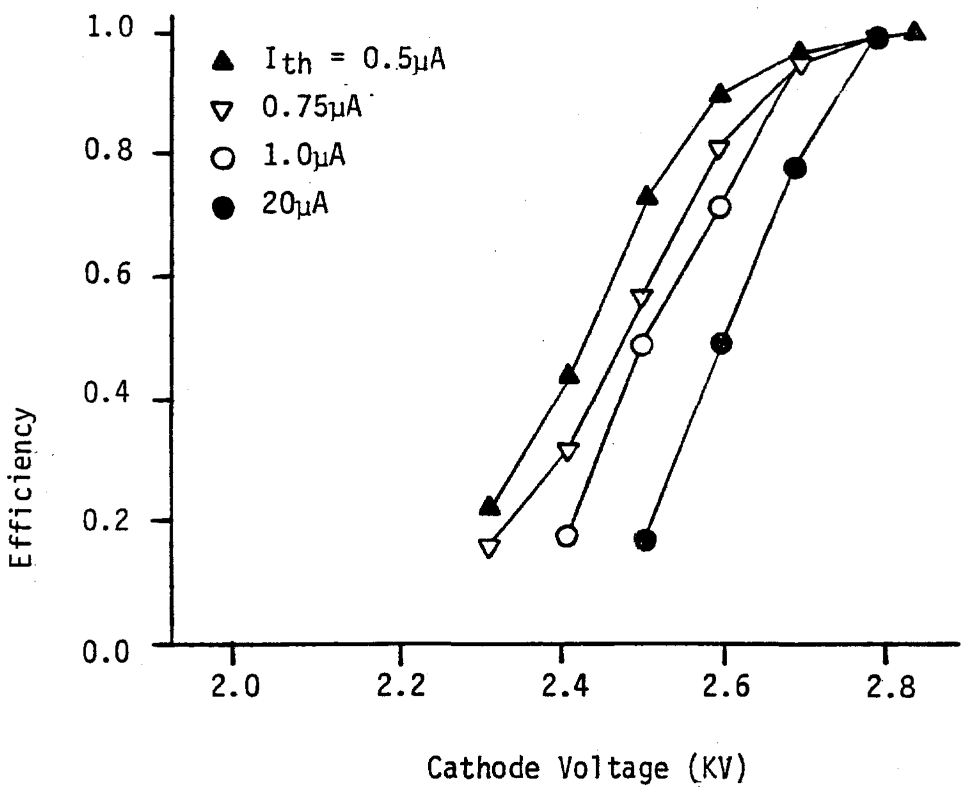

Figure A3. Plateau curves for the small prototype chamber filled with $ArCO_2$ + 0.24% Freon at various threshold current settings.