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MEASUREMENTS OF THE PERFORMANCE OF MULTIWIRE PROPORTIONAL CHAMBERS

by R. W. Austin, A. Eglitis, J. C. Gregory, S. A. Metzger, T. A. Parnell, H. F. Rutledge, W. Selig, and N. P. Cumings

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16. ABSTRACT

This report presents data that may be useful in formulating engineering specifications and test procedures for the proportional counter hodoscope to be flown as part of the High Energy Cosmic Ray Experiment on the High Energy Astronomy Observatory (HEAO), Mission A. A collection of preliminary data taken in laboratory tests of multiwire counters with an anode wire spacing of 5 mm and cathode gap spacing of 1 cm is presented. The data are from laboratory development models or counters for balloon flights and were selected to illustrate several aspects of proper and improper counter performance. Most of the data were taken from a large area proportional counter hodoscope which has an active area of 0.5 by 0.5 m and 104 wires per plane.

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MEASUREMENTS OF THE PERFORMANCE OF MULTIWIRE PROPORTIONAL CHAMBERS

INTRODUCTION

Several proportional counters of the Charpak geometry [1] have been constructed in the Space Sciences Laboratory, with the principal study directed toward the development of a trajectory measuring system for the High Energy Cosmic Ray Experiment (HECRE) on the High Energy Astronomy Observatory, Mission A (HEAO-A) [2]. Another application that has been examined for these counters is a diffractometer utilizing a radioactive X-ray source and a multiwire proportional counter for the simultaneous measurement of the diffraction pattern over a wide angular range [3].

This report is a collection of preliminary data taken in laboratory tests of multiwire counters of the anode wire spacing and cathode gap spacing that applies to the HECRE experiment. The data are from several counters that are laboratory development models or counters for balloon flights and were selected to illustrate several aspects of proper and improper counter performance. In some cases, the performance indicated anomalies caused by gas contaminants and mechanical problems such as improper anode alignment or tension. The purpose of this report is to present data that may be useful in formulating engineering specifications and test procedures for the HEAO counters.

The measurements were taken on two sizes of multiwire proportional counters. The first was a small counter constructed so that the gap spacing and wire spacing could be changed easily. In this report, all data on the small counter were taken with a cathode spacing of 1 cm and an anode spacing of 0.5 cm, the same as the large counter described below. Most of the measurements were taken in the gas flow-through mode.

The large area counter is a balloon flight model of the counter proposed for HEAO-A [2]. The useful active area of the counter is 0.5 by 0.5 m. There are 104 wires per plane with an anode spacing of 0.5 cm. Two versions of this counter were tested, differing primarily in the technique used to construct the cathode planes.

PERFORMANCE OF A SMALL MULTIWIRE COUNTER

Figure 1 shows a small counter of the Charpak geometry which was used to determine some performance figures for various cathode and anode spacings. A cross section of the counter is shown in Figure 2. The construction was such that the geometry could be easily varied over a wide range without a redesign of the entire counter. It was necessary to change only the cathode block and anode insulators to modify the cathode or anode spacing.

The data presented here are for a cathode spacing of 1 cm, an anode spacing of 0.5 cm, and a nominal counter gain of 10^3, which required about 1850 V with 50-μm anode

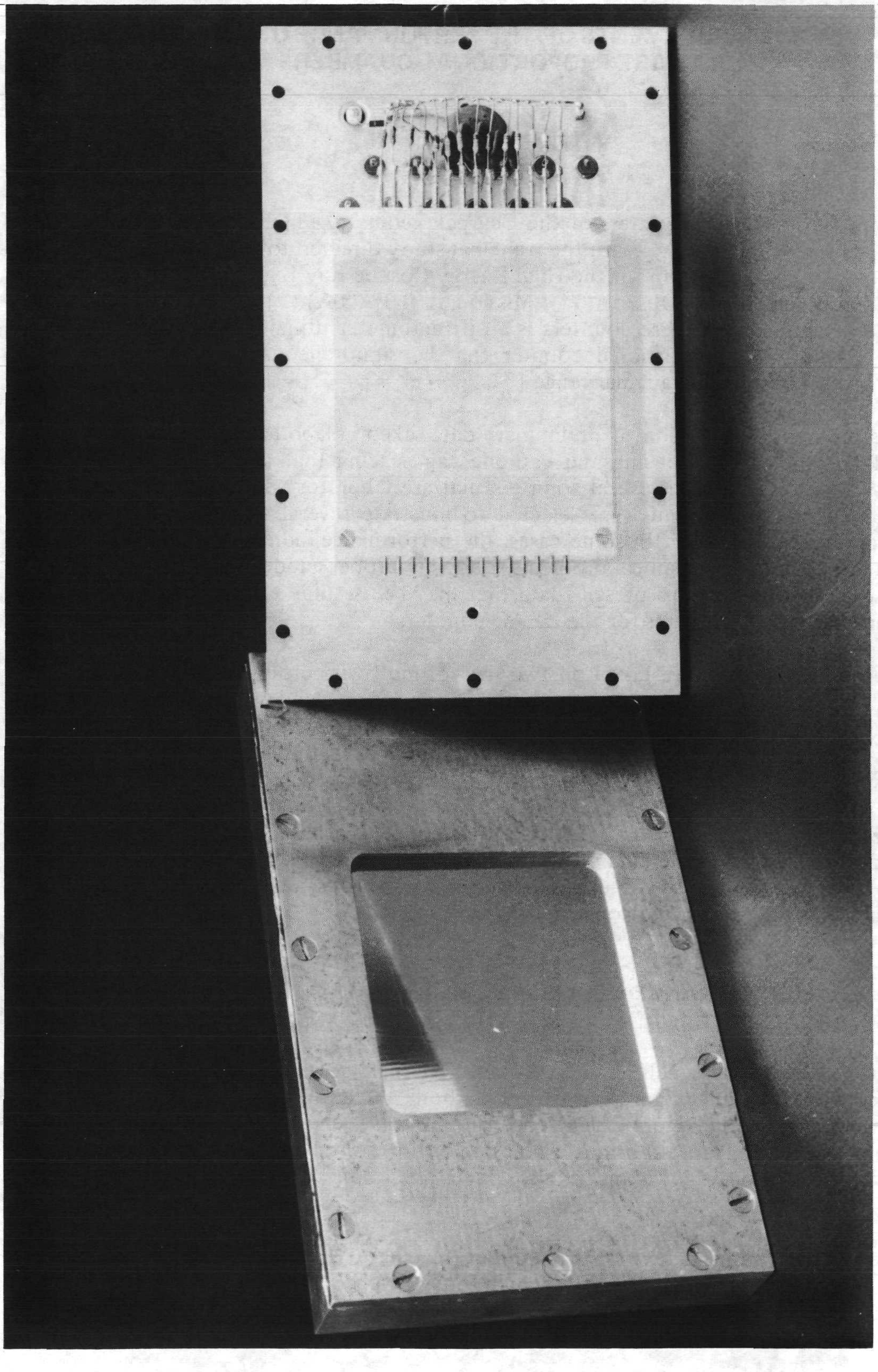
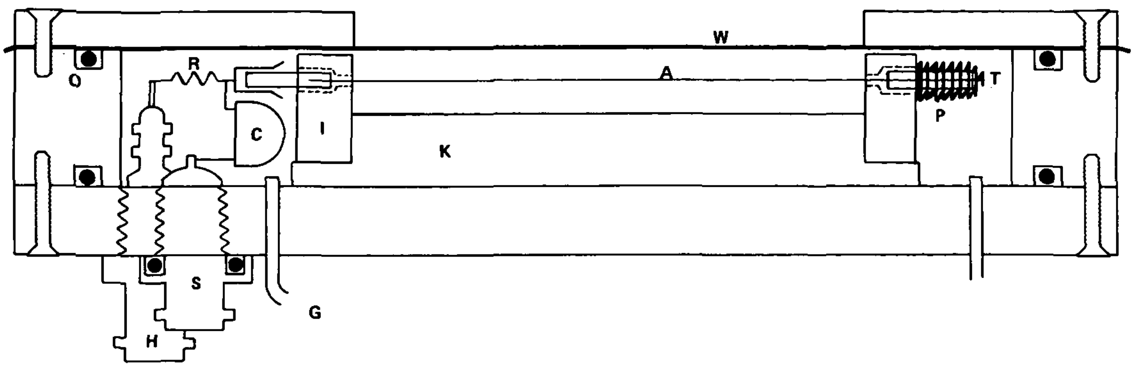


Figure 1. Small counter of Charpak geometry with changeable anode mounts.



LEGEND

A - ANODE WIRES (2 MIL)	O - O RING SEAL
C - COUPLING CAPACITOR	P - ANODE POSITIONING PIN
G - GAS CONNECTIONS	R - LOAD RESISTOR
H - HIGH VOLTAGE CONNECTOR (MHV)	S - SIGNAL CONNECTOR (BNC)
I - INSULATOR BLOCK (KEL F)	T - ANODE TENSION SPRING
K - CATHODE BLOCK	W - WINDOW (ALUMINIZED MYLAR OR AL FOIL)

Figure 2. Cross section of small multiwire counter.

wires and an argon-methane (P-10) mixture. The data were taken with an Fe^{55} source collimated by two 0.018-cm slits separated by 3.75 cm. This defined a fan-shaped beam 40 degrees by 0.26 degrees wide. The Fe^{55} beam was approximately 1 mm wide in the center of the counter. For the data shown in Figures 3, 4 and 5, the collimated beam was driven perpendicular to the anode wires by a small lathe tool drive shown in Figure 6.

These data show the functioning of the multiwire proportional counter in collecting the charge of the incident particle on the nearest anode. There is only a small region in which charge may be "shared" between anode wires. The pulse height spectra show that the counter acts much as if it were composed of rectangular cells centered on the anode wires.

LARGE AREA HODOSCOPE FOR BALLOON FLIGHT

Figure 7 shows a cross section of the large area counter with the associated key to the components, and Figure 8 is a photograph of these counters. Three cathode planes and two anode planes constitute one X-Y pair. The anode planes are composed of individual electrically isolated wires, and the wires of one plane are perpendicular to the other so that they provide a set of X-Y coordinates for the particle position. The anodes are 1 cm apart with a cathode plane centered between them and a cathode plane on the outside of each. (Therefore, there are three cathode planes, with the center cathode plane being shared by the two anode planes.) The cathode planes are 5 mm from the anodes. The anodes are 50-μm (2-mil) diameter stainless steel wires spaced 5 mm apart in the plane. Each anode wire is under 50 grams of tension which is maintained nearly constant with a spring.

Test Counter No. 1

The outer cathode planes of test counter No. 1 are continuously strung stainless steel wires 0.015 cm in diameter and spaced 1.5 mm apart. Each length of wire is under 50 grams of tension provided by toroidal springs at each span. Therefore, for a 50-cm length, relatively large forces are built up on the supporting brackets. The cathode plane wires are perpendicular to the anode wires. The center cathode plane is stainless steel mesh composed of 50-μm wires spaced to give 50-percent transparency.

Figure 9 shows how the ends of the anode wire are secured. Each anode plane has 104 wires, of which 100 are counting wires. The last wires in each plane are 0.05 cm in diameter to allow greater tension to aid in uniformity at the edges. The outer cathode planes also have an additional 0.05-cm diameter wire as the outer wire in each plane.

This X-Y pair configuration was installed in a housing and sealed off on both top and bottom with two diaphragms. The seals for these tests were conventional O-rings. The top diaphragm was 0.63-cm thick plexiglass. This diaphragm had three slits cut through for irradiation of the counter with an Fe^{55} source located outside. These slits were sealed with transparent tape on the inside of the diaphragm. This formed an adequate window when the counter was operated in the flow-through mode at about 0.1 ft^3/hour. The bottom diaphragm was of aluminum honeycomb construction, 0.73 cm thick. The diaphragm was made from a 74-cm by 74-cm aluminum sheet with a 50-cm by 50-cm window cut out for the honeycomb, thus leaving solid aluminum around the periphery for sealing. Honeycomb was installed in the 50-cm by 50-cm area with 0.05-cm face sheets covering both the window and the solid aluminum.

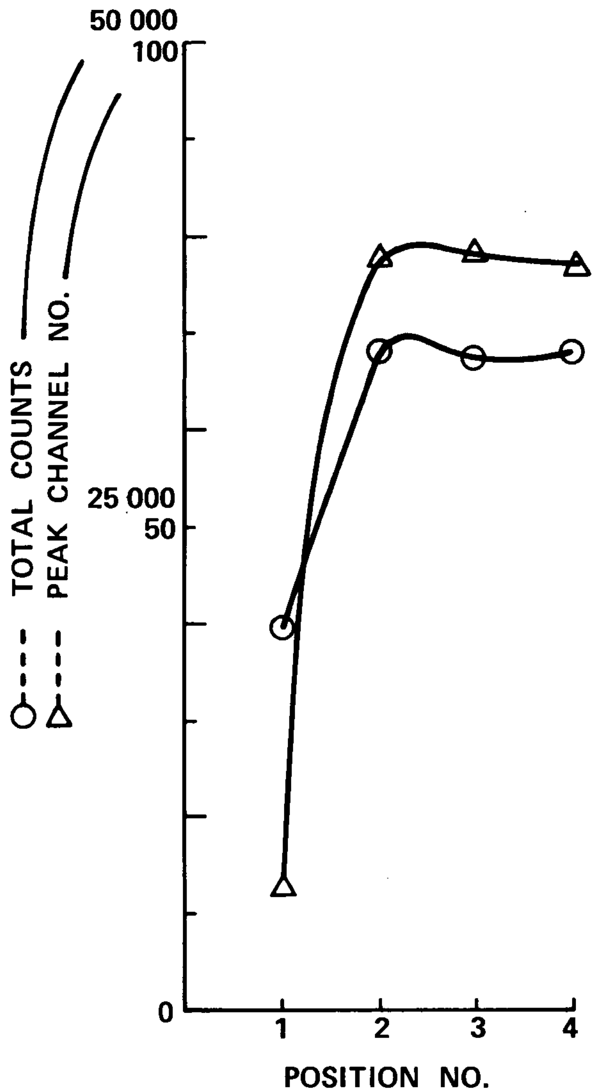


Figure 3. Position resolution of small counter at boundary of counter cell.

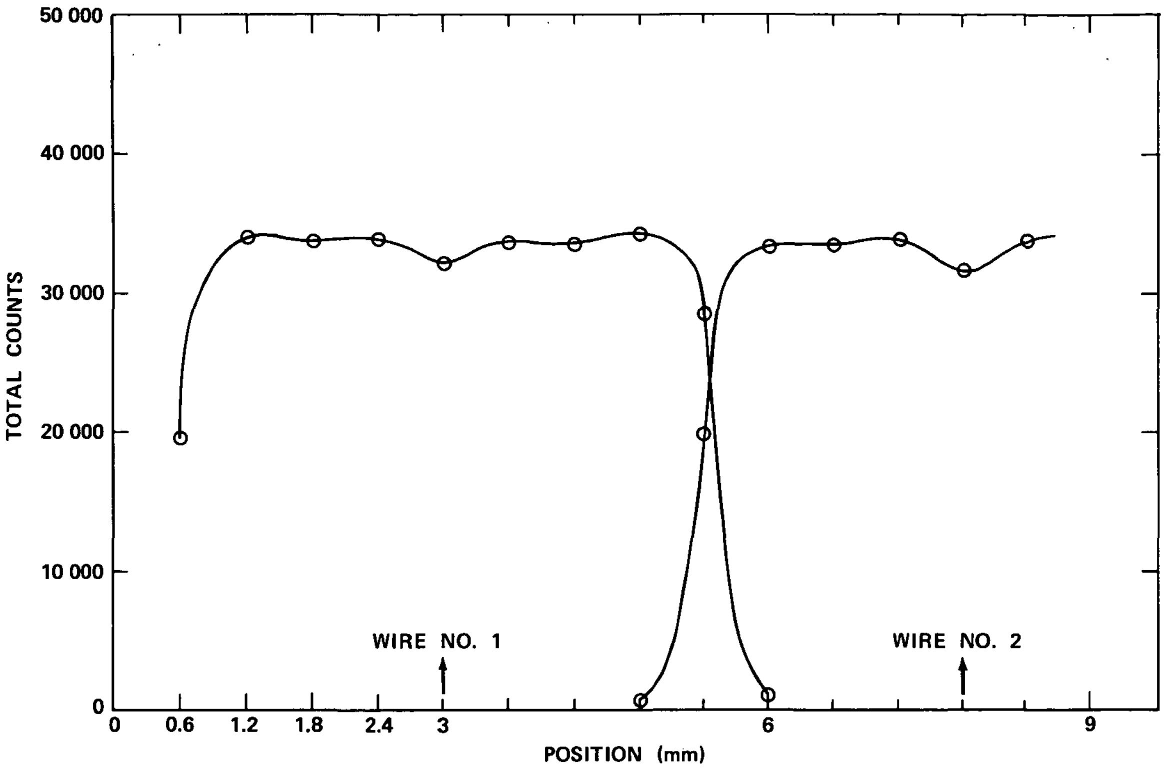


Figure 4. Position resolution of small counter for two adjacent wires.

Test Counter No. 2

Test counter No. 2 is of the same general configuration as test counter No. 1 except that all three cathode planes are stretched stainless steel mesh of 50-percent transparency and there are only 10 anode wires near the center of each plane. Thus, the active area was only 5 cm by 50 cm. The counter housing is the same as counter No. 1, and both diaphragms are of the aluminum honeycomb construction. The Fe^{55} source was mounted on soft iron plates and placed inside the counter. The source was moved from the outside using a permanent magnet.

MEASUREMENTS ON THE LARGE AREA COUNTERS

Purpose of Tests

The principal purpose of the tests described here was to develop procedures to be used in checking out large area multiwire proportional counters for the HEAO experiment ACR-6. The counters under test were designed for a balloon instrument and had a smaller

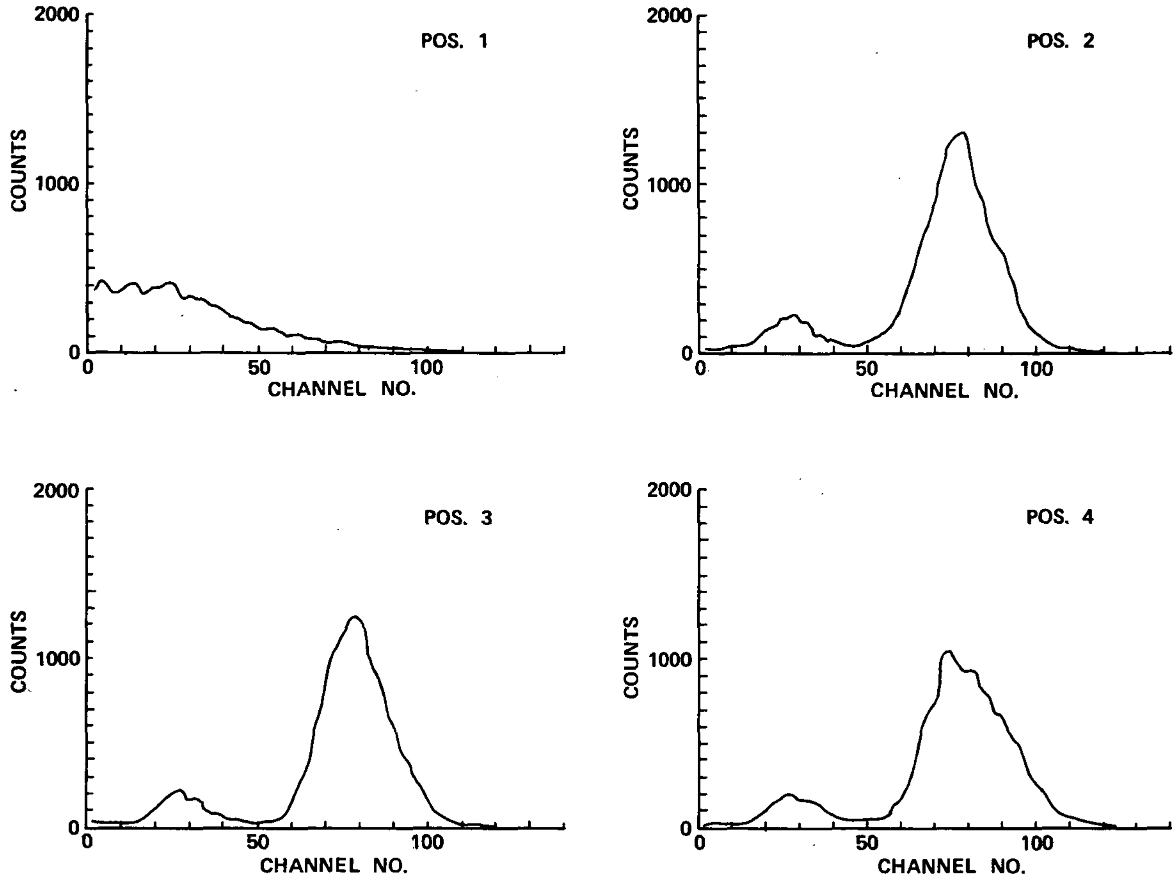


Figure 5. Fe^{55} pulse height distribution corresponding to Figure 4.

area than the HEAO counters, but the construction techniques were very similar to those proposed for flight. The data presented here indicate several problems, particularly in the mechanical area, which will be rectified in the flight hardware design. These tests indicated that mechanical tolerances, maintenance of anode and cathode wire tension, and freedom of electrodes from sharp conducting points and metal filings are vital concerns.

Conditions of Tests

Figure 10 is a block diagram of the test setup.

1. Two different counters were used. The main difference was that test counter No. 2 used stretched stainless steel mesh for all three cathode planes. Test counter No. 1 had stretched stainless steel mesh for only the inner cathode plane. The two outer cathode planes were continuously strung 0.015-cm stainless steel wire. The same gas housing was used for both counters. This housing was cleaned ultrasonically in trichlorethylene after bead blasting, but no leak testing had been performed.

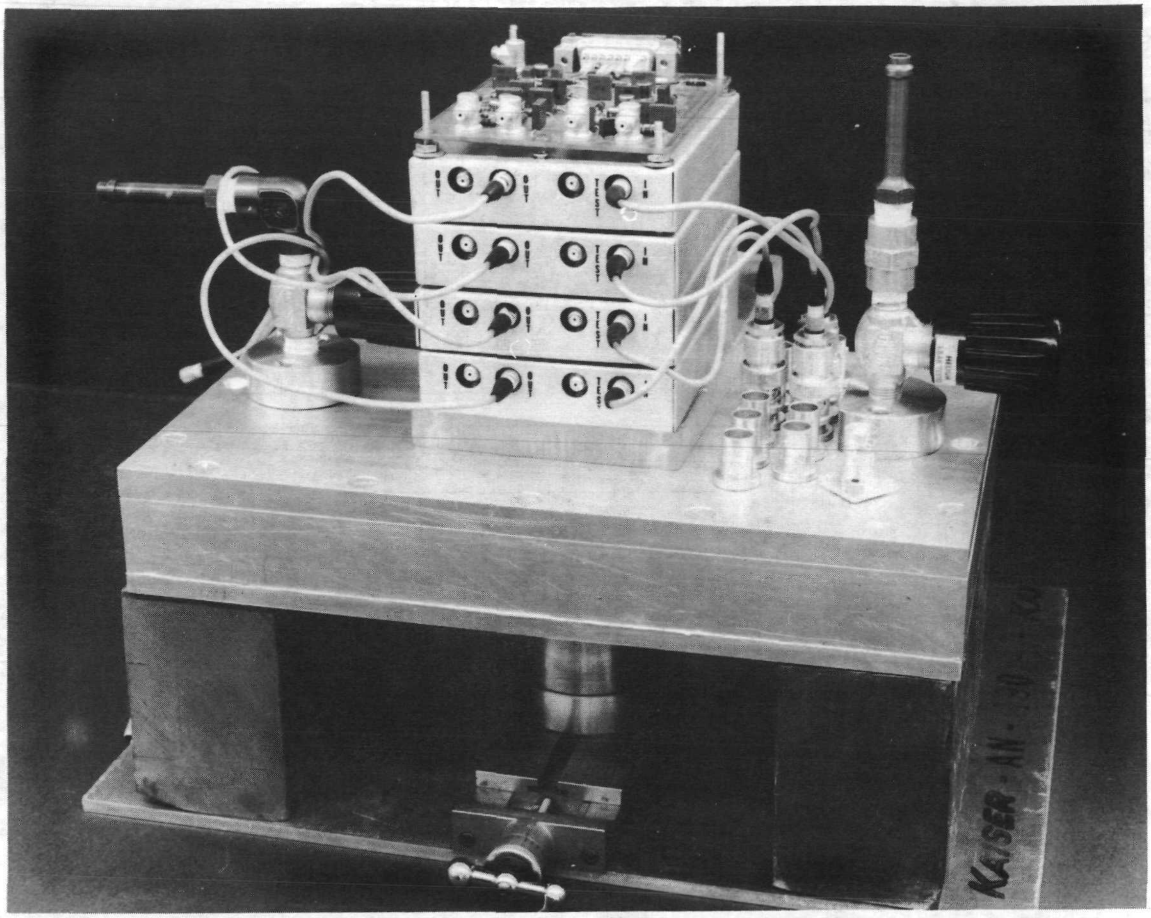


Figure 6. View of small counter in operating position showing lathe tool drive for moving Fe^{55} source.

2. Mode of operation was a gas flow-through of 92.5-percent Ar and 7.5-percent CO_2 at 0.1 to 0.25 ft^3/hour.

3. Results were not adjusted according to daily fluctuations in barometric pressure.

4. Data analysis uses the "highest number" of counts to determine the peak channel number. For most data, between 10^2 and 10^4 counts were accumulated in the peak. For a sample of data, a curve-fitting method of determining the peak was used. The peak channel differed, at most, by five channels, or about 3 percent, between the two methods of finding the peak.

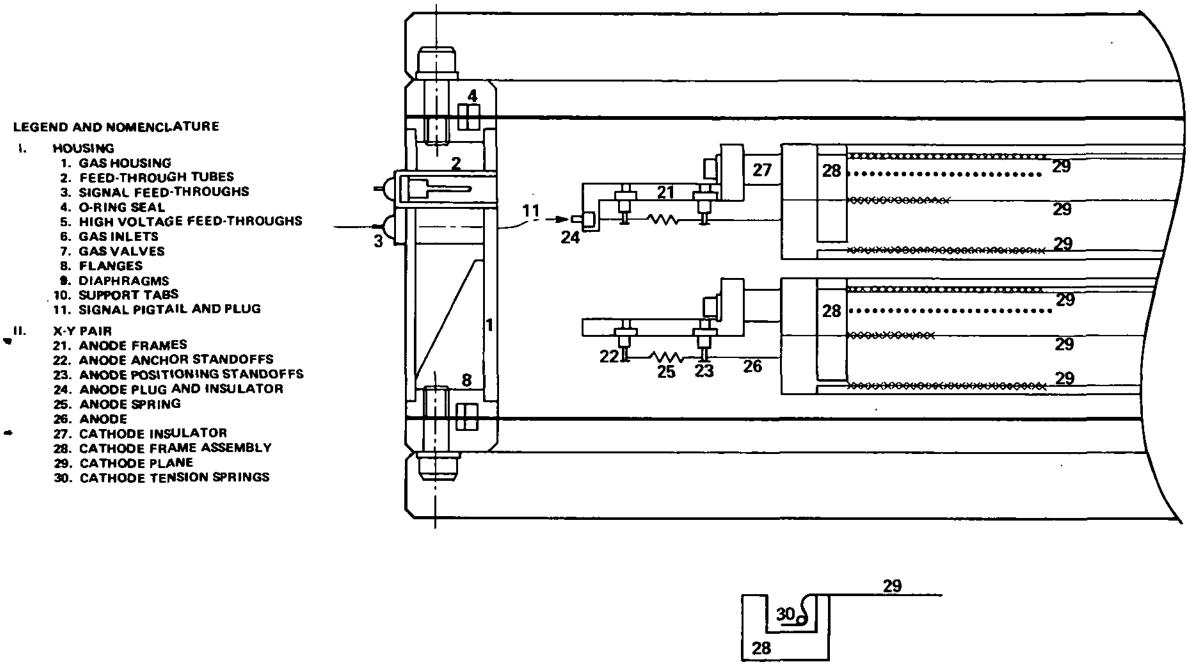


Figure 7. Balloon proportional counter (HEAO).

5. The full width-half maximum (FWHM) resolution was determined in the usual manner. Since the pulse height analyzer (PHA) had a zero offset, the resolution was determined by the following correction:

$$\left(\frac{2.96}{Ep-Ees}\right) \left(\frac{FWHM}{5.89}\right) ,$$

where

Ep = peak channel number,

Ees = escape peak channel number,

2.96 = energy level of escape peak

and

5.89 = energy level of main peak.

6. An Fe^{55} source was used for most of the performance tests. Some tests with mu-mesons are reported.

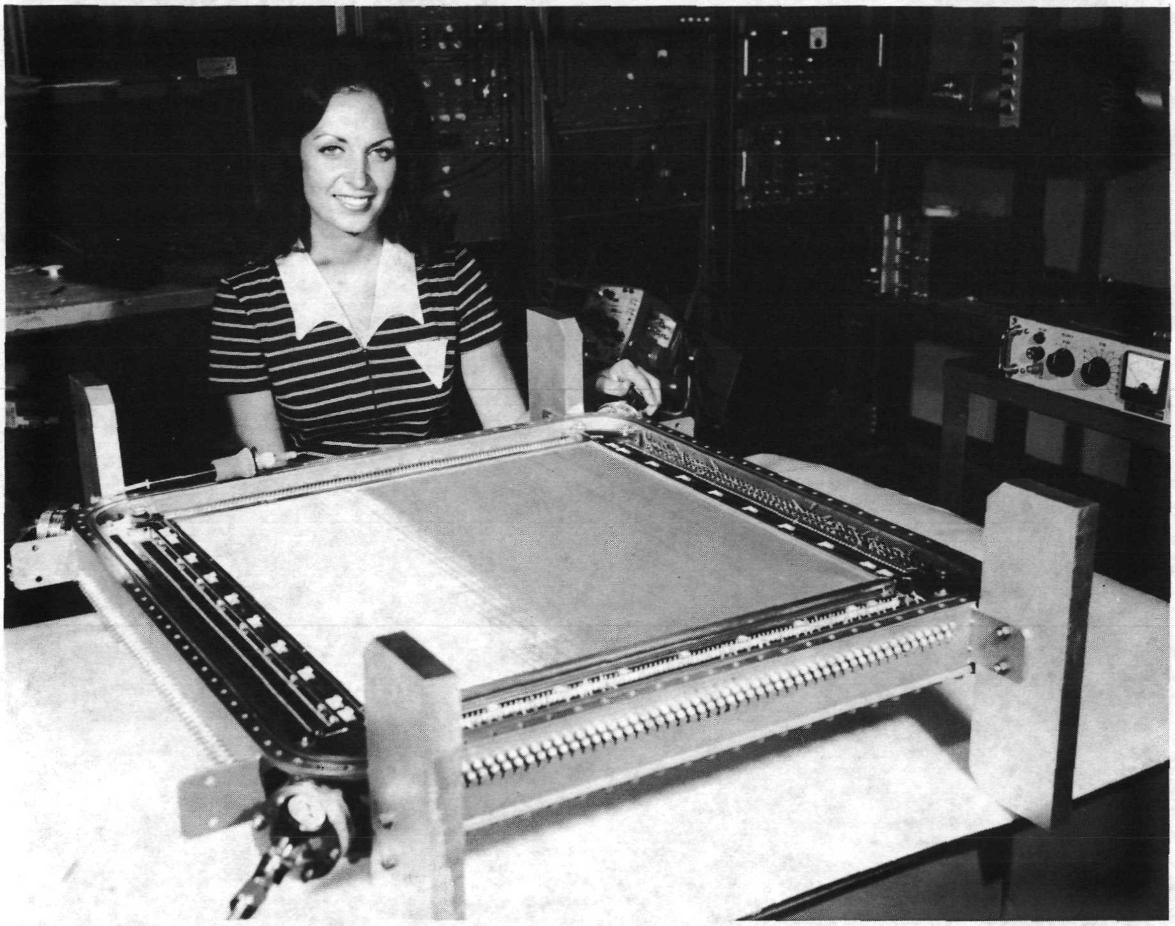


Figure 8. Overall view of large area proportional counter.

Gain Uniformity Tests

The first counter under test was counter No. 1, described previously. The ends of all signal outputs were at ground except the one under test, and the cathode potential was 1950 V. The first test was run on wire No. 53 of the Y-plane. The radioactive source was moved along the length of the wire, and spectra were taken at different positions. Test results are shown in Figure 11. After examining the remainder of the data, the high gain on the end of the wire was explained by a warped outer cathode plane. This warpage was a result of the accumulated stress of the 50-gram tension on the individual cathode wires. Fluctuations in gain toward the center of the wire were suspected to have their origins in the nonuniformity of the inner cathode and electrostatic force problems. There were obvious wrinkles in the cathode screen that could be seen by reflected light.

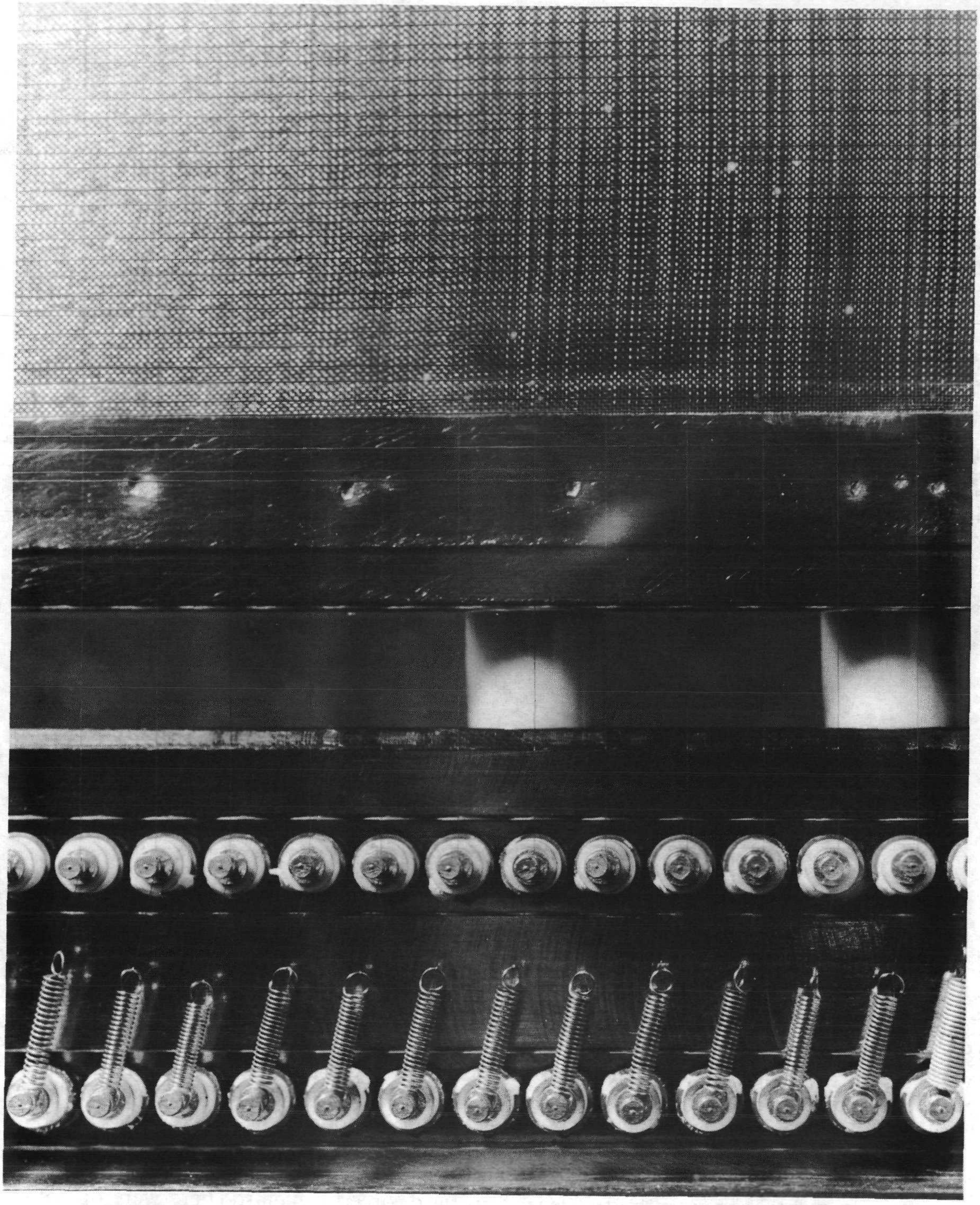


Figure 9. Large area proportional counter showing mechanical attachment of anode wires.

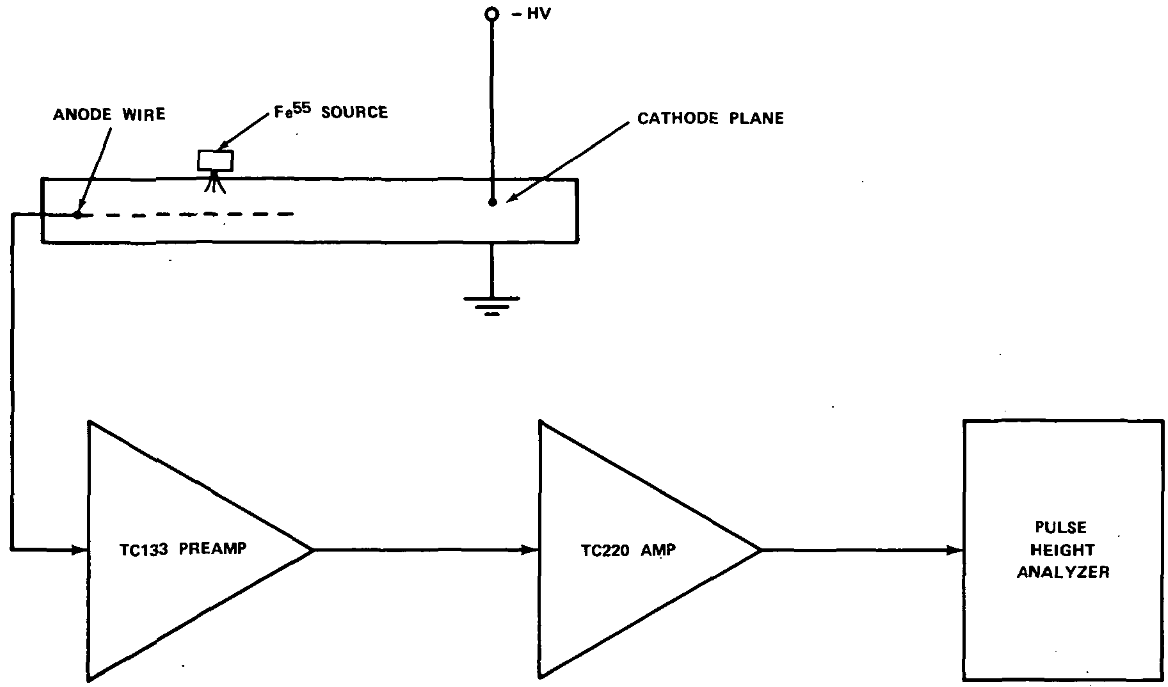


Figure 10. Experimental test setup.

All the remaining data were taken with the high voltage at 2100 V. The various anomalies in the center cathode screen were inspected in the following manner. The source was positioned above the Y-plane anode and a spectrum was taken. Then the corresponding X-plane anode wire was inspected without moving the source. The data taken in this configuration confirmed the suspicion that anomalies in the inner cathode screen caused gain variations. The data in Figure 12 show the overall sag of the screen, since the highest gain in the X-plane corresponds to the point of lowest gain in the Y-plane. The same type of test was done on anode 78 and corresponding X-wires. The same general results were observed.

The counter configuration was changed for the following data. The X-plane was on the top closest to the radioactive source on the plexiglass diaphragm. An aluminum rod 54 cm long and weighing 413 grams was laid across the continuously strung cathode plane above the X-plane counting wires approximately in the center of the plane. A measurement showed the total deflection of the cathode plane by the bar to be approximately 1.5 mm. The maximum gain change caused by this deflection was about 130 percent (Fig. 13). The bar was then removed, and gains were measured on the same wires (Fig. 14). The gain variation was approximately 20 percent, neglecting the high gain on wire 50, which was possibly permanently deformed during the presence of the bar. This measurement confirmed an approximate calculation that a 1-mm deflection of the cathode (anodes held fixed) would cause a 100-percent gain change.

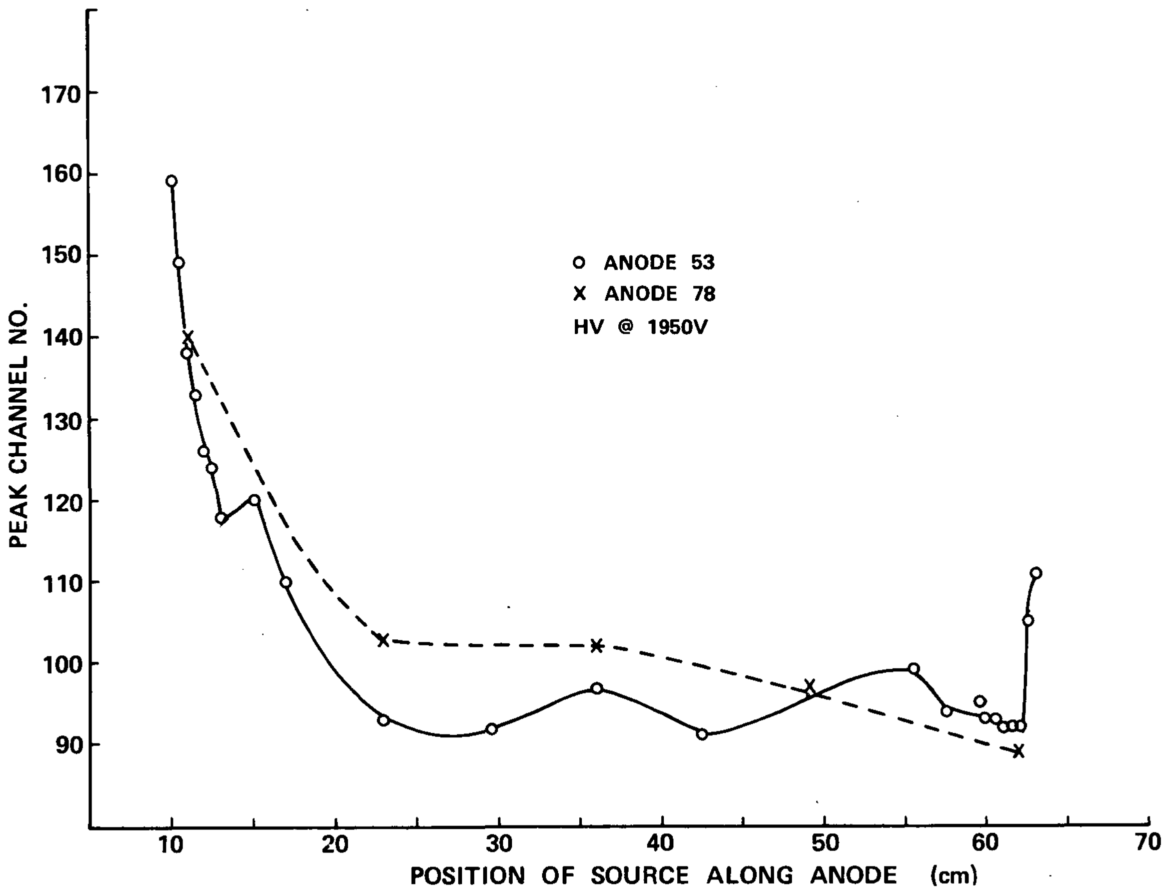


Figure 11. Warpage of cathode plane resulting in high gain near ends of anode.

A test was run to determine whether the wire spacing of the continuously strung cathode plane was small enough to provide a sufficiently even electric field distribution near the anode. On anode 78 of the Y-plane, the source was moved in 10 steps of 0.63 mm from one position. Gain change of less than 3 percent (the statistical error) indicated that a spacing of 2 mm is suitable for the continuously strung cathode plane.

Gas Purge Test

With the gas flow-through mode of operation, the counter has a continuous fresh supply of Ar-CO_2, and minor leaks are not important. The experimental setup includes an outflow through a 0.3175-cm diameter stainless steel tube into a test tube filled with HE 200 vacuum pump fluid (silicone oil). By monitoring the bubbles of the outflow and using a

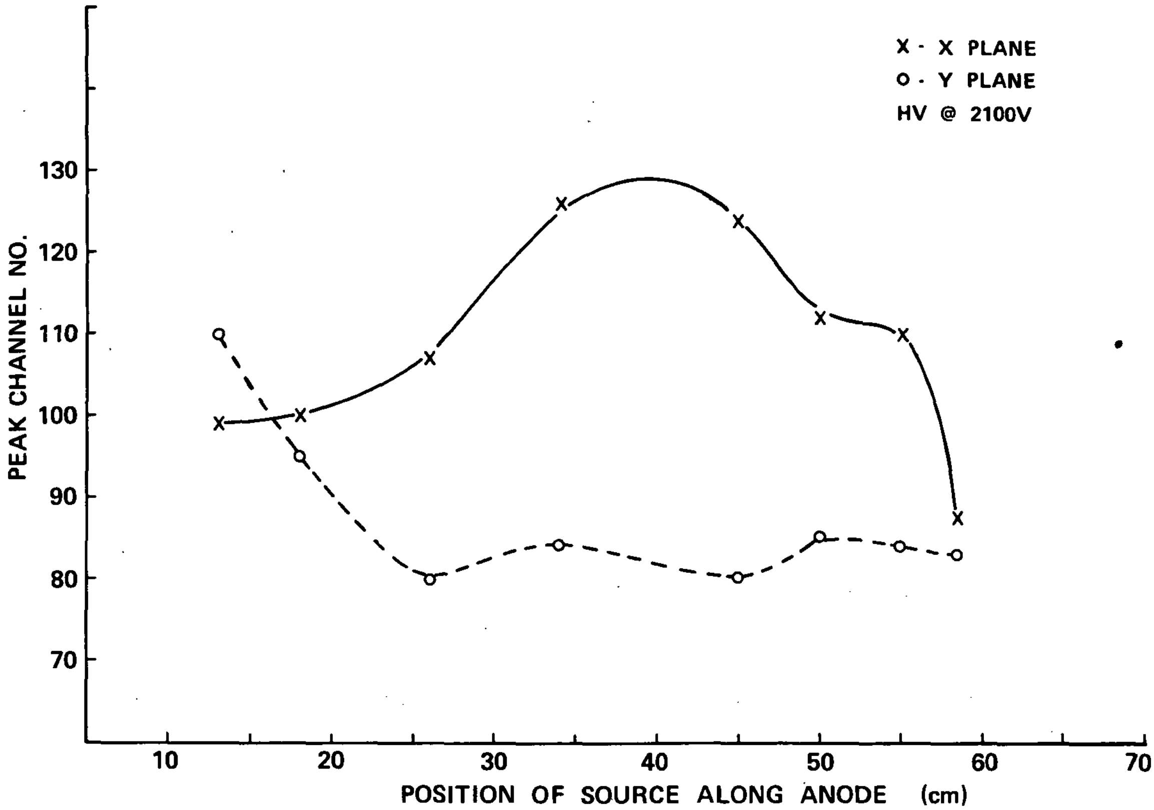


Figure 12. *Anomalies in cathode plane resulting in a nonuniform field.*

gas flowmeter, the actual gas flow can be easily monitored over a wide range of flow rates. A purge of 0.1 ft^3/hour was usually maintained on our counters during the tests described here.

The time required to purge a counter from initial filling with air to stable counting operation is approximately that required to flow through a volume of gas equivalent to ten times the counter volume. The large area counter described here had a volume of about 1 ft^3 and required 15 to 20 hours at 0.5 ft^3/hour to stabilize in gain. Figure 15 is a curve of pulse height versus time for a counter being purged at 0.5 ft^3/hour. This was performed with the plexiglas diaphragm configuration. The Fe^{55} resolution was nearly constant at 23 percent over the 8 hours.

Mu-meson Tests

Six wires on a counter were tied together and one preamplifier was used to accumulate the pulse height distributions shown in Figure 16. The upper photograph of the figure shows an Fe^{55} spectrum from the six wires. The middle photograph shows an

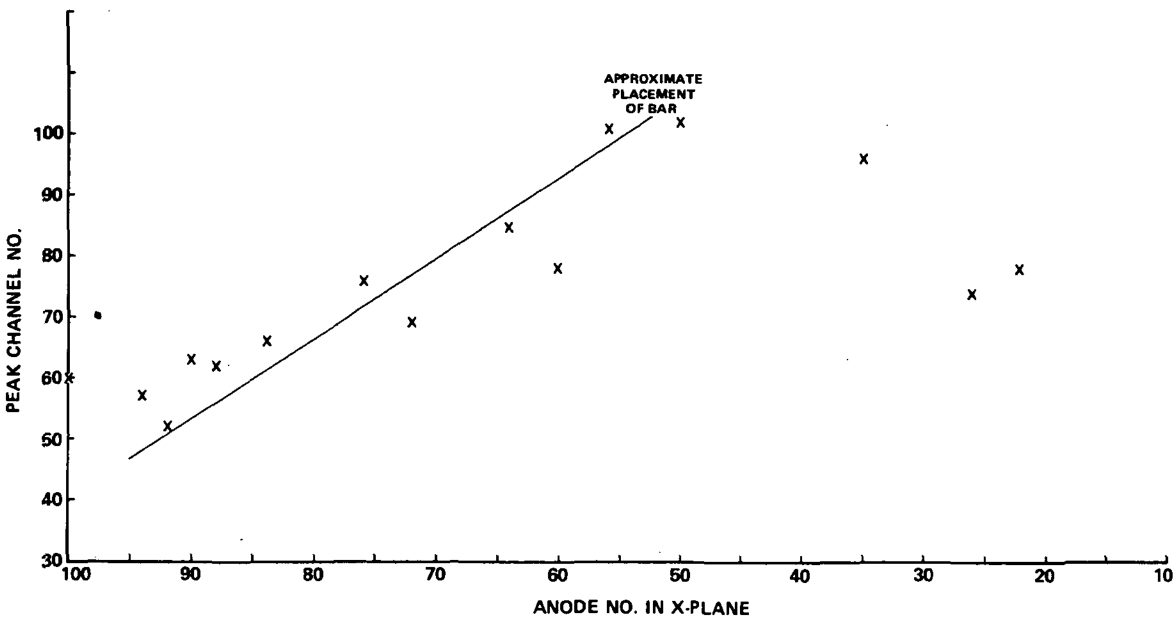


Figure 13. Gain change resulting from deflection of cathode by aluminum rod.

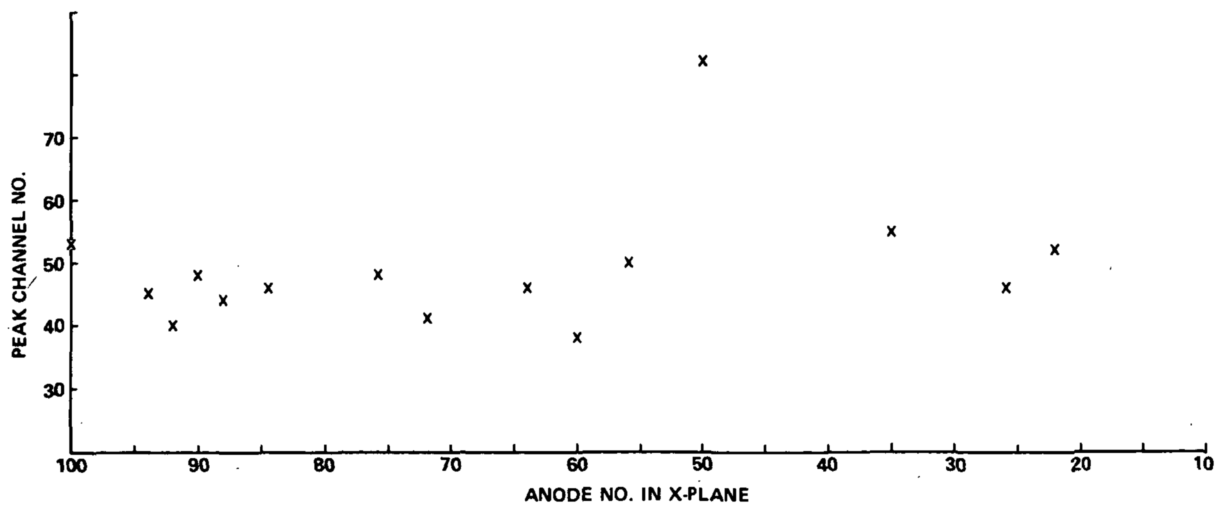


Figure 14. Plot of gain versus position after removal of aluminum rod.

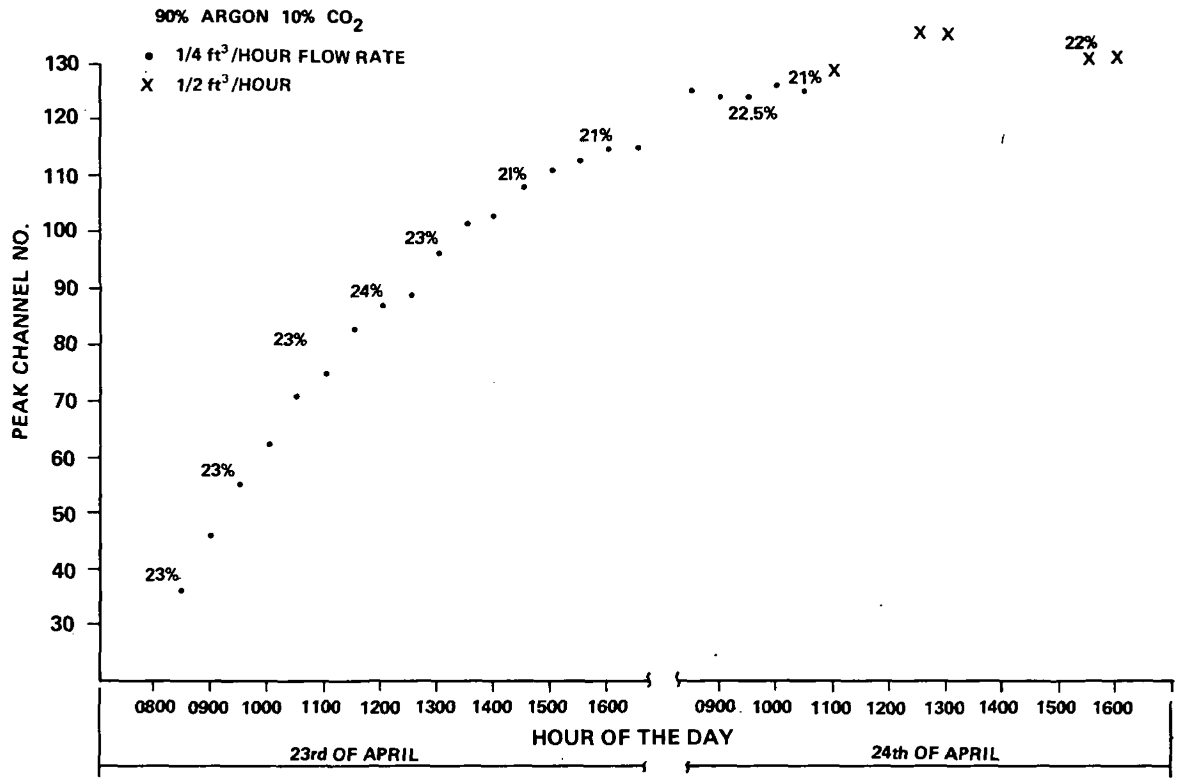


Figure 15. Plot of pulse height versus time for a gas purge.

ungated spectrum of the outputs of the six wires exposed to the background radiation in the laboratory for 12 hours. The mu-meson peak in this spectrum is obvious. Next, two scintillators (one above and one below the counter) were used to gate the outputs of the six wires to produce the relatively pure mu-meson spectrum seen in the lower photograph. It is broad since no attempt at collimation or energy discrimination was made. Nevertheless, it is seen that the peak of the distribution is near the predicted 2 keV.

The second large area counter under test was the 10-wire counter with all three cathode planes composed of stainless steel mesh. The two diaphragms were composed of 0.0508-cm aluminum sheets with a honeycomb web sandwiched between them. The source was Fe^{55} at 1.2 mCi inside an aluminum collimator. The source was manually moved by a magnet from the outside. The source beam was collimated and was 5.72 mm in diameter on the X-plane and 7.75 mm in diameter on the Y-plane.

With the X-plane closest to the radioactive source, tests were performed to determine the gain uniformity from wire to wire and at different positions along each wire. Test results are shown in Figure 17. The average gain change along one wire is 20 percent. From wire to wire, the gain change is about 20 percent and total variation is 20 percent, considering only the inner six wires. The four outer wires vary more in gain because of the electric field nonuniformities.

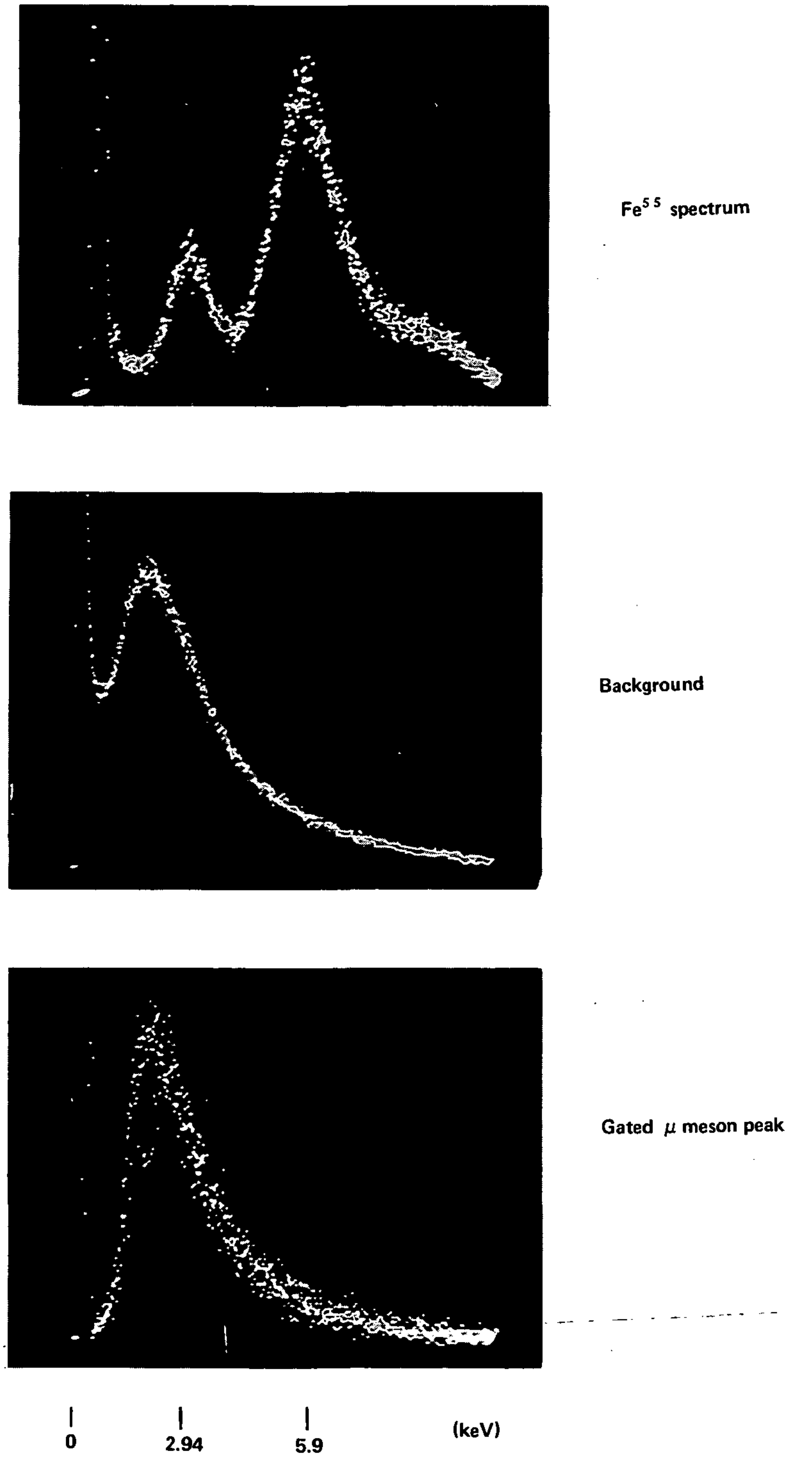


Figure 16. Mu-meson test showing Fe^{55} and mu-meson peaks.

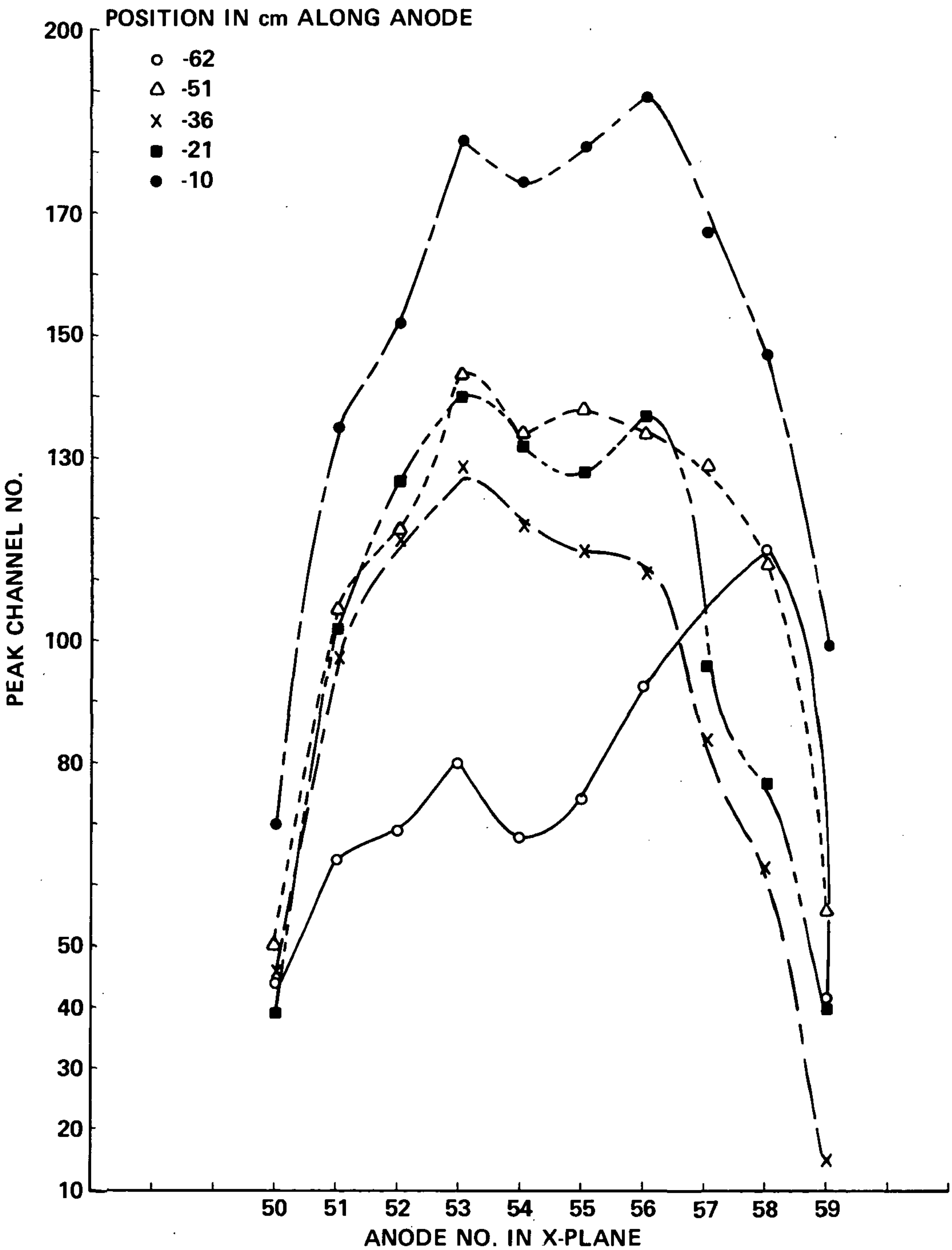


Figure 17. Plot of gain versus position and anode for large area counter No. 3.

Spectra taken on the X-plane consistently had an anomalous hump on the high energy side of the distribution (Fig. 18). A similar anomaly of the Fe^{55} pulse height spectra in proportional counters has been previously reported [4] and attributed to deposits on the anode wire. Inconsistencies in the reproducibility of this effect in our counters have led to the speculation that the cause in our case may be nonuniform electric fields caused by anode or cathode sagging. Testing on this effort is inconclusive at this time.

Gain Versus Pressure and High Voltage

A measurement was made to determine how pressure affects gain. The same setup was used, and to obtain pressure variation, the stainless steel tube for the gas vent was positioned deeper into the oil-filled test tube on the outflow line. From approximately atmospheric pressure in the counter at the top of the test tube to 30.48 cm into the tube, which corresponds to a pressure change of 2.7 percent, the gain decreased by 20 percent (Fig. 19). Resolution was not affected.

The high voltage versus gain test results are shown in Figure 20. These results show that a 1 percent change in counter high voltage brings about a 16 percent change in the counter gain around the operating voltage. The high voltage versus gain is actually an exponential.

CONCLUSION

This report has described a number of measurements made on multiwire proportional counters. The data presented here were taken with the first development models of the counters and are intended to illustrate some methods of testing rather than the correct performance of flight model counters.

Nonuniformity of counter gain, which is evident in Figures 11 and 12, will be corrected in the flight model by stiffer frames for the X-Y pairs and improved cathode assembly insulators. These improvements should increase the gain uniformity to ±20 percent, which is the goal for the flight counters.

The large area counters proved very easy to use and relatively trouble free in the flow-through mode. The only difficulties encountered have been caused by small metal filings caught in the cathode screens which have on a few occasions caused corona below the lowest operating voltage. These filings have been removable by a thorough vacuum cleaning of the counter interior. However, in the flight model, all cathodes will utilize stretched wires rather than screen, which should aid in the cleaning process.

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812, March 15, 1973

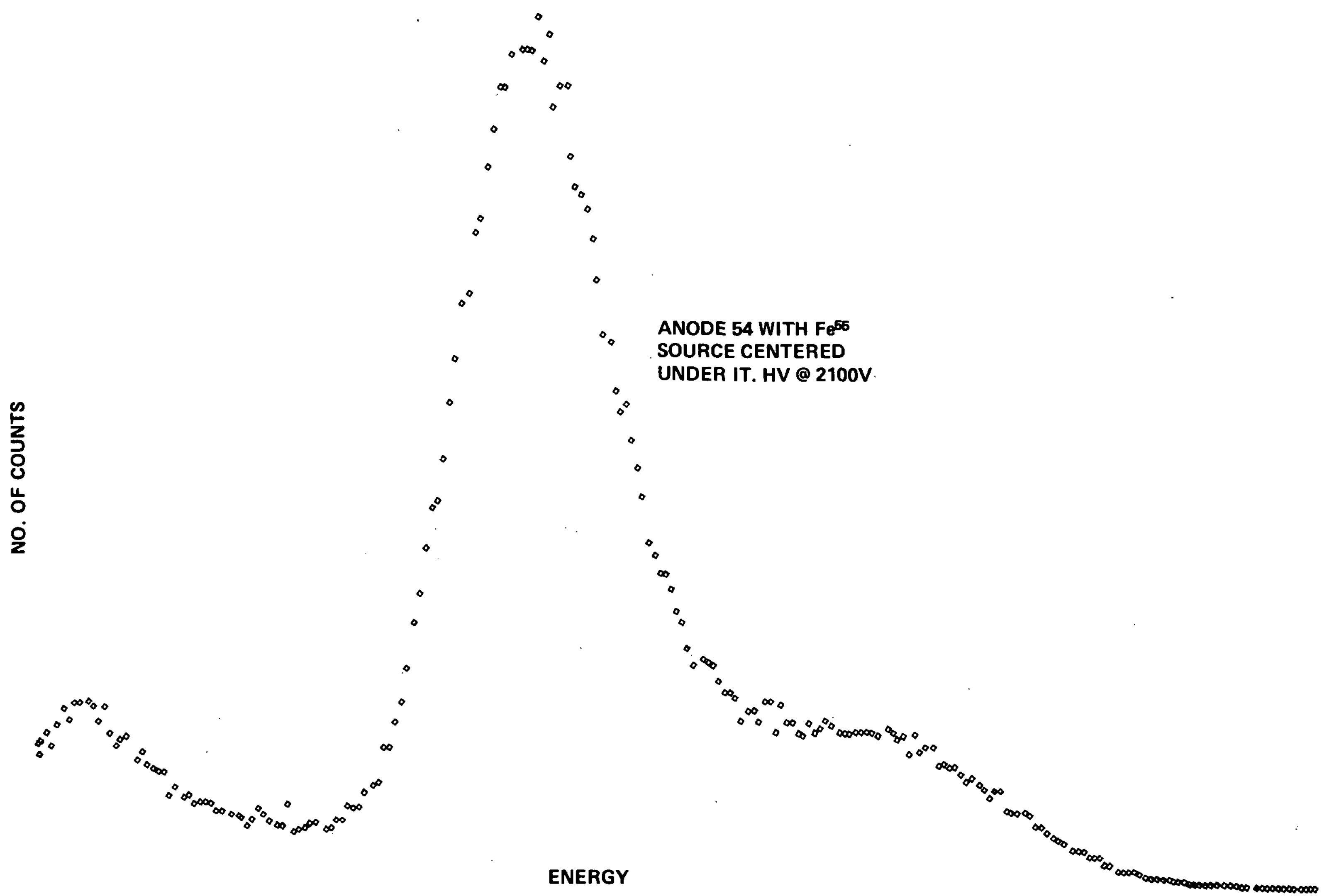


Figure 18. Fe^{55} spectrum with anomaly.

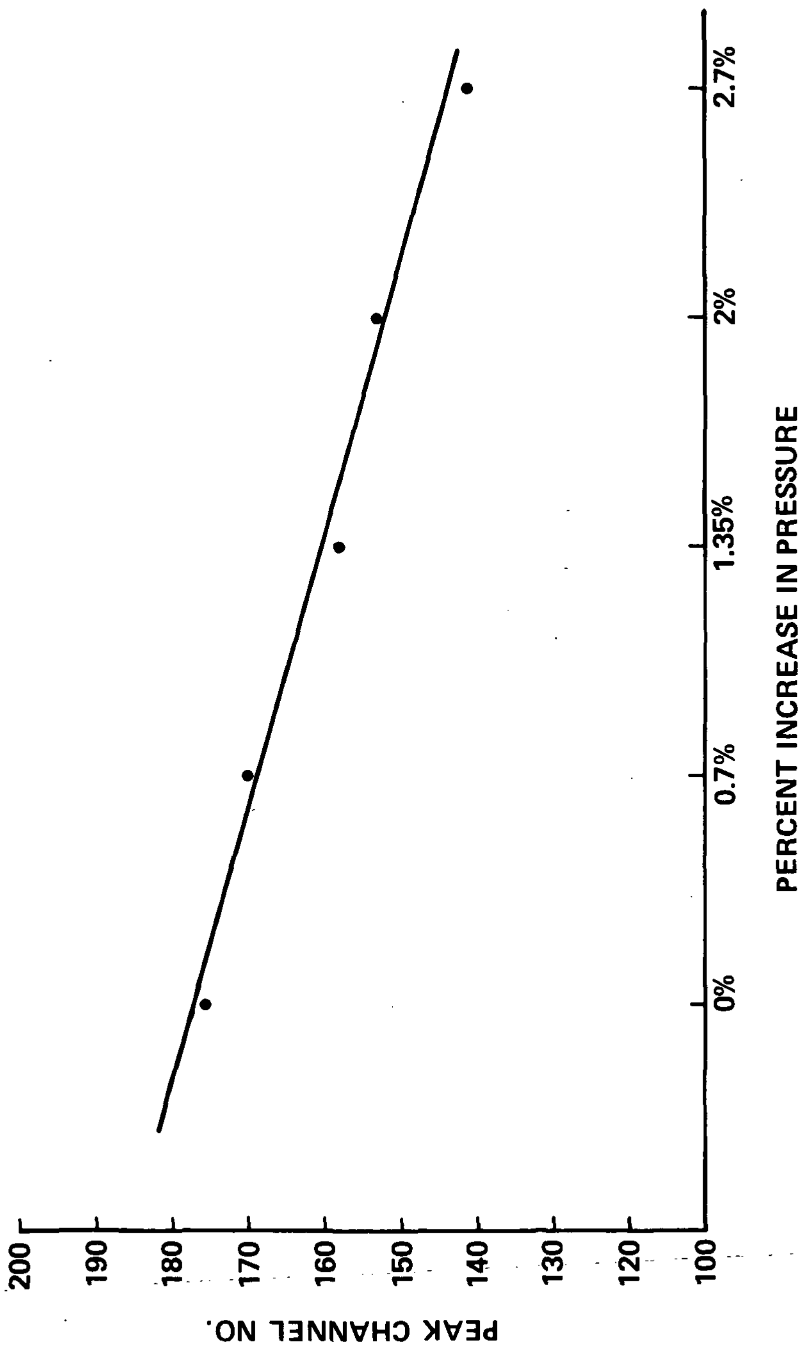

PEAK CHANNEL NO.
200
190
180
170
160
150
140
130
120
100
0%
0.7%
1.35%
2%
2.7%
PERCENT INCREASE IN PRESSURE

Figure 19. Counter gain versus pressure change.

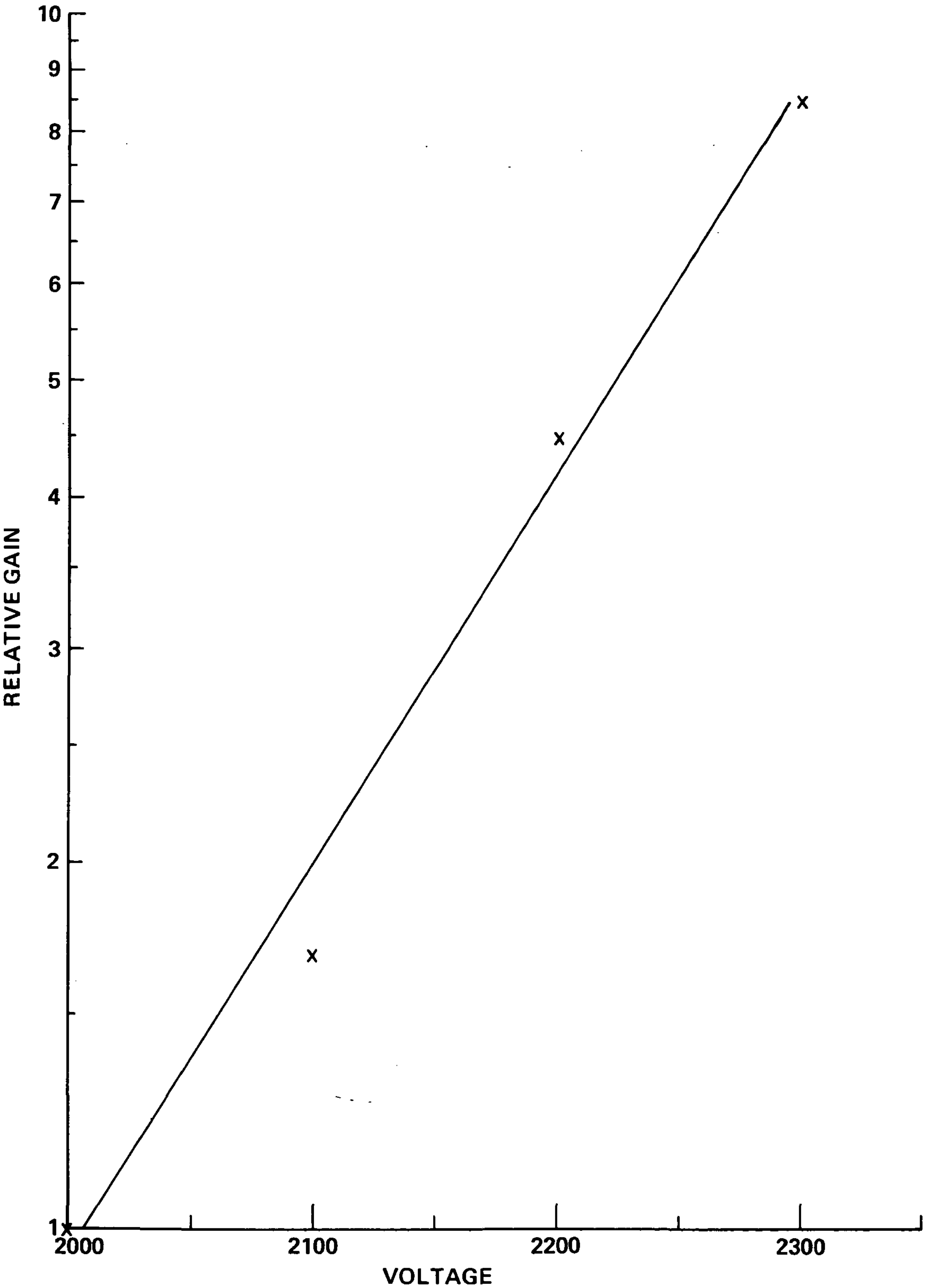


Figure 20. Counter gain versus high voltage.

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