Title
ALPHA-PARTICLE SPECTROGRAPH

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F. L. Reynolds

March 30, 1951

Berkeley, California

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ABSTRACT

An alpha-particle spectrometer, using a 60° sector magnet capable of focusing alpha particles of energies up to 14 mev, is described. Description of the instrument, sample technique, focusing properties, and current supplies are discussed. Transmission is about 0.01% of the total solid angle of the sample and with a resolution of 8 kev.

INTRODUCTION

Initially, the spectrograph was designed to function as a mass spectrograph, but before completion and testing of the mass spectrograph source design it was considered worth while exploring the possibilities of using the instrument as an alpha particle spectrometer and spectrograph. Simple calculation showed that the Hρ values were suitable for focusing all known alpha particle energies and that the dispersion would be adequate for the detection of alpha particle energies differing by as little as eight kilovolts.

GENERAL DESCRIPTION

The field sector is 60°, having a pole face area of 331 square inches. The normal trajectory has a radius of curvature of 75 centimeters.

The entire magnet yoke and coils, which weigh 7 tons are supported on a I beam frame such that the trajectory beam height is about 40 inches off the floor. The source and receiver beam tubes are supported separately on adjustable I beam frames, the beam tubes connected to the gap tank through large bellows for focusing adjustment and alignment. Both the source and receiver ends are equipped with vacuum locks, so that the main trajectory tank remains at high vacuum at all times. From each beam tube there is mounted a liquid nitrogen trap and a 260 liter per second diffusion pump, each diffusion pump unit separated from the tank by a four-inch McBain value. The liquid nitrogen level in the traps is automatically controlled by electronic means and a pressure of 10^{-6} mm of Hg is maintained in the trajectory sections of the vacuum system. General dimensions of the magnet yoke are shown in Fig. 1. The yoke slabs are made of 1010 mild hot rolled steel, machined to a fine finish at their surface of contact and bolted together. The coil slabs are made of similar steel shaped to fit the coil spool, Fig. 2, and bolted to the yoke.

The pole faces form part of the vacuum chamber, and are machined very accurately to fit between the surfaces of the coil slabs. The gap distance of one inch is maintained by brass spacers and the gap tank proper is welded vacuum tight to the pole faces. The gap tank and beam tubes are fabricated of nonmagnetic stainless steel.

The coils are wound on brass spools, having a shape as drawn in Fig. 2. They consist of 17,600 turns each of number 19 formex covered copper wire, each coil having a measured resistance of 1288 ohms. With

0.500 amperes, at 1200 volts the coils will develop 8000 gauss in the gap. No cooling of the magnet coils is required, the maximum temperature rise being about 10°C.

The pole face shape is similar to the coil spool shape, except that the exit beam surface is machined to a radius of curvature of 77 inches to help reduce line spread due to a divergent entering beam. If alpha is the half angle of divergence of the beam from the final focusing slit, the spread of the image line is a function of square of the divergent angle and the radius of curvature. This $r\alpha^2$ term may be reduced by curving one or both pole faces.[1]

SOURCE

The source, Fig. 3, consists of two defining slits 0.018 inches wide by 3/4 of an inch high. These are machined out of 1 1/8 inch diameter stainless disk stock which is 1/32 of an inch in thickness. The slit section is recessed to 0.015 inches, and the slit cut is made by a small circular saw. These plates are supported by two studs, and separated by stainless metal cylinders which may be interchanged to provide different geometry. The sample is mounted in the slot section shown in the figure, the sample holder consisting of a highly polished piece of stainless steel, or platinum.

The sample is prepared by placing the material to be studied on an auxiliary filament, masking off the sample holder plate to a line whose rectangular shape is approximately 1/8 by 1 inch and vaporizing the sample in a vacuum onto the sample holder plate. This technique offers an improvement over direct application of salts from solution, avoiding a high concentration of crystallized salts and thus thick sample troubles. The sample is then counted on a low geometry counter to ascertain the amount of activity present before running in the spectrograph. At the present time about one alpha track appears on the plate for every 5×10^4 disintegrations at the source using the low geometry slit spacing.

RECEIVER

The photographic plate receiver is shown in Fig. 4. The essential features of this holder are a multiple plate carriage so that several plates may be employed during a given run without letting the receiver section down to air. In addition, the plate holder has a light tight cover which serves as a shutter during exposures and as means of removing the receiver section to the darkroom without exposing the plates to light. Both the multiple carriage and shutter are operated through Wilson[2] seals. The carriage may also be moved normal to the plane of the photographic plate to assist in fine focusing adjustment, by a combination of screw-Wilson seal technique.

The photographic plates are alpha particle sensitive plates having an emulsion thickness of 25 to 100 microns. All the tracks appear parallel to each other, thus making it possible to discard nearly all background tracks that might appear on the plates from other causes. The tracks are counted by employing a microscope and a mechanical stage, the magnification factor being 450. One eyepiece of the binocular microscope is equipped with a ruled reticle giving a square 0.25 by 0.25 mm in the field. This large square is divided into nine equal squares to assist in counting the tracks. The method used is to scan vertically a field of view, move horizontally one field of view and repeat the process. At 5.9 mev alpha particle energies one field of view on the plate corresponds to one kilovolt in energy spread.

An alternative method, especially when the ratio of activity of the main alpha groups is very large in reference to the complex structure groups, is to employ a scintillation counter to measure the main group and long exposures with alpha particle track plates to measure the weaker complex structure groups. In conjunction with the scintillation counter type of detection, a proton moment flux meter is being installed to measure the magnetic field accurately to 0.01% or better. This will allow a direct calculation of the Hp values, once the value of p for the central normal trajectory is accurately determined from known alpha particle samples.

MAGNET POWER SUPPLY AND REGULATOR

The block diagram of the circuit used to supply regulated direct current to the magnet is shown in Fig. 5. This supply is capable of a current constant to 1 part in 15000 over several hours and about 1 part in 10,000 over a 24 hour period. Metering is accomplished by measuring the drop across a Leeds and Northrup 2 ohm standard resistor, using a Rubicon potentiometer and a Leeds and Northrup galvanometer, sensitivity 0.0004 microamperes per millimeter. This signal may also be recorded on a Leeds and Northrup speedomax recorder for checking the magnet current during long exposures.

DISPERSION AND RESOLUTION

The dispersion in kev per mm on the plate versus alpha particle energy is shown in Fig. 6. This graph is based on a normal radius of curvature of 75 centimeters. If a p of 75 cm strikes the plate in the middle, either end of the 20 cm plate will detect changes of the normal p value amounting to $\pm$ 2.5 cm. In calculating the value kev/mm at any other value than the normal p, a correction must be applied. The usual method is to use internal alpha energy standards and calculate the change in Δp for unknown positions on the plate, holding the field value constant.

The least energy spread obtained to date is about eight kilovolts for the half-width of a line; these results are obtained from runs on curium, mass 242 and by alpha track counting methods. A long exposure run, with the same sample gave the result shown in Fig. 7, where a complex structure line of this isotope is shown approximately 44 kev from the main higher energy alpha group. This energy calculation is approximate at the present writing because an accurate measurement of the radius of curvature has not been made. These results will be presented in a separate paper by other members of this laboratory.

Fig. 8 and 9 give an over-all picture of the instrument while Fig. 10 shows a typical field of alpha particle tracks and a graphic idea of this energy dispersion for one field of view along the photographic plate.

The author wishes to acknowledge the valuable assistance of Robert L. Olson and Wallace Decker in design studies, and H. D. Farnsworth and

E. Powers in electronic design and installation. The author is indebted to Frank Asaro for making the exposure shown in Fig. 7.

This work was performed under the auspices of the A.E.C.

References:

1. H. Hintenberger, Rev. Sci. Instruments 20, 748 (1949).

2. R. R. Wilson, Rev. Sci. Instruments 12, 91 (1941).

LIST OF ILLUSTRATIONS

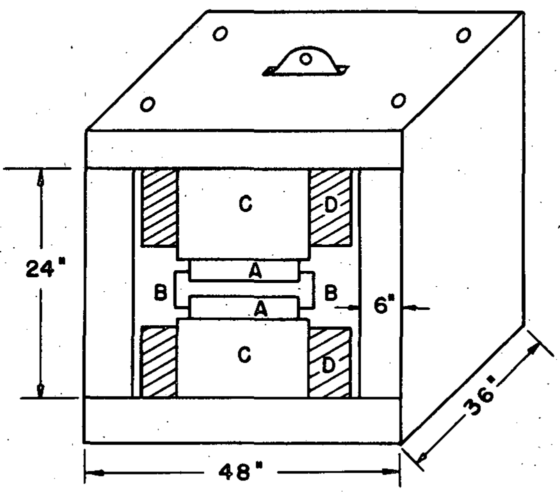


FIG. 1

DRAWING SHOWS CONSTRUCTION OF MAGNET YOKE AND COIL POSITION. PIECES A, A ARE THE POLE FACES WHICH FORM PART OF THE VACUUM TANK B, B. PIECES C, C ARE THE COIL CORES, D, D THE COILS.

MU 1577

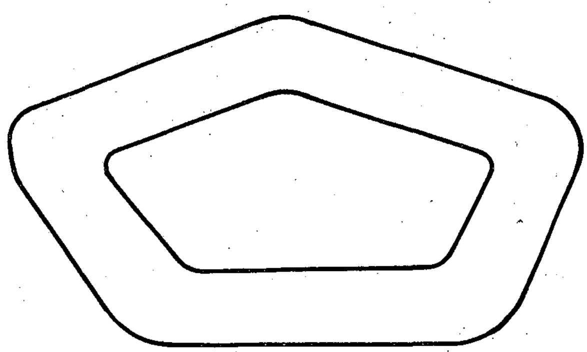
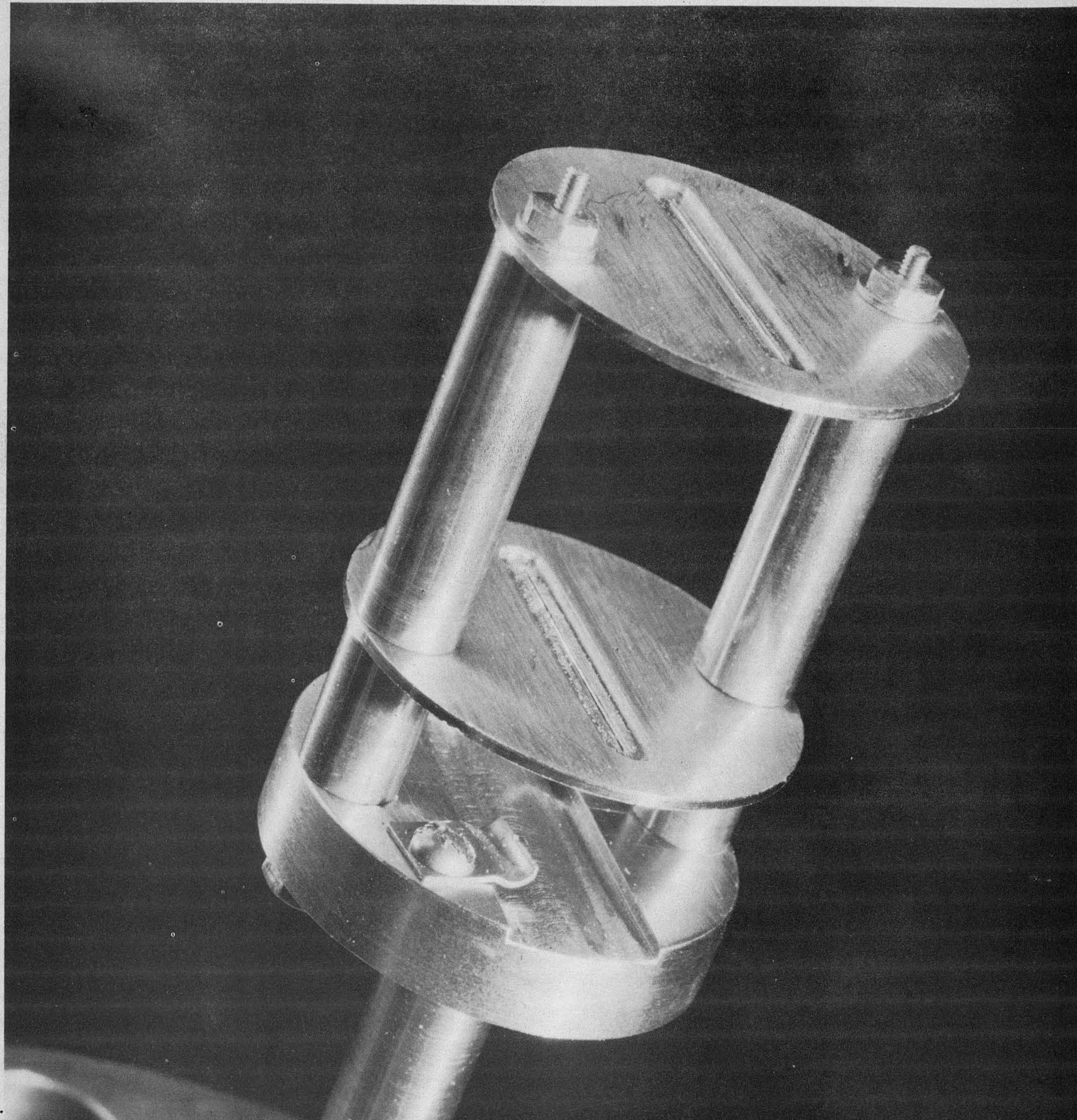


FIG. 2

DRAWING SHOWS SHAPE OF COIL SPOOL, AND GENERAL SHAPE OF COIL SLAB AND POLE PIECES.

MU 1578



ZN 13

Fig. 3

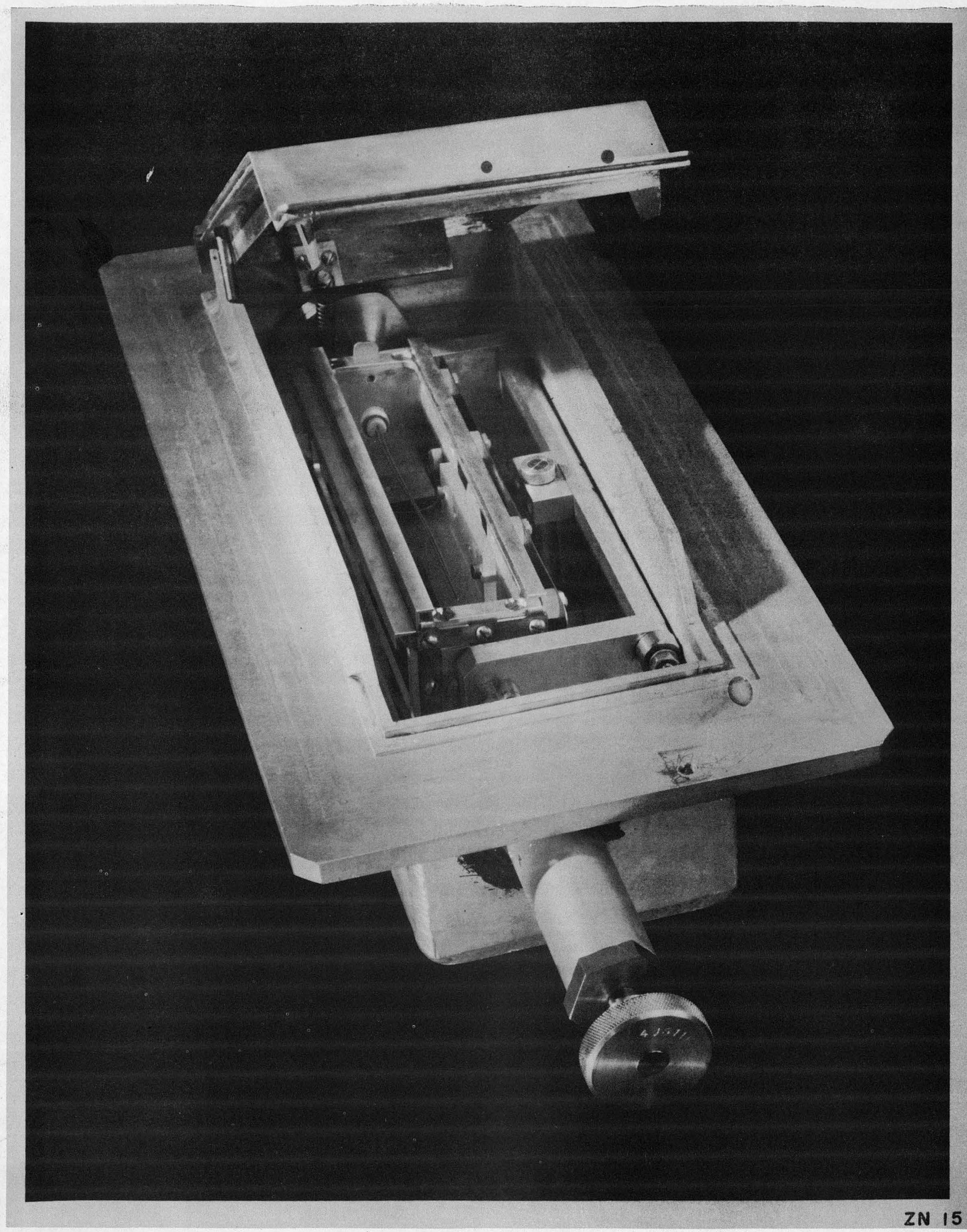


Fig. 4

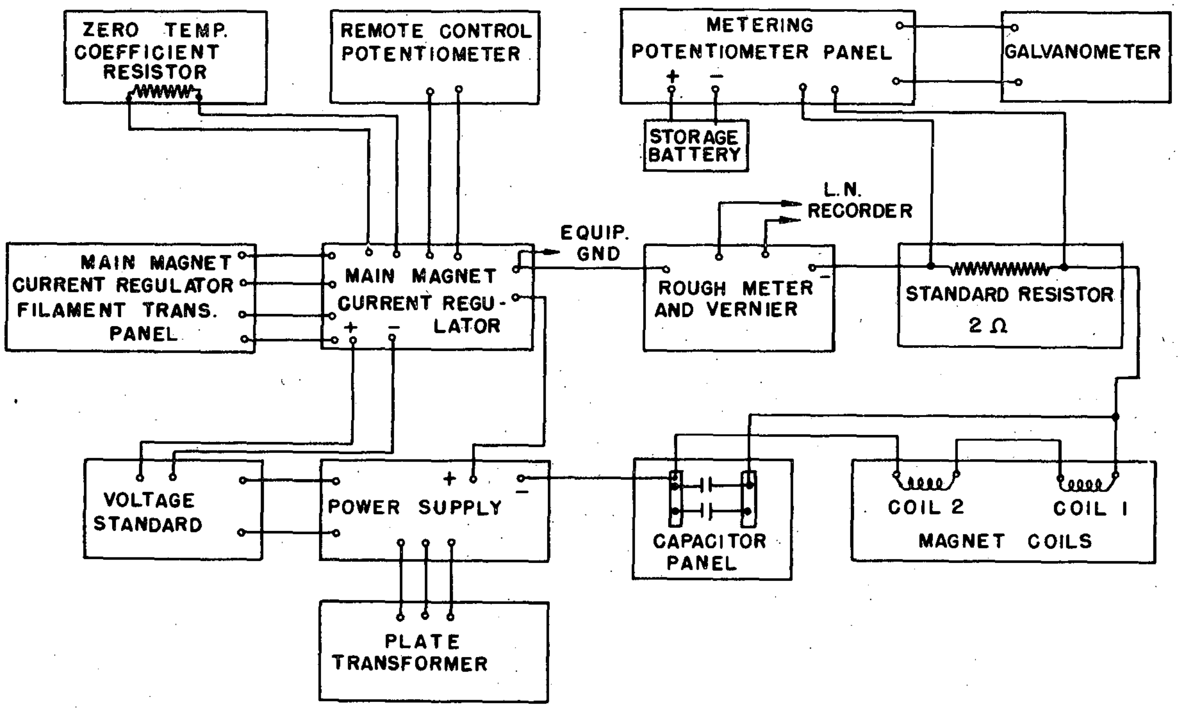


FIG. 5
BLOCK DIAGRAM - MAGNET POWER SUPPLY

MU 1579

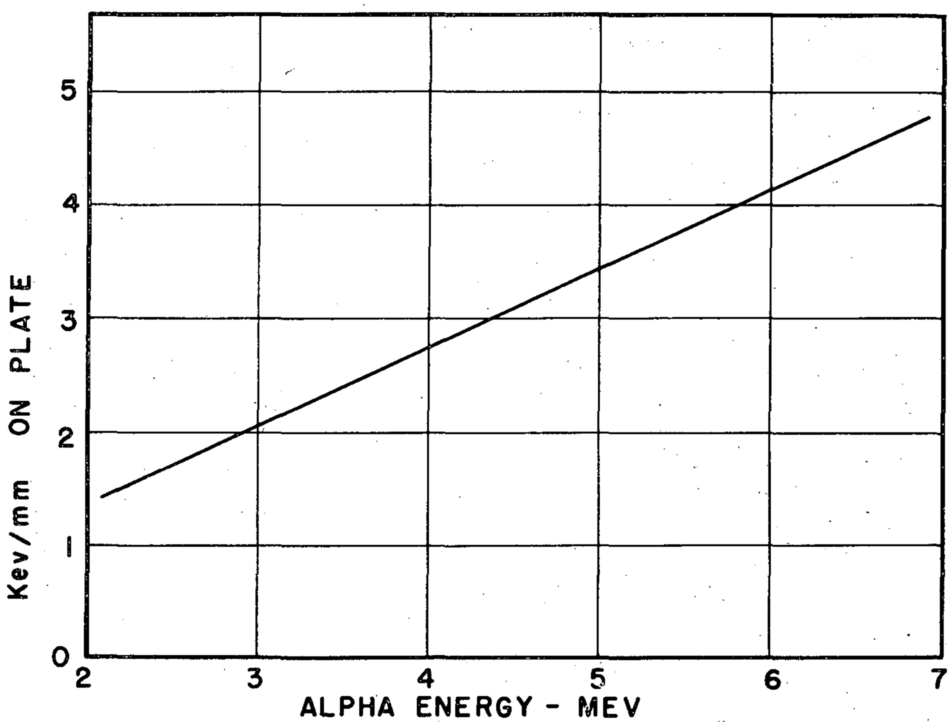
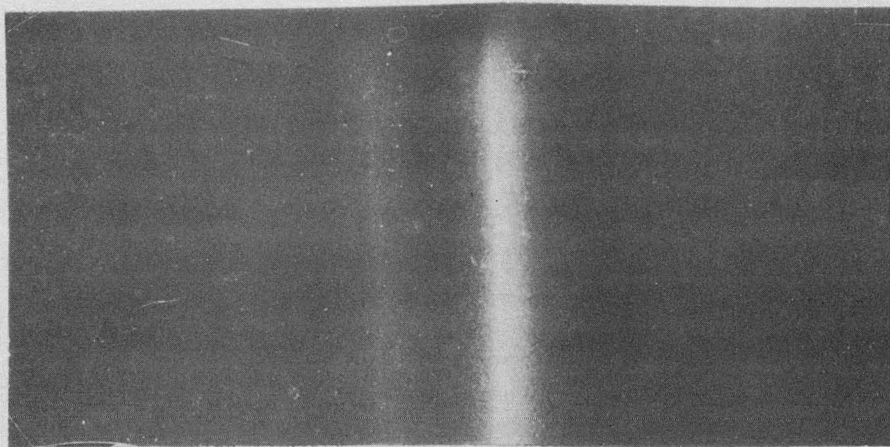


FIG. 6

DISPERSION [Kev/mm vs ALPHA ENERGY]

MU 1580

Cm^{242} α-PARTICLE SPECTRA

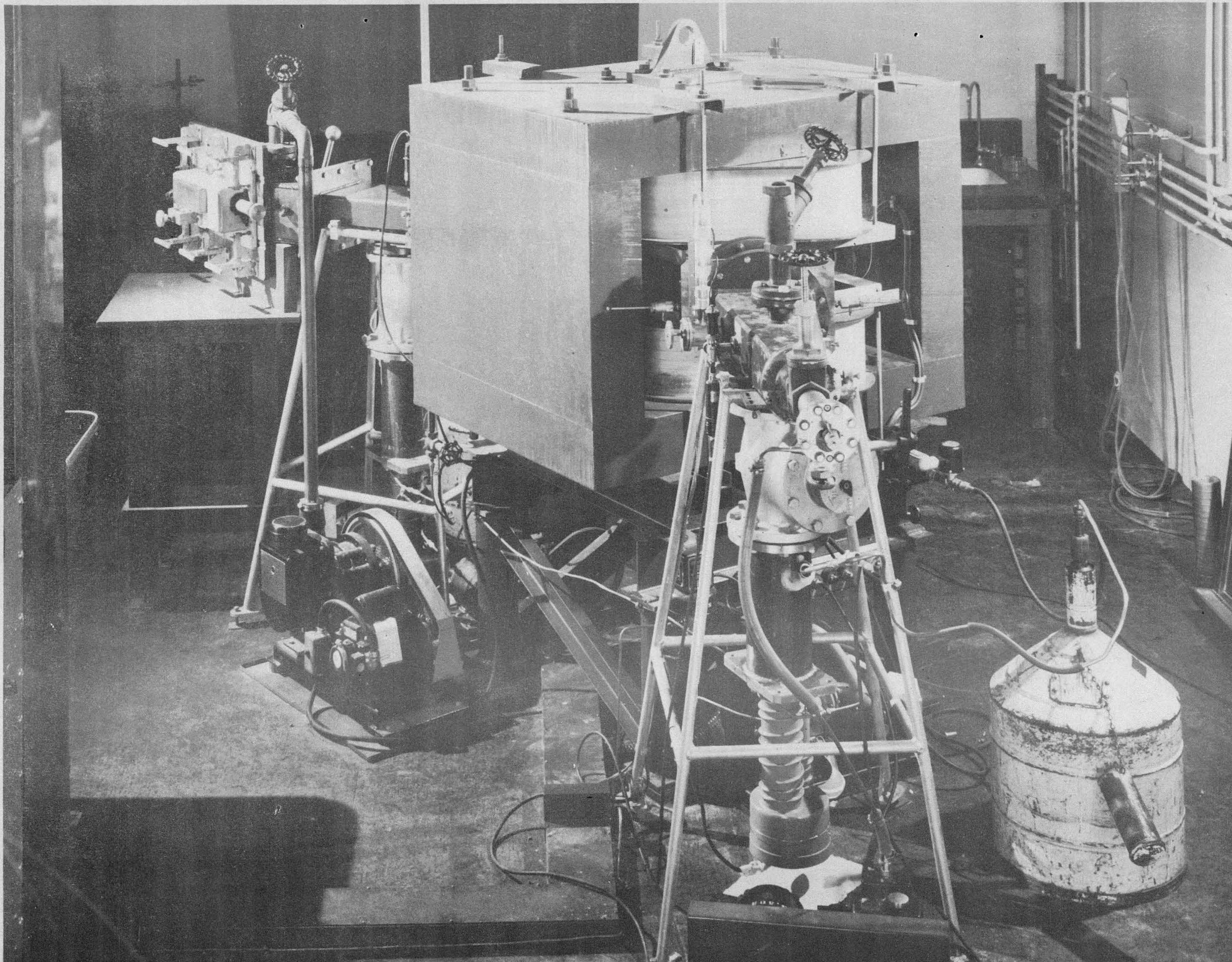


6.08
MEV

FORTY EIGHT HOUR EXPOSURE OF ALPHAS FROM Cm^{242} SHOWING THE MAIN ENERGY GROUP AT 6.08 MEV AND A FINE STRUCTURE GROUP APPROXIMATELY 44 KEV LOWER IN ENERGY.

ZN 16

Fig. 7



ZN 12

Fig. 8

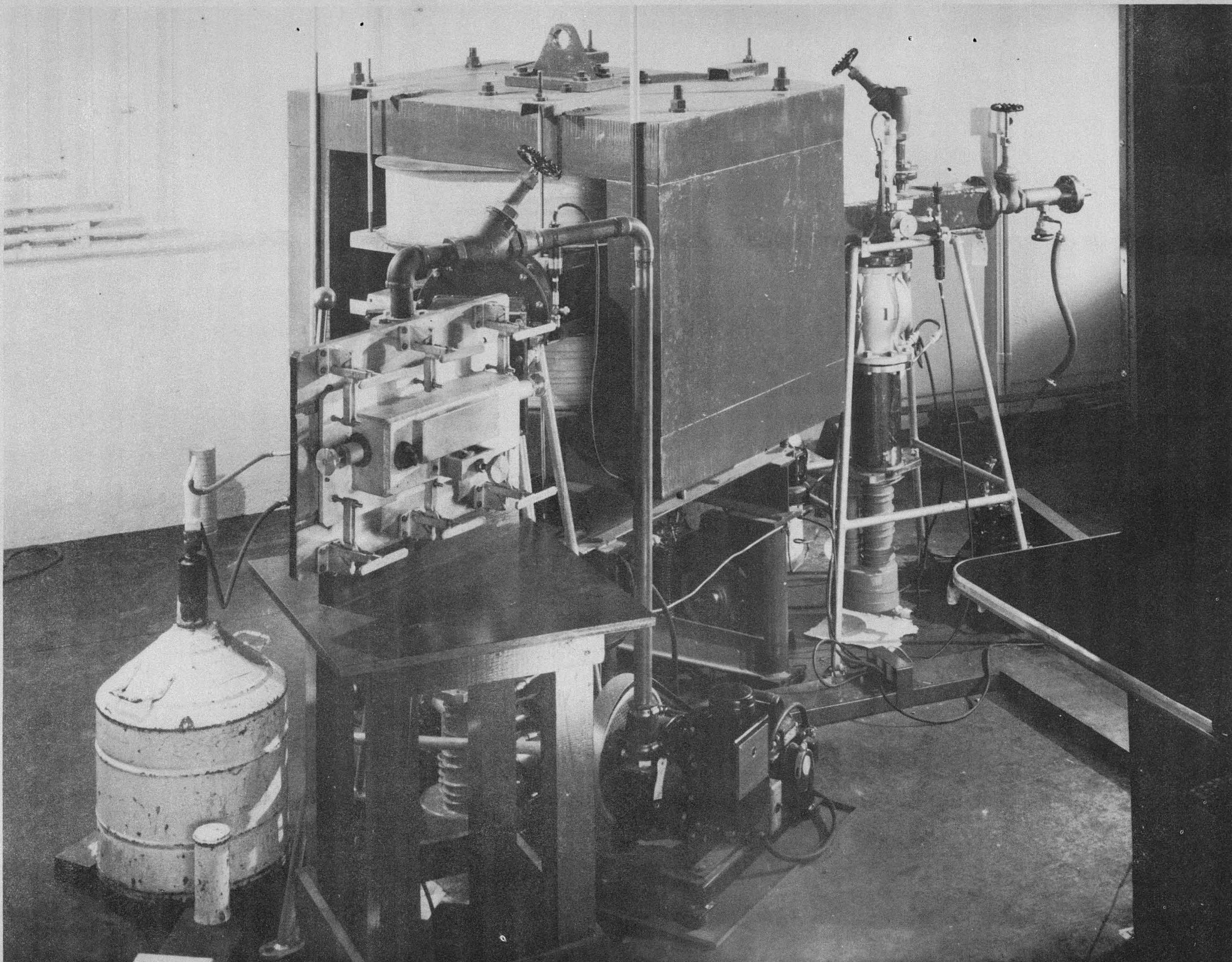

ZN 14

Fig. 9

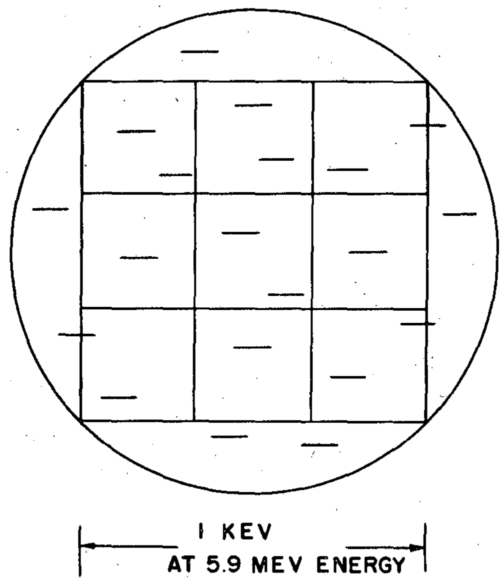


FIG. 10

DRAWING SHOWS RELATIVE LENGTH OF 5.9 MEV ALPHA TRACKS TO FIELD OF VIEW AT 450 MAGNIFICATION. LARGE SQUARE IS 250 MICRONS ON A SIDE, WHICH IS ONE KILOVOLT IN ENERGY SPREAD ON THE PLATE AT A 5.9 MEV ALPHA ENERGY. AT THIS ENERGY THE ALPHA TRACKS ARE ABOUT 25 MICRONS IN LENGTH.

MU 1581