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Berkeley, California

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ABSTRACT

A Wilson cloud chamber 22 inches in diameter in a magnet producing a magnetic field of 21,700 gauss at the center of the chamber is described. The magnet is pulsed in synchronism with the 184-inch Berkeley cyclotron and can be operated with a steady field of 10,000 gauss. The use of the instrument for identifying light atoms is discussed briefly.

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Introduction

The 184-inch cyclotron has recently undergone a conversion so that it accelerates protons up to an energy of 350 Mev. A large cloud chamber with magnet for use with the cyclotron has been designed so that particles with $H\rho$ up to 3×10^6 gauss cm. will produce cloud chamber tracks of measurable curvatures. In order to accomplish this, the cloud chamber must be in a high magnetic field and a long section of the particle's path must be observable. This magnet produces a field of 22,000 gauss and the cloud chamber has a useful diameter of 19.5 inches. The track of a 350 Mev proton crossing the diamter of the chamber would have a sagitta of 2.3 cm. and thus a very accurate curvature measurement can be made.

The Magnet

The magnet, Fig. 1, consists of a pair of coils, two poles, and an iron yoke. The coils were made of bare copper strap, 1 inch by 1/8 inch in cross section, wound in eight pancakes of 75 turns each and insulated between turns with two layers of glass tape 7 mils thick. The pancakes were separated by wooden spacers 5/16 inch thick and 3/4 inch wide, so arranged as to direct the cooling oil back and forth across the pancakes as shown in Fig. 2. These wooden spacers were attached to wooden rings which insulated the pancakes from the 1/4 inch thick iron tank that contained them. The inner wooden rings were only 1/2 inch thick so that the inside diameter of the pancakes was only 1-5/8 inches greater than the 19-1/2 inch inside diameter of the coil tank. The pancakes were dropped into the iron tank, the reentrant lid dropped on top of them, and great pressure applied to the lid as it was welded down. This was done to prevent the motion of the pancakes inside the coil tank.

The bottom pole fills the cylindrical space bounded by the inside of the coil tank. The upper pole has a conical hole which allows the camera to see a circular region having a diameter of 50 cm.

The current for the magnet is supplied by a navy pulse generator with a five-ton flywheel. It is energized by a 150 H.P. motor and pulsed once a minute. In order to build the current up rapidly, the circuit to the magnet is interrupted by opening a contactor while the current in the generator field windings is rising to its maximum value. Then the contactor is closed after the terminals of the generator have reached full voltage. During a pulse the speed of the generator and flywheel is reduced by 10 percent. Fig. 3 shows how the field at the center of the gap rises with time reaching a peak value in about 2.1 seconds and remaining constant for 0.2 seconds. At a time 2.3 seconds after closing the contactor, the generator field winding circuit is opened and the current to the magnet drops from 1000 amperes to about 30 amperes in the conductor in 7 seconds. Shortly after this, the contactor is opened, the field windings energized and the generator is ready for another pulse.

The two coils are connected in series, the current passing through each coil in four parallel paths. When the magnet is pulsed as described above, the maximum current is 4000 amperes and the power 800 kilowatts; this produces a field of 21,700 gauss at the center of the gap. The field is constant over the 0.2 second period of steady current; during this time, the cyclotron is pulsed and the cloud chamber expanded. The magnet can also be operated with a steady field of 10,000 gauss; this requires 1300 amperes and 85 kilowatts. Fig. 4 shows the magnetization curve measured at the center of the magnet and Fig. 5, the shape of the field at 10,000 and 21,700 gauss.

The coils of the magnet are cooled by oil which circulates through an oil-water heat exchanger (see Fig. 6) mounted on the frame supporting the magnet. During the pulsed operation the temperature of the cooling oil rises to 45° C. after several hours. In order to protect the cloud chamber from the heat radiated by the coils water-cooled, stainless steel pads line all the surfaces of the magnet that are exposed to the cloud chamber. See heat shields, Fig. 1. The temperature of the water circulated through these pads is maintained at 19.3° C. Heavy foam rubber pads protect the chamber from the outside and a small fan circulates the air around the chamber to keep it at a uniform temperature.

The Cloud Chamber

The cloud chamber, Fig. 7, is built on a duraluminum manifold, circular except for a neck that extends out beyond the magnet coils and to which the expansion valves may be connected. The upper part of the cloud chamber consists of a 22-inch Lucite cylinder, 3-1/2 inches high, and with a 3/4 inch wall topped by a one-inch thick Tufflex disc which is attached to the manifold through a dural clamping ring. In order to keep the height of the cloud chamber at a minimum, both the top glass and the clamping ring are bevelled at an angle of 30° to the perpendicular so that the top surface of the clamping ring is level with that of the top glass.

The diaphragm consists of a 3/8 inch Lucite disc, 20-1/2 inches in diameter, with 1/16 inch gum rubber glued to its top surface. The rubber has a diameter of about 23-1.2 inches so that it extends beyond the edge of the Lucite and makes the seal between the manifold and the bottom of the Lucite cylinder. There is a pantagraph connecting the Lucite disc to the bottom of the manifold; its purpose is to guide the disc during the expansion so that it moves parallel to the cylinder walls. The motion of the disc is stopped by 5/8 inch neoprene pads which cover the bottom of the manifold except for three air channels, each three inches wide.

Several problems arose owing to the eddy currents that are induced in metal parts of the chamber when the field is rising and falling. The forces that were produced were large enough to move the whole chamber. For this reason a hole 19-1/2 inches in diameter was cut in the bottom of the manifold and the duraluminum replaced by a 1/2 inch thick iron disc. When the chamber is in place, this disc becomes part of the lower pole and serves to increase the field at the center of the chamber as well as to prevent any violent motions of the chamber since it is attracted to the lower pole when the field comes on. The clamping ring that holds the top glass to the chamber has been broken and clamped together with a layer of paper insulation at the break. In addition, the studs that go between the clamping ring and the manifold have been insulated from the clamping ring by paper washers.

The clearing field voltage is applied across two grids of wires. The high voltage is connected to a set of parallel wires spaced 1/2 inch apart and supported by a Lucite hoop just below the top glass, while the ground connection is made to a corresponding set under a layer of black velvet that is glued to the top surface of the diaphragm. It is not sufficient simply to ground the manifold since the rubber diaphragm is an insulator. Two aquadag rings were painted near the top and bottom edges of the Lucite cylinder and connected to ground to prevent the surfaces from charging up.

The Optical System

The cloud chamber is illuminated through the Lucite walls of the cylinder by a pair of General Electric FT 422 flash tubes. Each tube is wrapped in aluminum foil except for a strip 3/16 inch wide going the length of the tube. The foil was held on by winding 5 mil tungsten wire in a spiral with half inch spacing around the tube; this wire and the aluminum foil acted as the tickler electrode. Although the width of the light source is reduced, the intrinsic brilliance increases so that the intensity of the illumination reaching the lens is reduced by only 20 percent. This lens is cylindrical, 18 inches long and 2-1/4 inches wide; it provides a beam of light approximately two inches wide at the center of the chamber. Because of the aberration appearing when rays pass obliquely through the cylindrical lenses, it was necessary to place baffles covered with black velvet between the lens and the source in vertical planes perpendicular to both. These louvres were spaced every two inches starting three inches from the center of the lens. The Lucite surfaces of the cloud chamber cylinder scattered light onto the black velvet in an intensity amounting to about 2 percent of the intensity at the center of the chamber. The resulting background made it necessary to use the Eastman Orthochromatic Linagraph film instead of Super XX. This film is at least twice as sensitive to the light from the flash tubes and has much greater contrast.

460 μf at 1600 volts were discharged through each flash tube. The combination of the resulting surge of current and the magnetic field produces forces large enough to break the tube. This difficulty has been overcome by bringing the ground lead back along the tube and binding it tightly so that it produces a force on the tube in the opposite direction. Wherever possible, the two leads coming to the tube are twisted.

The stereoscopic camera uses a pair of Leitz Summar, F2, 50 mm lenses separated by 4.5 inches. The camera is located about 25 inches above the center of the cloud chamber with each lens toed in toward the other so that the optic axis of each makes an angle of 5° with the perpendicular to the cloud chamber. The film gate is tipped at an angle of .34 degrees from the perpendicular to the optic axis in the proper direction to keep all parts of the chamber in the best possible focus when the camera is placed directly above the center of the chamber. A third lens in the back of the camera permits a counter and an ammeter showing the magnet current to be photographed at the instant when the cyclotron is pulsed. This is accomplished by discharging a condenser through a flash light bulb illuminating counter and meter at the proper time.

Two sets of cam driven switches control the timing of the cloud chamber. The slow timer with seven cams driven continuously by a variable speed motor performs the following operations: (1) rings a warning bell ten seconds before an expansion, (2) turns on the magnet, (3) resets the clearing field, (4) resets the generator circuit, (5) operates a valve to make the cloud chamber expand slowly as many times as desired. The cams are made adjustable by clamping onto them the desired number of dogs which operate microswitches. The maximum time for one revolution is four minutes, the shortest 1.5 minutes. By doubling the number of dogs the cycle can be repeated twice in one revolution.

The second set of cams controls the more rapid sequence and is called the fast timer, Fig. 8. A small synchronous motor running continuously is coupled to the cam shaft by means of a solenoid operated clutch. The cam shaft makes one revolution in half a second. Only five of the seven cams are used. Dogs are attached to the cam wheels at suitable intervals as in the slow timer, and each microswitch is mounted on a wheel which can be rotated by means of a worm gear from the front panel. The microswitch wheels are coaxial with the cam shaft but do not rotate with it. Scales marked in hundredths of a second intervals are pasted to the edges of the wheels so that their phasing may be read on the front panel and adjusted by means of the worm gear. Cam 1 turns off the clearing field, cam 2 expands the chamber, cam 3 turns on the R.F. oscillator on the cyclotron, cam 4 pulses the ion source in the cyclotron, and cam 5 flashes the lights. Cam 6 interrupts the current going to the magnetic clutch so that the cam shaft stops rotating. The timing sequence is as follows when operating with 100 cm. pressure of helium when the chamber is expanded and using water vapor. The time of starting of the cam shaft will be called zero. The clearing field is turned off 0.12 seconds later, the chamber expanded at 0.16 seconds, the R.F. turned on at 0.18 seconds, the arc pulsed at 0.21 seconds, the lights flashed at 0.23 to 0.24 seconds. For gases of higher molecular cross section, greater time must be allowed between the arc pulses and the lights. Higher gas pressures increase this time also. If the arc is pulsed 0.02 seconds earlier, then about half the time the tracks appear slightly broadened because the ions have diffused before the chamber has reached the appropriate supersaturation to start forming drops. There is a jitter of 0.01 seconds in the time interval between the expansion of the chamber and the pulsing of the arc. This arises from the fact that the beam from the cyclotron comes out in pulses 0.01 seconds apart arbitrarily phased with the timing of the cloud chamber. Good pictures can be obtained with both arc and light excitation 0.02 seconds later, but the longer time makes the tracks less straight in the pictures taken without magnetic field.

Track Endings

This cloud chamber and magnet may be used not only to make accurate curvature measurements on the tracks of fast particles but also to identify the slow particles that result from the disintegrations of nuclei. Fig. 9 has been prepared to demonstrate how the lightest nuclear fragments may be identified near the end of their range. The lighter particles have a longer range for the same curvature and, hence, curl up more in the magnetic field. It is necessary to use hydrogen or helium gas at 100 cm. of mercury or less with water vapor if a distinction between tritons and alpha particles is to be made. Even under these conditions about 20 percent of the tritons will show curvatures identical with those for an alpha particle over the last 20 cm. of the track. Protons, alpha particles and deuterons can be distinguished with little ambiguity in this range.

Acknowledgments

The major portion of the engineering of the magnet and cloud chamber was done by Paul Hernandez. Walter Hartsough, Dr. Evans Hayward, and Keith Brueckner were responsible for much of the work necessary for successful operation of the chamber, and Marguerite Hayward for the photography. This work was performed under the auspices of the Atomic Energy Commission.

Information Division
scb/7-18-49

Fig. 1

The cloud chamber magnet showing the location of the cloud chamber, the camera, and the lights.

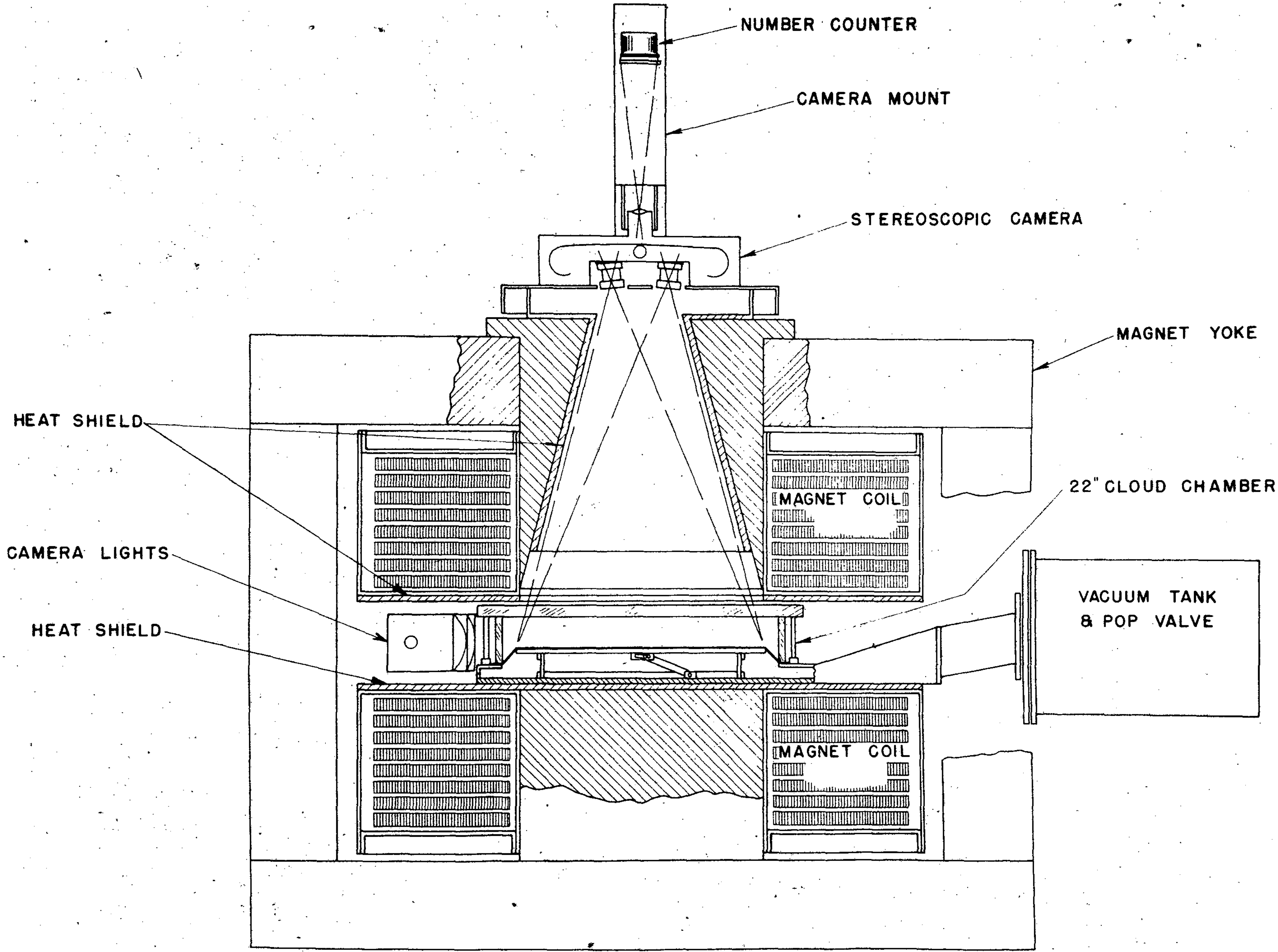


FIG. 1

22 CLOUD CHAMBER ASSEMBLY

0Z-354

Fig. 2

Plan view of a magnet coil, showing the flow of the cooling oil.

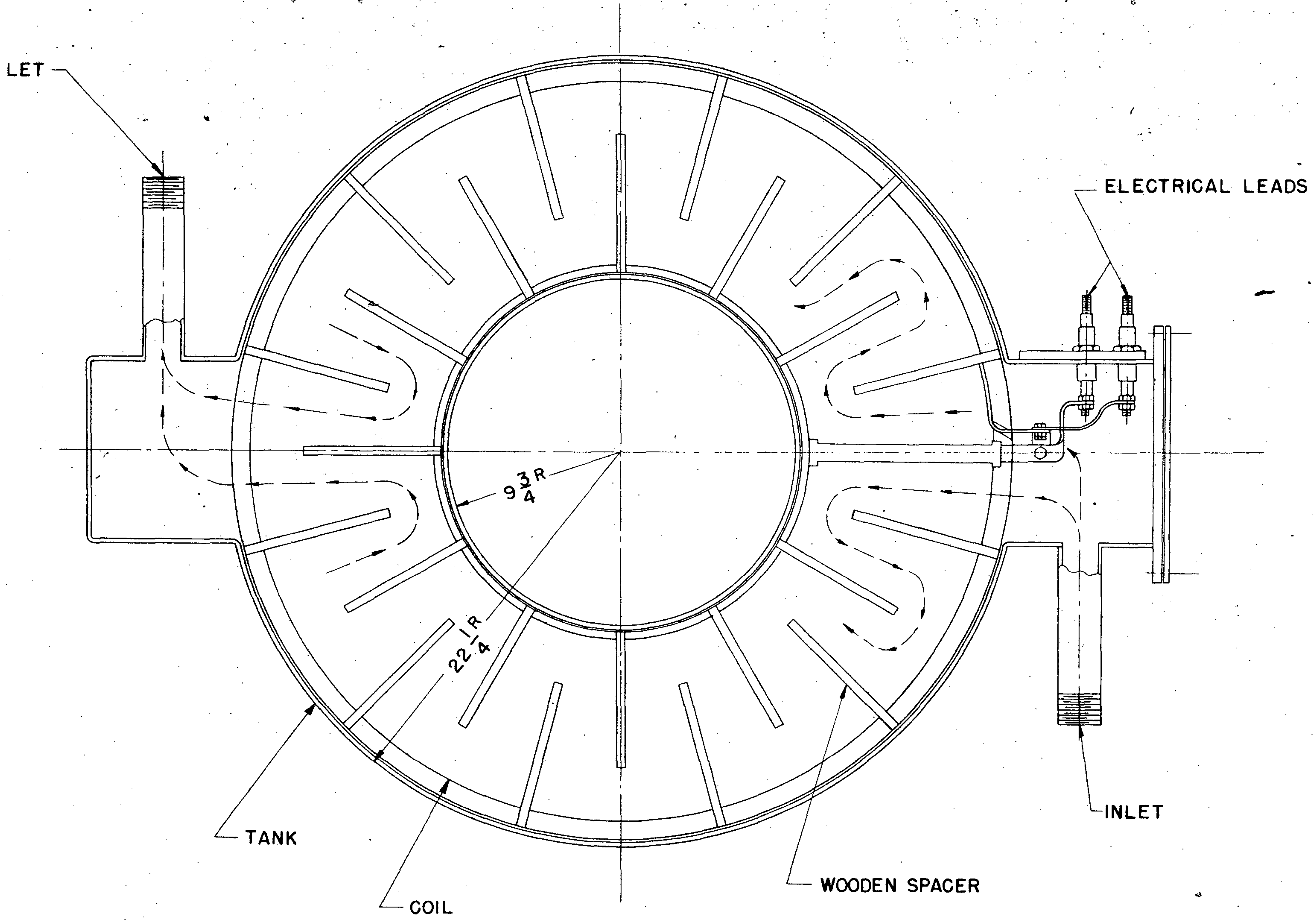
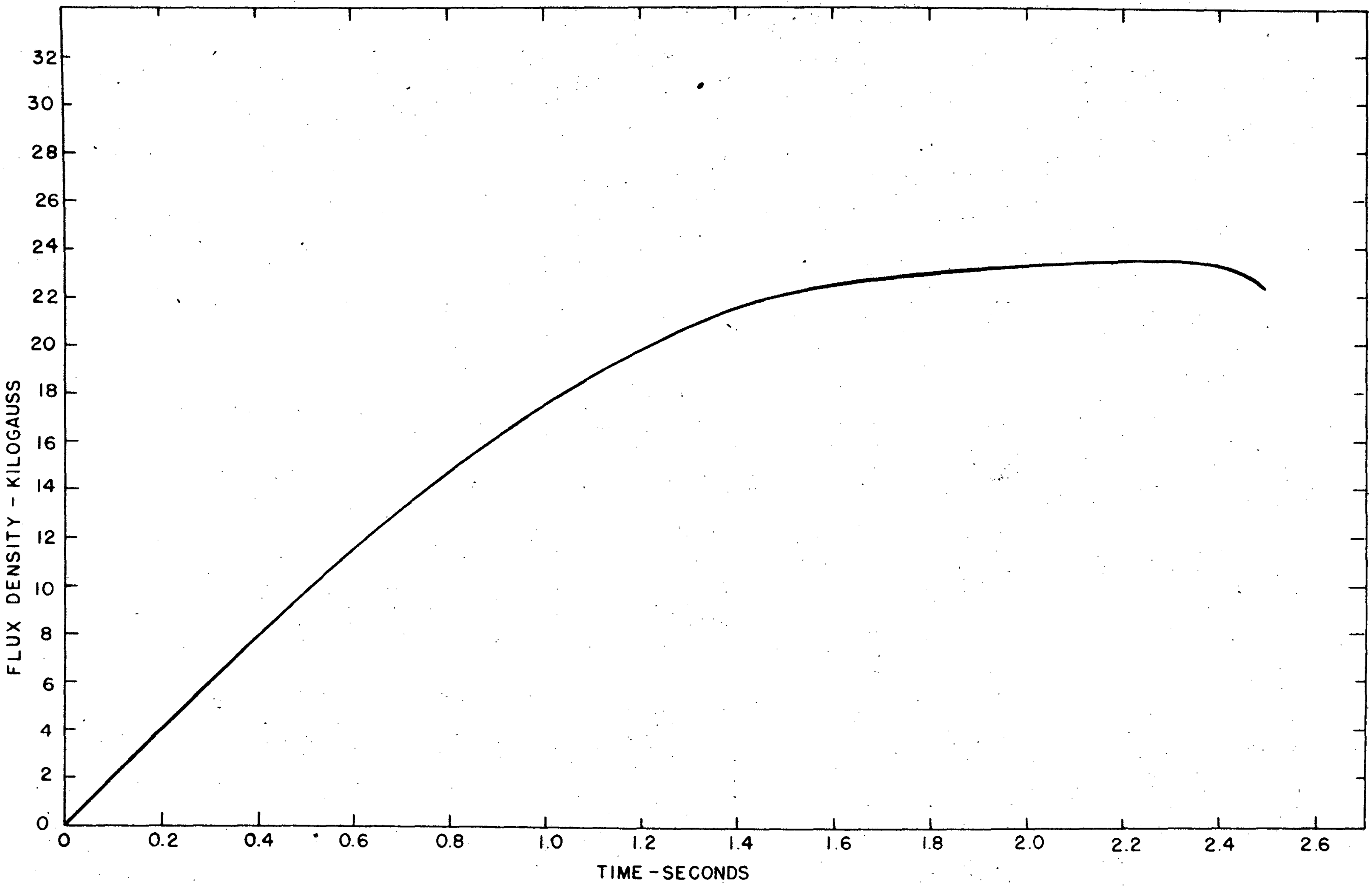

LET
ELECTRICAL LEADS
$9\frac{3}{4}$R
$22\frac{1}{4}$R
TANK
COIL
WOODEN SPACER
INLET

FIG. 2

OZ-353

Fig. 3

The rise of the magnetic field at the center of the cloud chamber as a function of time.

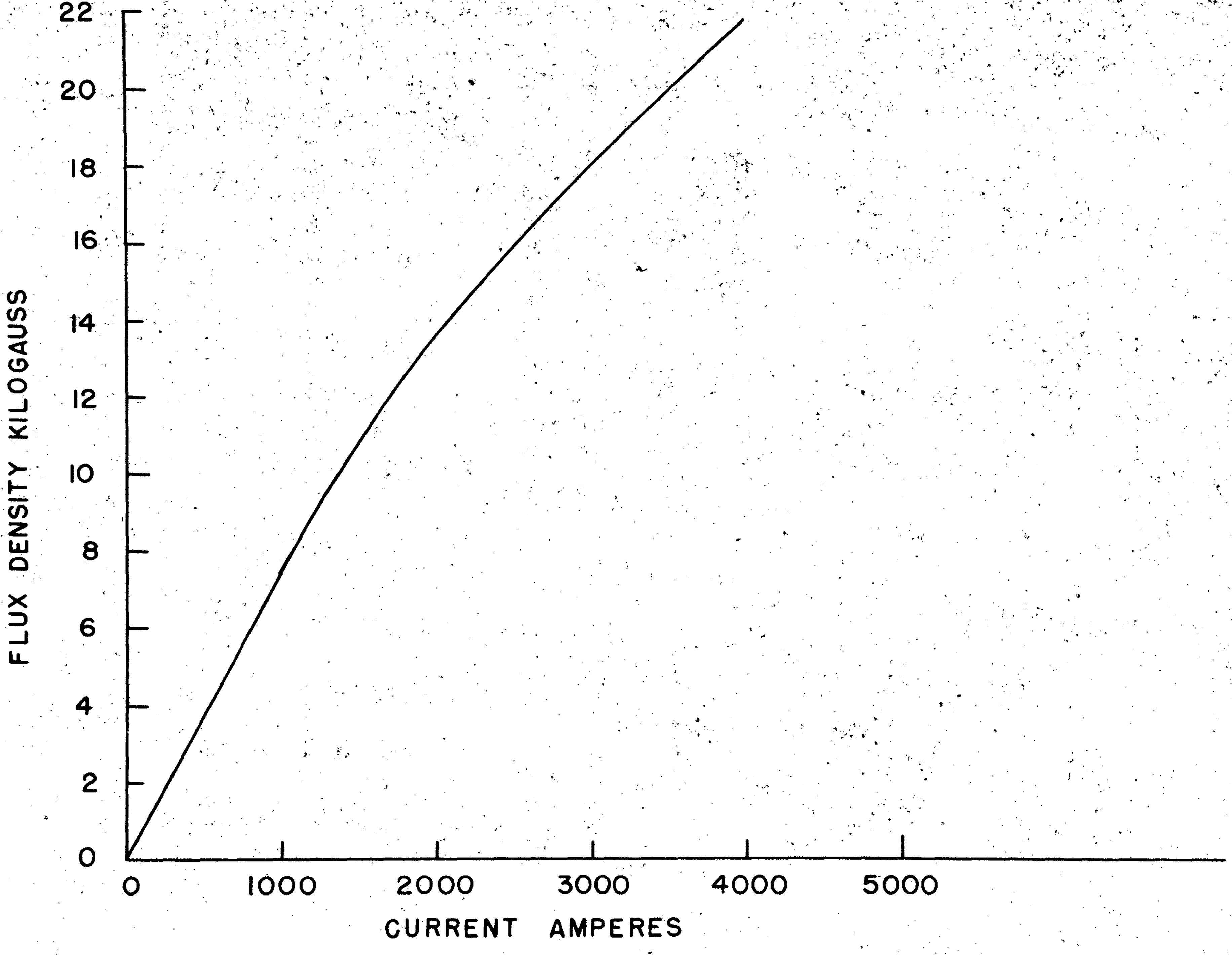


FLUX DENSITY - KILOGAUSS
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
TIME - SECONDS

FIG. 3

Fig. 4

The magnetization curve of the magnet.



FLUX DENSITY KILOGAUSS
22
20
18
16
14
12
10
8
6
4
2
0
0
1000
2000
3000
4000
5000
CURRENT AMPERES

FIG. 4

OZ-355

Fig. 5

The upper curve is the percentage of the field at the center of the chamber as a function of radius when the chamber is operated with 10,000 gauss at the center. The lower curve refers to a field at the center of 21,700 gauss.

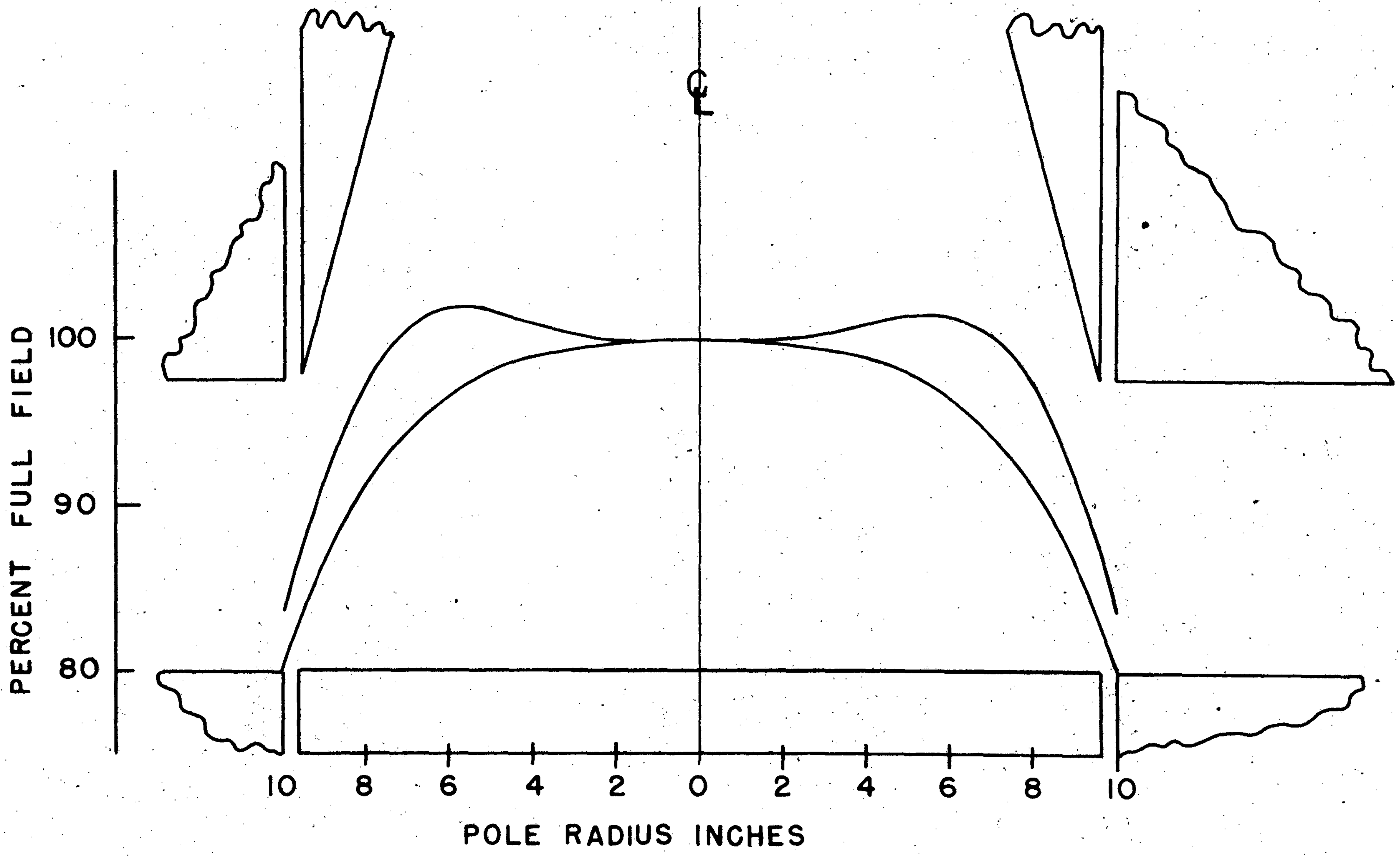

PERCENT FULL FIELD
100
90
80
℄
10
8
6
4
2
0
2
4
6
8
10
POLE RADIUS INCHES

FIG. 5

OZ-351

Fig. 6

General assembly of the cloud chamber and magnet.

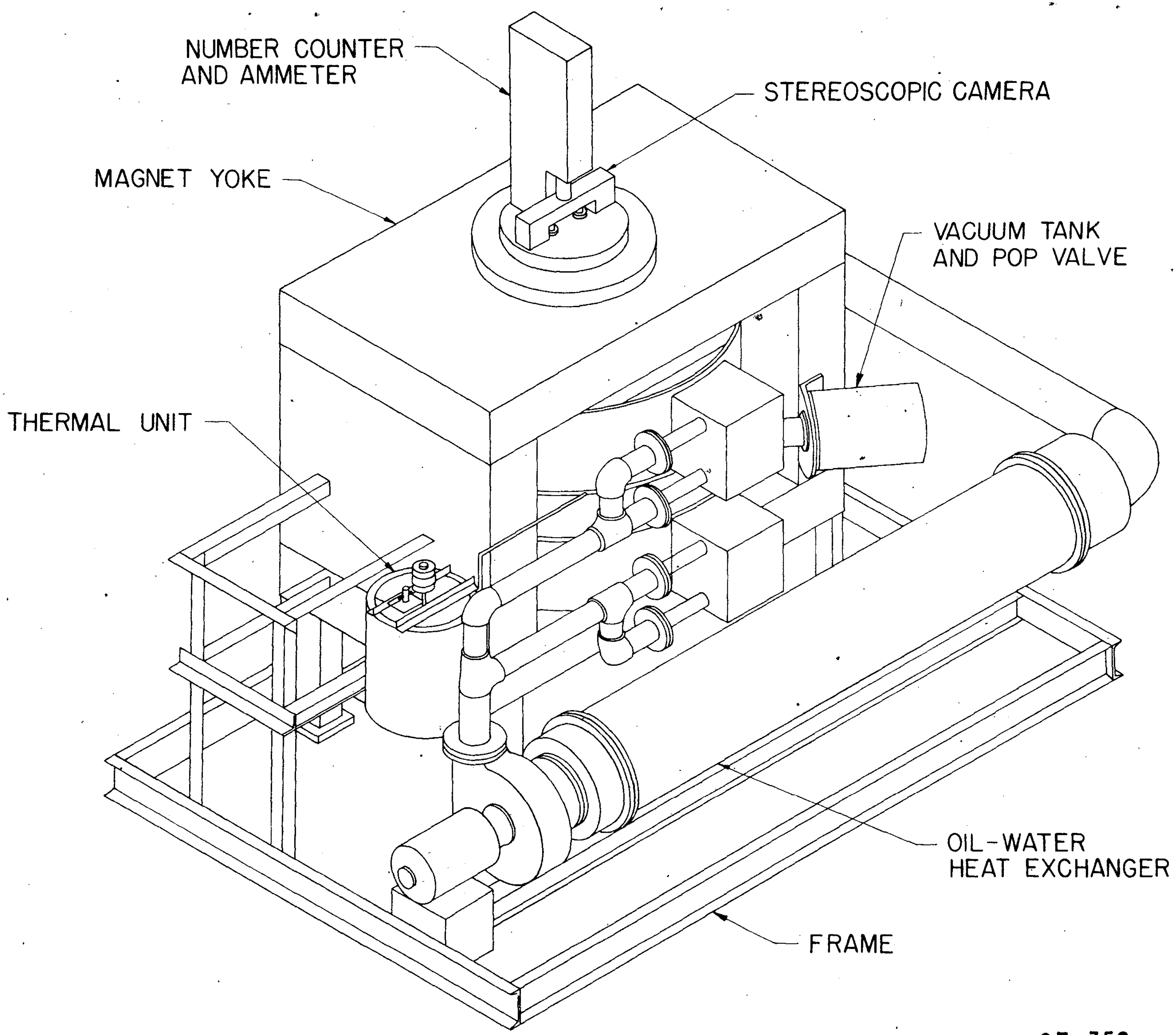

NUMBER COUNTER AND AMMETER
STEREOSCOPIC CAMERA
MAGNET YOKE
VACUUM TANK AND POP VALVE
THERMAL UNIT
OIL-WATER HEAT EXCHANGER
FRAME

FIG. 6

OZ-352

Fig. 7

Cross section of the Wilson cloud chamber.

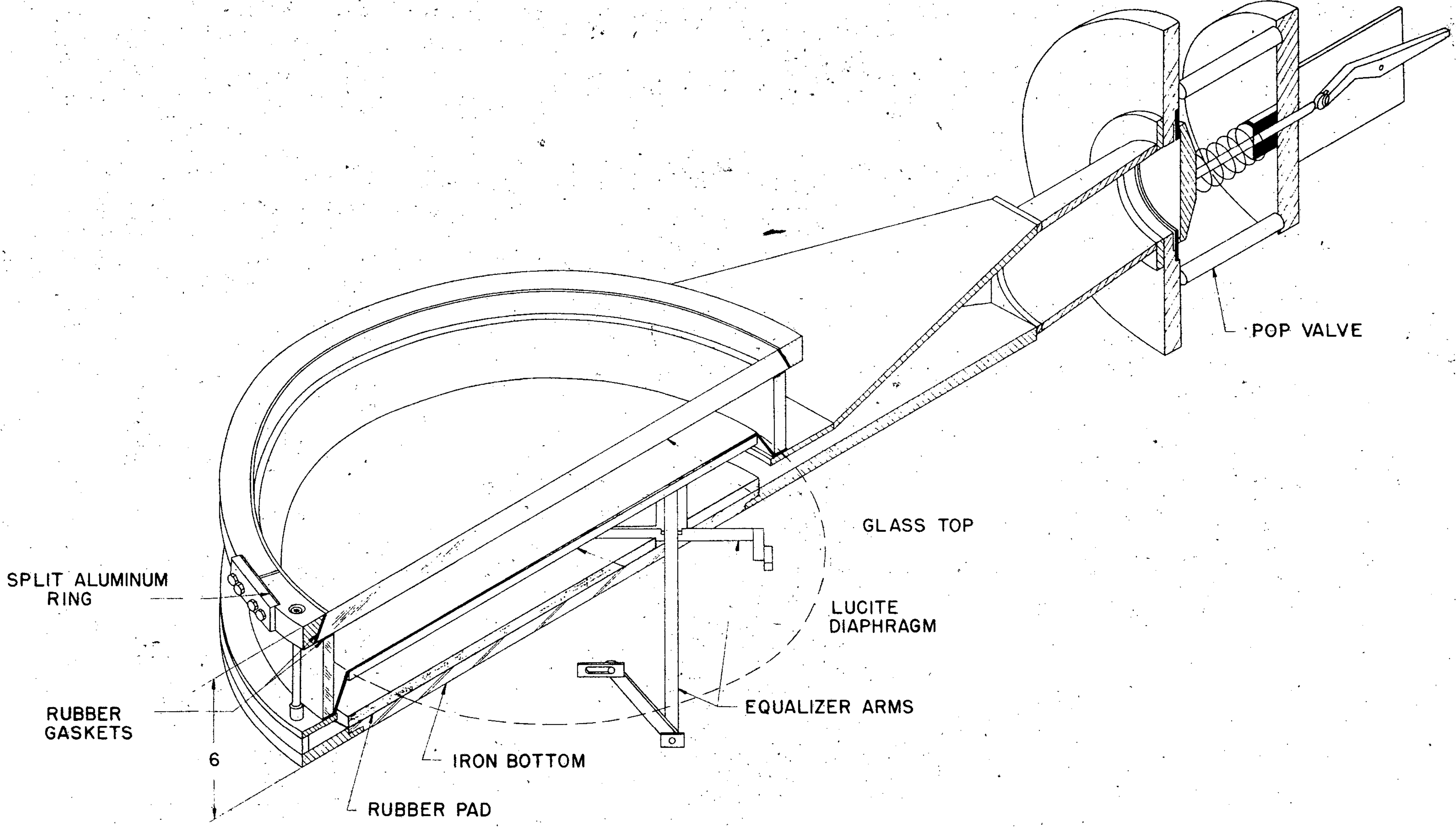

POP VALVE
GLASS TOP
SPLIT ALUMINUM RING
LUCITE DIAPHRAGM
RUBBER GASKETS
EQUALIZER ARMS
6
IRON BOTTOM
RUBBER PAD

FIG. 7

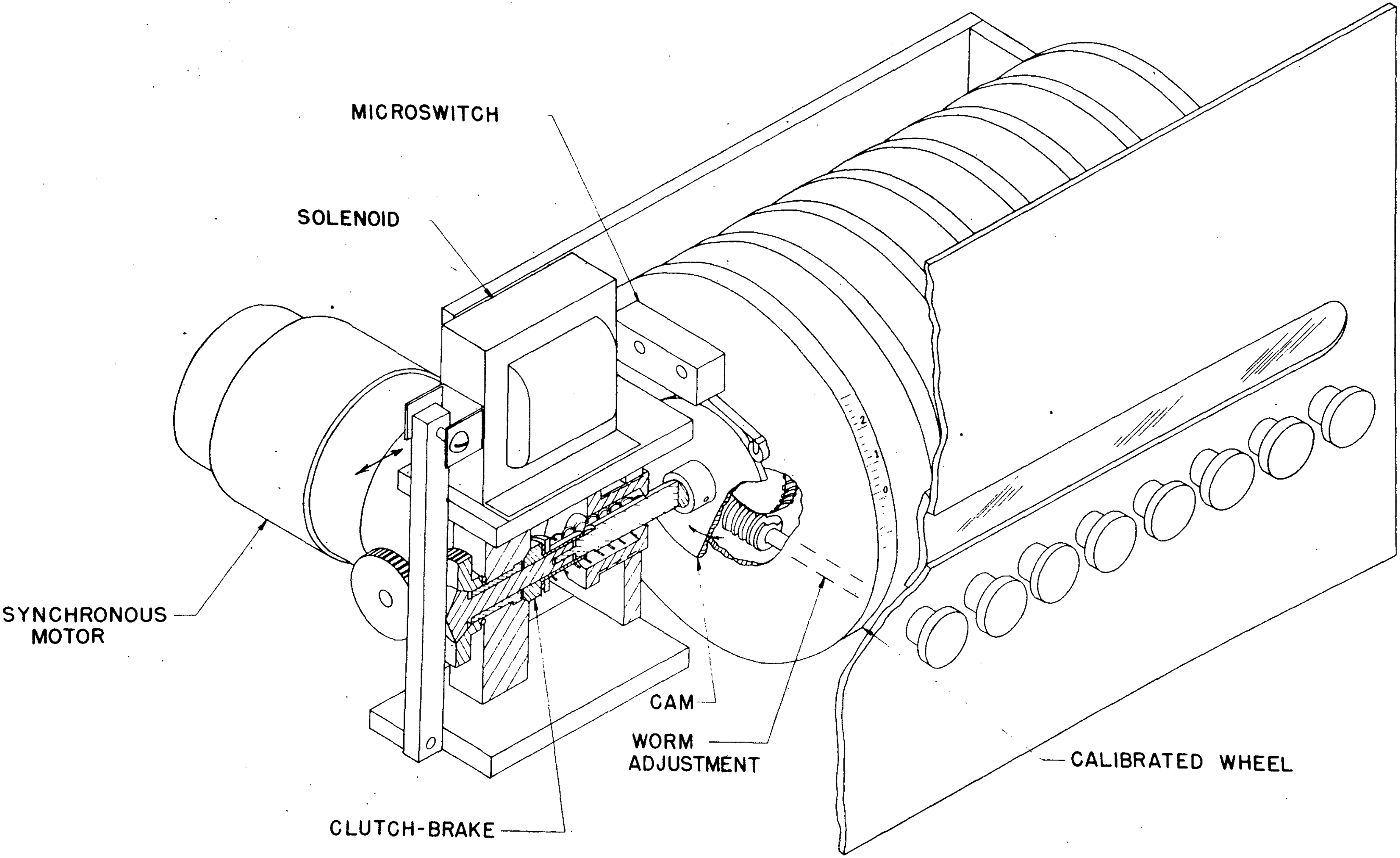
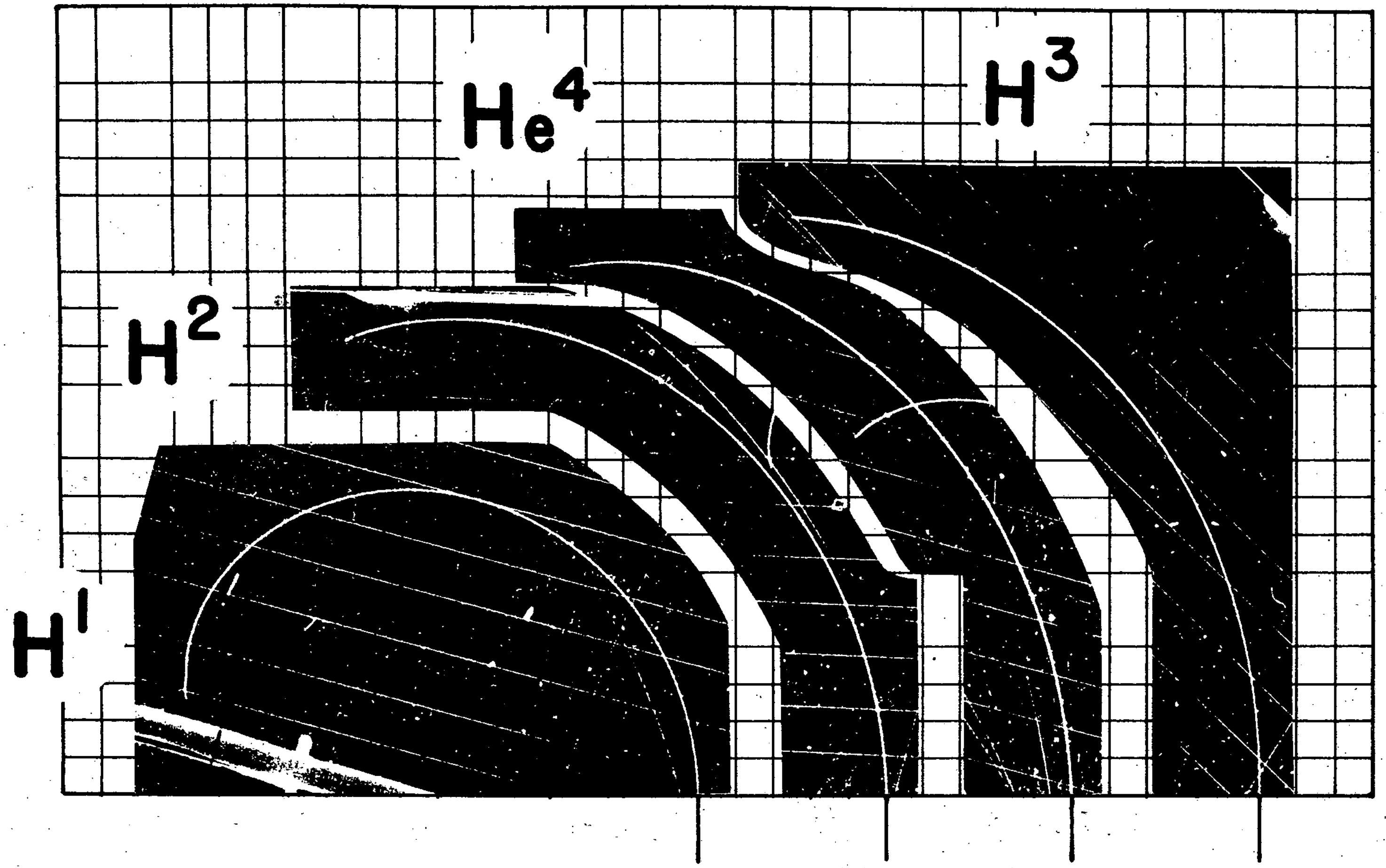

MICROSWITCH
SOLENOID
SYNCHRONOUS MOTOR
CAM
WORM ADJUSTMENT
CALIBRATED WHEEL
CLUTCH-BRAKE
2
1
0

FIG. 8

Fig. 9

Track endings in a field of 21,700 gauss with 100 cm. Hg pressure of helium and water vapor at 19.3° C.



CHARACTERISTIC TRACK ENDINGS

LAST 22 CENTIMETERS

ALL TRACKS PERPENDICULAR TO BASE LINE

FIG. 9