Cloud Chamber for Nuclear Disintegration Studies

H. R. CRANE
University of Michigan, Ann Arbor, Michigan
(Received July 31, 1937)

Construction of an entirely automatic cloud chamber particularly adapted to the study of the high energy electrons produced in artificial disintegration experiments is described. Air core coils which are capable of producing magnetic field strengths up to 4000 gauss at the time of expansion are used. An incandescent light source, using three 1000-watt projection bulbs furnishes sufficient light for $\frac{1}{5}$ second camera exposure.

THE use of cloud chambers in conjunction with apparatus for the acceleration of positive ions and for the types of problems which present themselves in artificial nuclear disintegration work has been responsible for the evolution of cloud chambers especially suited to those purposes. In the study of gamma-rays and beta-rays a cloud chamber equipped with air core coils which will produce magnetic field strengths up to at least 2000 gauss has been found necessary, and for particular problems involving very high energy particles even higher fields are of considerable advantage. Completely automatic operation and extreme reliability, which allows large numbers of pictures to be taken without interruption are valuable features. These requirements, however, necessarily increase the initial cost and complexity of the apparatus above the more simplified types of cloud chamber.

A cloud chamber which seems to fulfill the above requirements has been in operation in this laboratory for the past two years, and it is believed that a brief description of it may be of value to other experimenters. It is only fair to say at the outset that this, as any other cloud chamber, contains to a large extent features which have been invented and used previously by other investigators. The number of possible variations in the design of various parts of such an apparatus is practically infinite, and the author hopes therefore, at most, that some of the methods and ideas in his design may be found useful by other experimenters.

Let us proceed immediately to a description of the operation of the cloud chamber.

Cocking and Expanding Mechanism

A typical cycle beginning with the cocking operation, may be described as follows: The motor-driven contact system closes the electrical circuit of the air valve (Fig. 3). The plunger moves downward, causing air to flow into O (Fig. 1). This raises the cocking piston, which raises the central rod and piston of the cloud chamber until the toggle joint falls into the cocked position shown in Fig. 2. When the toggle joint arrives at the cocked position the contact in Fig. 2 automatically breaks the electrical circuit through the air valve. This switches the air pressure from O back to N, which blows the cocking piston down to the position shown in Fig. 1. The expansion is caused by simply passing current through the solenoid shown in Fig. 2.

Motor-Driven Contact System

A direct current $\frac{1}{16}$ hp motor is connected to a gear box which is provided with two shafts having speeds of 1/30 and 1/900 of the motor speed. The contacts which operate the expansion, camera, light, magnetic field etc. are operated by the faster of the two shafts. The common lead for all these latter circuits passes through a contact on the slower shaft. The contact on the slower shaft closes for a little less than one revolution of the faster shaft. This means that on every thirtieth revolution of the faster shaft the current passes through the various contacts for the cloud chamber in the proper sequence. The use of two shafts makes possible very accurate timing of the various events during the "shot." The slower shaft carries a contact which cocks the cloud chamber at some time between shots (usually 2 or 3 seconds after the expansion), and also a contact which controls the motor speed during the shot. This can be made independent of the motor speed between shots; in other words the interval between shots can be adjusted without disturbing the timing during the shot. A sketch of one of the wheels and contact bars[1] is shown in Fig. 4. A number of these are placed in line along each of the shafts, which are at right angle to each other.

[1] The design shown here is due to Messrs. J. Lawson and B. R. Curtis of this laboratory.

Adjustments of Expansion

The height of the piston of the cloud chamber in the expanded position is fixed by the dash-pot.

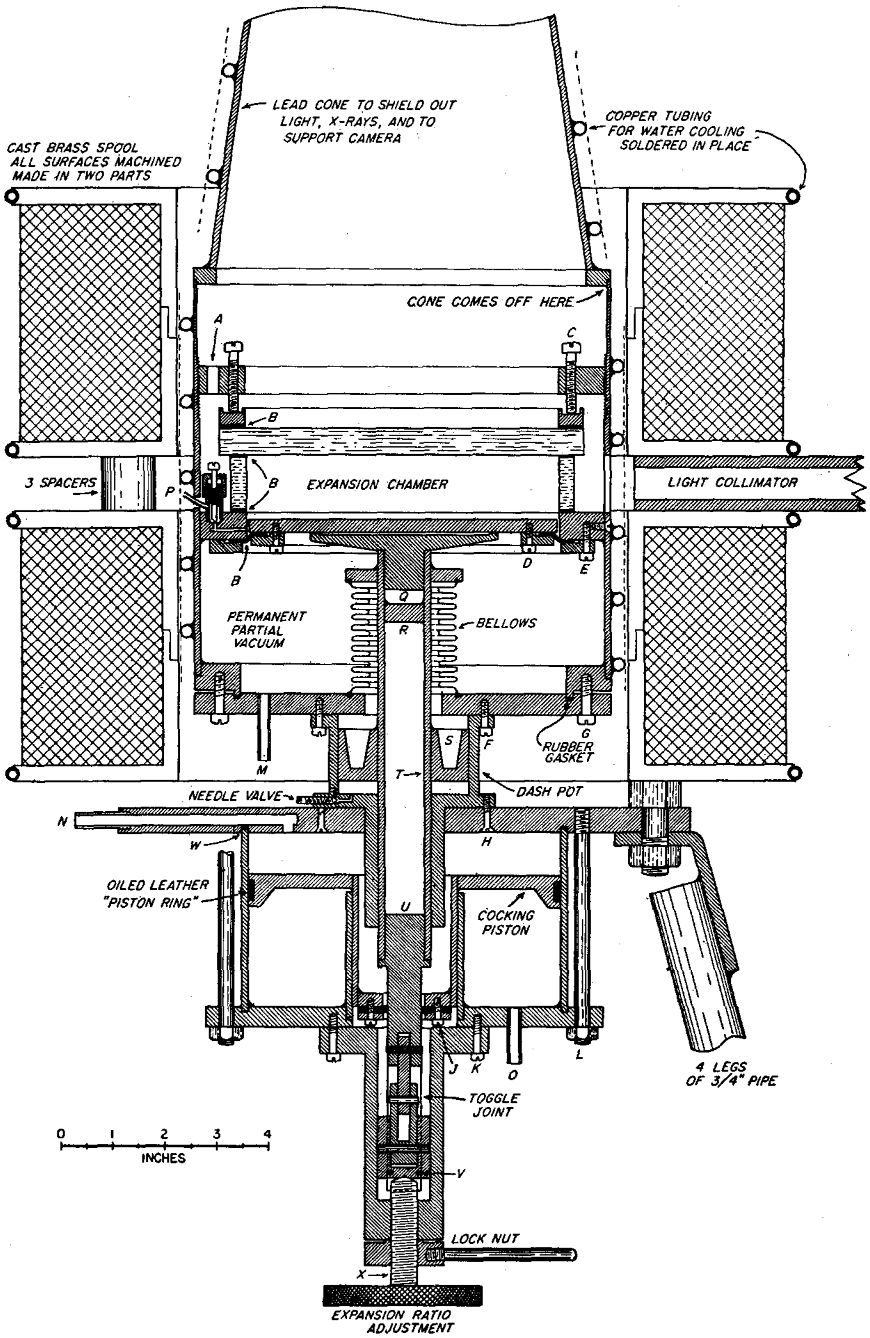

FIG. 1. Cross section of the assembled cloud chamber, with the piston shown in the cocked position.

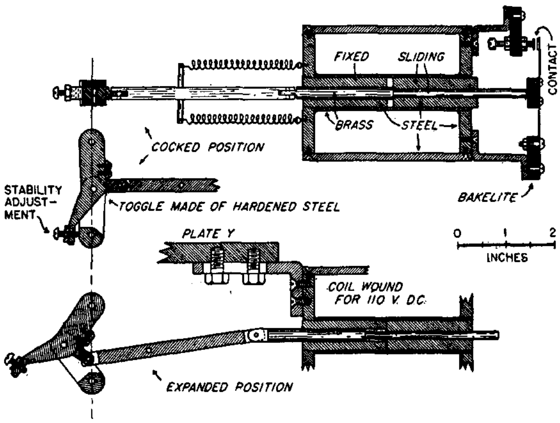

FIG. 2. Detail drawing of the toggle joint and the electromagnet for tripping the toggle.

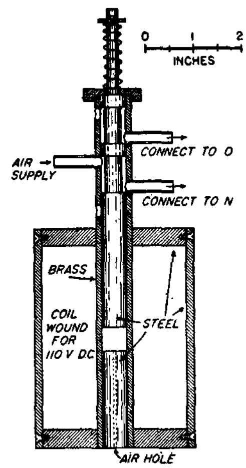

FIG. 3. Electrically operated air valve.

The height of the piston in the cocked position is adjustable, by means of the hand wheel at the extreme lower end of the chamber. Several controls are available for adjusting the speed with which the piston falls, during the expansion. The downward force depends upon the difference in the pressure of gas above and below the piston, which is usually maintained at $\frac{1}{3}$ to $\frac{1}{2}$ atmosphere. By means of the needle valve on the dash-pot, the piston can be made to come to a smooth stop at the end of the stroke. This is quite important in eliminating turbulence in the expansion chamber. If it is desired to reduce the speed of the stroke somewhat the air pipe N may be disconnected and left open. The cocking piston will then be pulled down by the central rod as the chamber expands. It has been found that this extra damping effect is desirable when air is used in the expansion chamber, but when hydrogen is used, the quicker expansion is preferable.

Magnetic Field

The spools on which the solenoids are wound are of cast brass, $\frac{5}{16}''$ thick. Each spool was made of two identical castings, fitted together and soldered at the center as shown in Fig. 1. Semicircular grooves were machined in the edges and copper tubes soldered into the grooves. Water is circulated through these four tubes in parallel. The good conductivity of the heavy brass casting causes the entire spool to be maintained at practically the temperature of the water. The spools are wound with No. 8 square, double cotton covered copper wire; about 270 pounds were used. Each of the coils has a resistance of one ohm, and they are operated in series. The magnetic field produced is approximately 30 gauss per ampere when the coils are in series. The time constant of the coils is of the order of 0.1 sec., and therefore current is usually passed through them for almost 1 second before the expansion is made, to insure that the field is completely built up. Making 2 expansions per minute the coils do not heat excessively at 3000 gauss, but approximately 4000 gauss would probably be the limit, with the present cooling system. Somewhat higher fields could undoubtedly be obtained by cooling the outer surface of the winding, or by increasing the time between expansions.

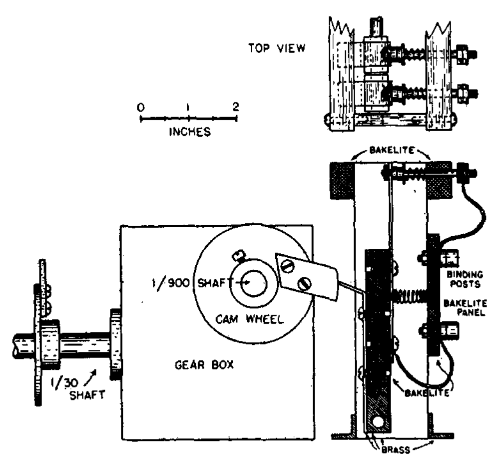

FIG. 4. Cross section of one of the contact levers, gear box and cam wheels.

Accurate measurements of the field strength have been made by means of a pick-up coil and a standard mutual inductance, and the results are shown in Fig. 5, which serves to indicate the degree of uniformity of the field.

Cooling

In addition to the cooling of the solenoid spools, copper tubing is soldered in a helix around the 8″ brass tube which forms the shell of the cloud chamber. Circulating water through this absolutely protects the chamber from heat which may come from the solenoids. The lead cone which supports the camera is also cooled, but this is important only if the temperature of the air in the room is considerably higher than the water temperature.

Camera Arrangement

The lead cone, the lower part of which is shown in Fig. 1, supports a small wooden platform on which the camera is fastened. The cone is provided with a slot for visual observation of the chamber while pictures are being taken. A Sept 35 mm movie camera is used and is located 21 inches above the center of the expansion chamber.

Light Source

During most of the work with the present cloud chamber a carbon arc, which is flashed at about 300 amperes for $\frac{1}{2}$ second, has been used. Recently an arrangement of three 1000-watt, 110-volt Mazda projection lamps has been used (Fig. 6), which gives ample light for an exposure of $\frac{1}{5}$ second or less at f:1.9, on super-X film. The lamps are flashed at 120 volts and are allowed about 1 second to come to full intensity before the camera is opened. A sketch of the optical arrangement is shown in Fig. 6. This produces a beam of nearly parallel light $2\frac{1}{2}$ inches high by $7\frac{1}{2}$ inches wide. The use of three spherical lenses has an advantage over the use of a cylindrical lens, when working with a sheet of absorbing material in the cloud chamber, as for example in experiments on electron absorption. The cylindrical lens makes the light parallel only in the vertical plane; consequently light enters the chamber through a large range of angles in the horizontal plane, and illuminates the surfaces of the vertical sheet of material in the chamber. A magnetically operated shutter in the light beam is used to reduce the heating in the chamber, and this is operated in parallel with the magnet which opens the camera. A water cell does not seem to be necessary when the light is only allowed to enter the chamber during the actual camera exposure.

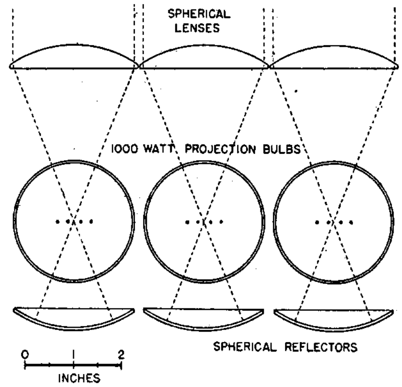

FIG. 6. Scale drawing of the light source.

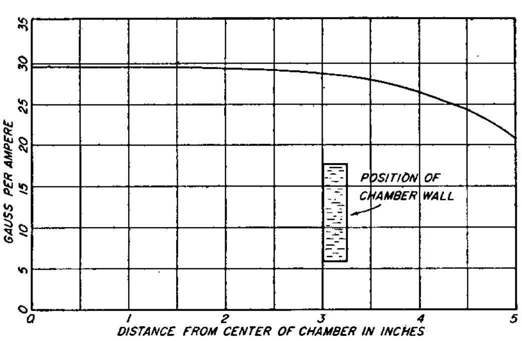

FIG. 5. Curve showing the results of measurements made on the magnetic field strength, at various distances from the center of the chamber.

Miscellaneous

In order to obtain a black surface on the floor of the chamber, a disk of black silk or rayon velvet is laid on the piston. When this is wetted slightly with ethyl alcohol (which furnishes the vapor for the chamber) it sticks sufficiently to the piston so that it does not move during the expansion. The clearing field is produced by a ring of thin aluminum just under the top glass plate. The ring extends partly over the rubber gasket and extends out into the chamber about

$\frac{1}{8}''$. This is maintained at about 100 volts by means of B batteries and is not grounded during the expansion. The rubber gaskets are made of $\frac{1}{16}''$ "pure gum" rubber, and are fastened to the glass ring by means of rubber cement. The glass ring is of Pyrex, $6\frac{1}{2}''$ *OD*, $\frac{1}{4}''$ wall thickness and 1″ high, and the top glass is of ordinary $\frac{1}{2}''$ plate glass. The toggle joint is made of steel, preferably hardened. The pins are made of $\frac{1}{8}''$ drill rod.

Details on Fig. 1

A, Hole for screw driver to reach needle valve.
B, "Pure gum" rubber, $\frac{1}{16}''$ thick.
C, 16 12–24 fillister head screws.
D, 16 8–32 fillister head screws.
E, 16 8–32 fillister head screws.
F, 8 8–32 fillister head screws.
G, 16 12–24 fillister head screws.
H, 8 8–32 flat head screws.
J, 4 8–32 fillister head screws.
K, 8 10–32 fillister head screws.
L, 6 $\frac{3}{8}''$ rods.
M, Connection to vacuum gauge.
N, Connection to air valve, Fig. 3.
O, Connection to air valve, Fig. 3.
P, $\frac{1}{8}''$ copper tubing from needle valve, wound around the body of the chamber between the water cooling tubes, so as to come out at the top.
Q, Support for the piston of the expansion chamber. This is not soldered into the central tube *T*.
R, Air tight plug soldered in tube *T*.
S, Dash-pot piston, soldered onto tube *T*.
U, Not soldered into tube *T*. This facilitates disassembling the chamber.
V, Steel pins which act as guides to keep the toggle joint assembly from rotating.
W, Rubber gasket joint.
X, $\frac{1}{2}''$ steel screw, 32 threads per inch.
Y, Plate, on which expanding magnet (Fig. 2) is mounted.

The author wishes to express his appreciation to the Rackham Endowment Fund for the support of this work.

NOVEMBER, 1937 R. S. I. VOLUME 8

Axial Magnetic Suspensions

F. T. Holmes
Rouss Physical Laboratory, University of Virginia, Charlottesville, Virginia
(Received August 5, 1937)

A vertical ferromagnetic needle can be supported in macroscopic equilibrium by magnetic forces alone. One method using a variable magnetic field is described and shown to have considerable latitude in details of application. A 6 g rotor having a moment of inertia of about 0.8 g cm^2 was suspended in this manner. It was spun at about 1200 rev./sec., its behavior indicating that with suitable driving arrangements much higher speeds should be attainable. At 600 rev./sec. with driving torque zero it exhibited a deceleration of about 2×10^{-3} rev./sec.^{2}. A suspended element weighing about $\frac{3}{4}$ g showed torsion constants, depending on adjustments, down to 7×10^{-6} dy cm/rad.

Many devices involve an element which may turn about a vertical axis. The element is sometimes mounted on mechanical bearings and sometimes hung from a flexible strip or fiber. The first method involves friction though restoring torque may be absent. The second involves restoring torque with a very small amount of friction.

It is axiomatic that some experiments could be profitably repeated if a rotatable element could be suspended in a simultaneously frictionless and torque-free manner. Although this will never be done, yet for a vertical magnetic needle of arbitrary weight supported by the coaxial field of a solenoid, there are apparently no theoretical lower limits for the frictional torque per unit angular velocity and the torsion constant. This paper contains a preliminary report on the behavior of such systems. The results given are intended to represent not ultimate values but merely those which can be obtained with ordinary care and technique.

Apparatus

It has usually been supposed that Earnshaw's theorem indicates the impossibility of attaining