A Large Cloud Chamber Using Rear Illumination

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A large cloud chamber is described that makes use of rear illumination by means of a transparent piston and back plate. This system of illumination is particularly advantageous for a large cloud chamber since the increase in the amount of scattered light for small angles of scattering from droplets reduces the total light required.

A LARGE cylindrical cloud chamber 87 cm in diameter and 15 cm in depth was constructed by Anderson and Neddermeyer in 1937. This same chamber with a few modifications has recently been placed in the pressurized cabin of a B-29 airplane and 3500 pictures have been taken without magnetic field at altitudes up to 13,500 meters. Since the chamber has operated very satisfactorily for these experiments and is of somewhat unconventional construction, the following description is given.

A photograph of the chamber mounted in the cabin of the airplane is shown in Fig. 1. A cross-sectional view of the chamber in Fig. 2 indicates the method used to obtain an axial expansion. A circular glass diaphragm, connected to the chamber by a ring-like rubber membrane, is supported by rollers resting on the lower part of the chamber walls. Compressed air admitted to the cavity behind the diaphragm (on the side opposite to that of the cloud chamber) moves the diaphragm forward and compresses the gas in the chamber, which is 10 or 20 cm Hg pressure above the outside pressure with the chamber in the expanded position. Expansion is accomplished by suddenly releasing this compressed air into the cabin through a large valve.

Eight equally-spaced push-rods are connected to a brass ring that surrounds the glass plate forming the diaphragm. The push-rods pass through sleeves in the rim of the cavity behind the chamber to aid in guiding the diaphragm. Alternate push-rods are supplied with adjustable nuts that limit the forward motion of the diaphragm and thus control the expansion ratio. Springs on the other push-rods are adjustable so that the diaphragm will remain perpendicular to the axis of the chamber during the expansion.

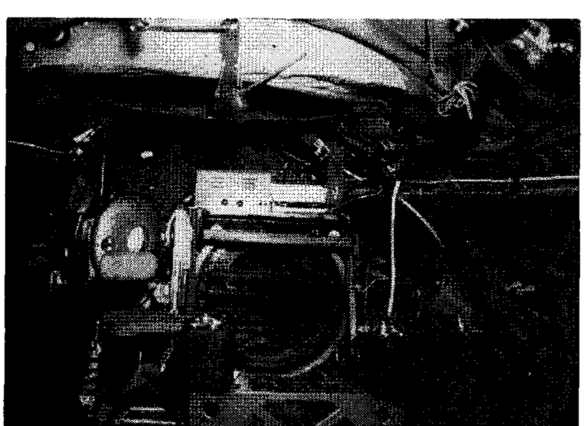

FIG. 1. Front view of cloud chamber mounted in cabin of B-29 airplane. Cameras appear on stand in front of chamber.

Figure 3 shows the manner in which three horizontal plates, one of carbon and two of lead, have been arranged inside the chamber for the high altitude experiments. Four wires, supported above and below the set of plates, and the center one of the three plates, are lowered to a potential of from 500 to 1000 volts below the potential of the outer two plates and the chamber walls to provide a sweep field for the chamber. An electric field of the order of 50 to 100 volts per centimeter is thus maintained in the chamber until the moment of the expansion.

As the diaphragm moves to expand the chamber, a mechanism connected to the push-rod at the top of the diaphragm short circuits the sweep-field circuit and reduces the sweep field to a small value. Simultaneously the same mechanism uncovers a hole and drops a small shot. The short flash of light illuminating the chamber to photograph the tracks also photographs the shot during its fall. In Fig. 5 the shot is indicated by an arrow just below the center of the bottom plate in the chamber. From a measurement of the distance the shot has fallen, the time interval between the short-circuiting of the sweep field and the instant of taking the picture may be calculated.

Tracks produced by particles passing through the chamber before the removal of the sweep field are spread out or separated by the action of the sweep field on the ions. The tracks appearing unseparated in the photographs are therefore caused by particles passing through the chamber after the removal of the sweep field. For a particle to produce a track appearing on the photograph, its passage also must have preceded the light flash by at least the time required for droplets to grow large enough about the ions to be photographed. Therefore the period of time between the removal of the sweep field and the light flash, as measured by the fall of the shot, minus the time required for droplets to grow large enough to be photographed (of the order of 0.050 to 0.100 seconds) is the sensitive time for tracks which show no separation by the sweep field. This is true provided that the flash of light is delayed only a sufficiently short time (of the order of a few tenths of a second) after the expansion so that the gas of the chamber is still capable of forming droplets about ions and is thus sensitive to particles at the time when the flash of light occurs.

Two Type K-25 aerial cameras have been modified for use with the chamber by adding an 0.75-diopter lens immediately in front of the camera lens, which is normally focused for large distances. The cameras are placed as shown in Fig. 4. Simultaneous pictures are taken from two different angles to provide a stereoscopic view of the chamber. Each camera takes 50 pictures, 13.9 cm by 11.4 cm, on a 6-meter roll of triple-X (exposure index 200) panchromatic film. Most of the pictures have been taken with a lens aperture of f:16.

Illumination is provided by four krypton-filled flash bulbs, each connected to a 23 μf condenser charged to a potential of 2000 volts. These flash bulbs and their power supplies are part of a Model S-1169 Army Signal Corps light identification unit. Since this unit is designed to operate on the standard 24-volt d.c. aircraft supply, it can be used with only minor modifications. Four of the Model X-400 flash-bulb units arranged in a straight line approximate the desired line source and are rugged and simple to mount.

The front plate of the chamber, the diaphragm, and the back plate of the air-filled cavity behind the chamber are all of "Tuflex" glass so that the chamber is essentially three transparent circular disks arranged to form a cylinder, with the center disk the movable diaphragm. This allows the chamber to be illuminated from the rear (side opposite from that of the cameras) as shown in Fig. 4. Because the spherical droplets in the chamber scatter many times more light per unit solid angle through a small angle of deviation than through a large angle, such rear illumination requires only a small fraction of the energy for lighting demanded by right-angle illumination with the light sources at the sides of the chamber. An arrangement of chromium-plated iron mirrors, shown edge-on in the side view in Fig. 4, helps distribute the light in the chamber so that tracks in different parts of the chamber will scatter more nearly equal amounts of light into the cameras.

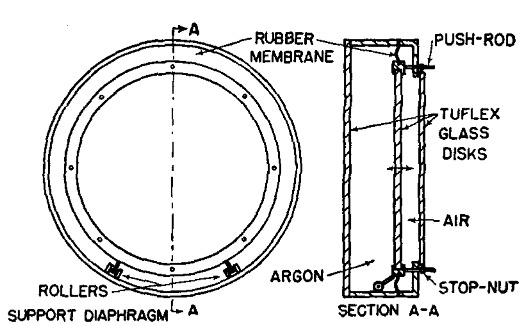

FIG. 2. Method of obtaining expansion of chamber.

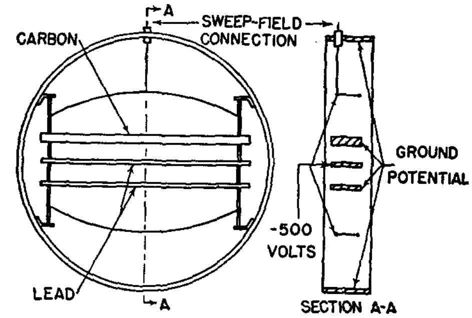

FIG. 3. Arrangement of plates in chamber.

The arrangement of the mirror system is symmetrical with respect to a horizontal plane through the center of the chamber. A more even distribution of illumination can be obtained by using brighter lights at a greater distance from the chamber. However, this was not permitted by the space available in the cabin of the airplane. Direct rays of light and rays scattered through only a very small angle are prevented from entering the cameras by arranging the source and mirrors so that they are hidden behind the carbon and lead plates mounted in the chamber, in the manner indicated in Fig. 4.

Argon gas saturated with ethyl-alcohol vapor is used to fill the chamber. Although the chamber has been tested to withstand a pressure of one atmosphere above the surrounding atmospheric pressure, a pressure somewhat less than half of this value (with the chamber in the compressed position) has been used for most of the high-altitude experiments because of the possible danger of losing pressure in the pressurized cabin in which the chamber was placed.

In order to insure that the gas near the top of the chamber is saturated with alcohol vapor, alcohol is pumped from a small pool in the bottom of the chamber through a filter and check valve up to two small pipes entering the top of the chamber. From these pipes the alcohol squirts onto the rubber part of the diaphragm and runs down again to the pool at the bottom of the chamber, providing a surface of alcohol of considerable

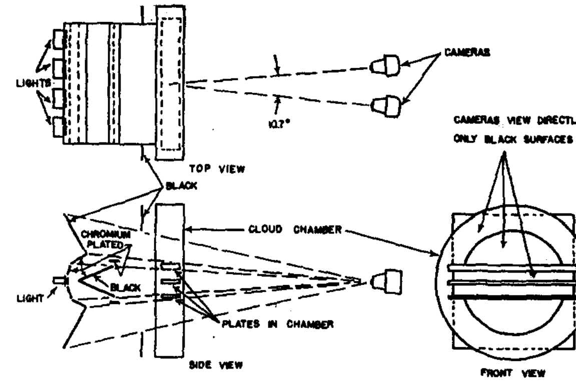

FIG. 4. Cameras and illumination.

area from which evaporation can take place. The alcohol pump is run only for a few seconds during the waiting part of the cycle of operation, when the diaphragm is in the position which compresses the chamber gas.

Regulation of the air pressure which controls the position of the diaphragm is accomplished by means of pressure-reducing valves and electrically-operated shut-off valves. Since the rubber part of the diaphragm is not perfectly stiff, changing the differential pressure across the diaphragm changes the chamber volume slightly even when the diaphragm is against the stops, thus providing a fine adjustment of the expansion ratio in addition to the rather coarse mechanical adjustment of the stops. Adjustment of the springs that control the angle of the diaphragm during its movement is best accomplished by watching as the chamber expands the relative motion of the images of a small light reflected in the three glass plates.

The air used to compress the chamber is dried to prevent the appearance of a cloud of water droplets behind the diaphragm on expansion and is warmed slightly to prevent cooling of the diaphragm and the resultant condensation of alcohol on the chamber side of the glass.

Operation of the chamber is controlled electrically by means of conventional circuits. Pictures have been taken both with the chamber expanded at predetermined intervals and with counter control. A cycle of operation with the former type of control requires approximately one minute. Although a slow expansion during each cycle is desirable for a few cycles when first placing the chamber in operation after filling it, further slow expansions are not necessary.

A typical photograph obtained with a random expansion at an altitude of 12,100 meters is shown in Fig. 5. A light delay long enough to take advantage of most of the sensitive time of the chamber was used. In some of the flights the length of time the light was delayed after the expansion was considerably reduced to decrease the number of tracks and the resultant confusion in each photograph. When the pictures are viewed stereoscopically, the effect of separating the tracks in a third dimension makes their interpretation clearer. Views from both cameras are shown in the final enlargement in Fig. 5. In Fig. 5 the photograph at the upper right shows an enlarged view of the region of the chamber enclosed by the rectangle shown in the left-hand photograph. A further enlargement is shown in the lower right-hand view which includes that part of the chamber enclosed by the rectangle which appears in the upper right-hand view. The successive enlargements show the large amount of detail which appears on these photographs, and show also the number and variety of tracks recorded by a single expan-

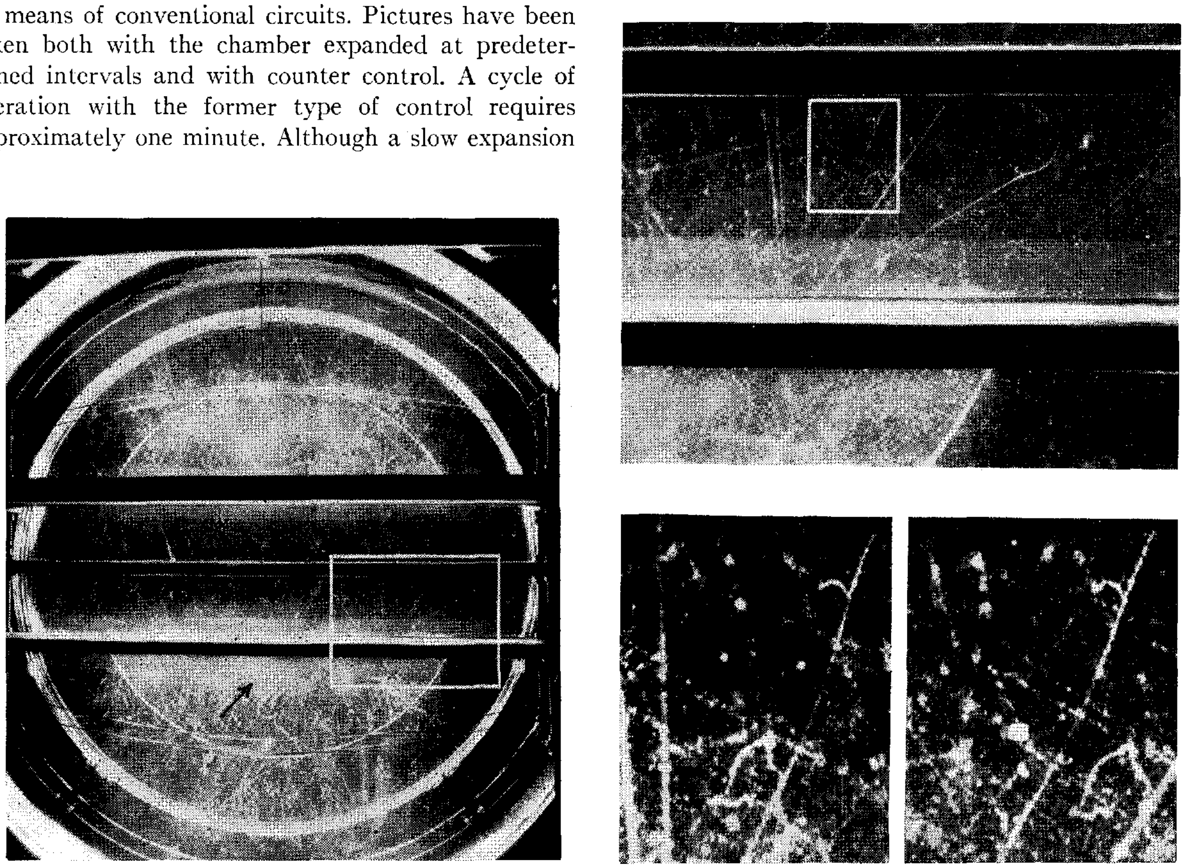

FIG. 5. Typical chamber photograph (long light delay) at 12,100 meters altitude. Enlargements show detail in right center of picture.

sion of the chamber at high altitude. Some results obtained with this equipment have previously been reported.[1,2]

I wish to express my indebtedness to Professor C. D. Anderson, who provided much helpful advice in the course of these experiments.

[1] E. W. Cowan, Science **108**, 534 (1948).
[2] Adams, Anderson, and Cowan, Rev. Mod. Phys. **21**, 72 (1949).

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The Ten-Channel Electrostatic Pulse Analyzer

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A ten-channel pulse height discriminator using a beam deflection tube is described. The instrument provides one-volt channels and has a high degree of stability. Essential circuits are given so that the analyzer may be readily duplicated. Performance and limitations are discussed.

To determine the energy spectra of particles in nuclear experiments, one method is to measure the height of pulses produced by the particles in an ionization chamber. Ordinarily these pulses are amplified and then sorted and counted by means of a counting circuit which incorporates a pulse-amplitude discriminator. In its usual form, this discriminator will produce a standard output pulse for input pulses exceeding a certain amplitude and will produce no output if the pulses are less than this amplitude. The discriminator level, or bias, is adjustable, and by taking consecutive sets of data, the well-known integral-bias curve is obtained. Another method employs a discriminator that responds to voltage pulses in a certain interval and does not respond to pulses outside this interval. Taking successive sets of data gives a differential-bias curve.

A device employing "*n*" single-channel discriminators responding to adjacent voltage intervals has been described by Freundlich, Hincks, and Ozeroff.[1] These analyzers employ 12, 20, and 30 channels. Similar instruments using ten channels have been built and are now being used at the Los Alamos Laboratory. These analyzers, although having several disadvantages, have proved very useful. In spite of regulated power supplies, it has been necessary to recalibrate them frequently, each of the ten channels having to be set individually. The smallest channel width obtainable has been about two to four volts. Physically, the analyzers are large and employ 168 vacuum tubes.

To overcome these limitations, a ten-channel analyzer using an electron beam tube has been devised. The analyzer is shown in Fig. 1. It occupies six $8\frac{3}{4}$-inch chassis in a standard relay rack. The units are, from top to bottom, (1) a pulse generator for calibration, (2) a pulse amplifier, (3) the analyzer chassis, (4) five "scale-of-sixteen" scalers, (5) five "scale-of-sixteen" scalers, and (6) the analyzer power supply. The ionization chamber and its preamplifier are the only additional items of equipment required.

Deflection Tube

The heart of the analyzer is the $\times 150$ beam deflection tube shown in Fig. 2. Its internal structure is shown in Fig. 3. The tube was developed by the Federal Telecommunication Laboratories at Nutley, New Jersey, as an outgrowth of their work on beam tubes for electronic switching and multiplexing.[2]

The operation of the tube as a pulse amplitude discriminator is shown in Fig. 4. The pulses from the amplifier are made push-pull and applied to the deflection plates. Initially the beam is deflected above the region of the dynodes by applying a d.c. voltage to the deflection plates. As the pulse is applied, the beam travels downward a distance proportional to the amplitude of the pulse, causing it to fall on one of the dynodes. In practice the beam is cut off during the first part of this interval by a negative bias on the focusing and gating electrode. One microsecond after the beginning of the input pulse the beam is gated on for 1.5 microsecond. Since the beam is off during the rise and fall of the input pulse, an output signal actually occurs only

[1] Freundlich, Hincks, and Ozeroff, Rev. Sci. Inst. **18**, 90–100 (1947).

[2] Grieg, Glauber, and Moskowitz, Proc. I.R.E., **35**, 1251–1257 (1947).