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Continuously Sensitive Diffusion Cloud Chambers*

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The following types of continuously sensitive diffusion cloud chamber have been built and successfully operated: a chamber designed to be photographed through the top for use with a particle accelerator; a chamber designed to be photographed from the side for cosmic-ray studies; and a very simple chamber for demonstration purposes. The construction and best operating conditions are described.

SEVERAL models of cloud chambers are described here which are of the same general type of continuously sensitive diffusion chamber described by Langsdorf.[1] Supersaturation is obtained by the diffusion of alcohol or water vapor from the warm roof of the chamber downward through an inert gas to the cold floor. Condensation occurs on ions in a sensitive layer of several inches depth near the floor of the chamber. Considerable simplification in the design and also some improvement in the results have been obtained.

The following general considerations apply to all of the specific types that will be described later. A pad of black velvet or other cloth soaked with alcohol and warmed by contact with a metal plate that forms the top of the chamber has been found to be the best vapor source. The deepest sensitive layers have been obtained with mixtures of methyl alcohol, ethyl alcohol, and water. However, since the composition of the mixture changes with evaporation, and since methyl alcohol alone gives very good results, pure methyl alcohol usually has been used.

As the temperature of the roof is increased, the depth of the sensitive layer increases until an optimum temperature is reached above which the sensitive volume splits into two layers. Since the exact temperature depends upon the dimensions of the chamber and the vapor used, numerical values will be given later only for specific instances. Droplets which form about ions in the upper sensitive layer grow very rapidly because the concentration of vapor is greatest near the source of vapor at the top of the chamber. These droplets fall to the bottom, and remove vapor that would otherwise increase the supersaturation of the lower part of the chamber so that below the top layer the supersaturation is not sufficient for ion condensation, except in a shallow layer near the bottom where the temperature gradient is large. As the temperature of the top plate approaches the value at which the vapor pressure of the liquid nears the total pressure in the chamber, which might appear at first sight to be the best temperature, the upper layer approaches the top of the chamber and fills the chamber with a general rainfall. The very rapid growth of droplets in the top layer results in a competition for vapor in which only a relatively few of the ions near the top of the layer are in regions of sufficient supersaturation to form droplets. No recognizable tracks are formed in this layer, and the fact that the condensation is actually on ions can be ascertained only by careful observation of the effect of an electric sweep field. A pulsed electric field, of one of the types to be described later, is of some value in preventing the splitting of the sensitive layer.

This type of general rainfall may have been the cause of some of the difficulties with Langsdorf's chamber attributed to droplet nuclei produced by the vapor source.[1] Although a general rainfall is produced by heating the vapor source above the boiling point, at the normal operating temperature "streamers" of droplets which sometimes appear have been traced to leaks that permit contaminated air from the outside to enter

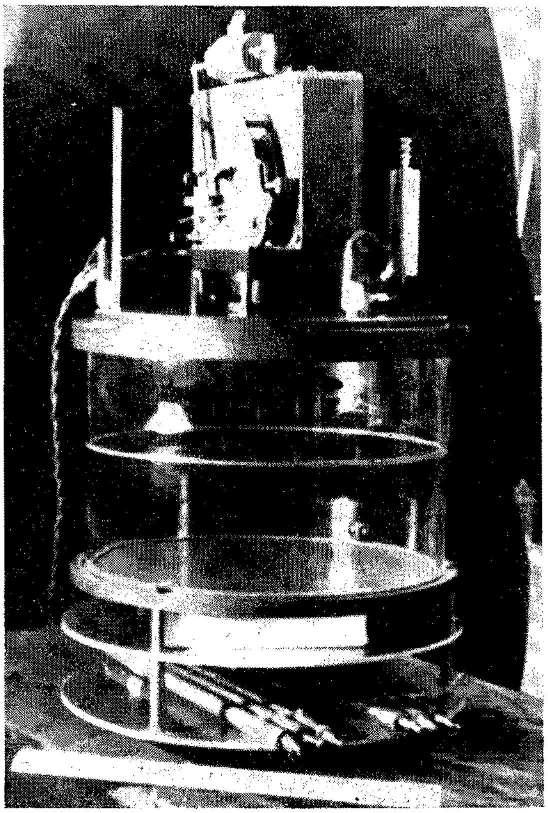

FIG. 1. Continuous chamber with camera mounted above.

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[1] Alexander Langsdorf, Rev. Sci. Inst. 10, 91 (1939).

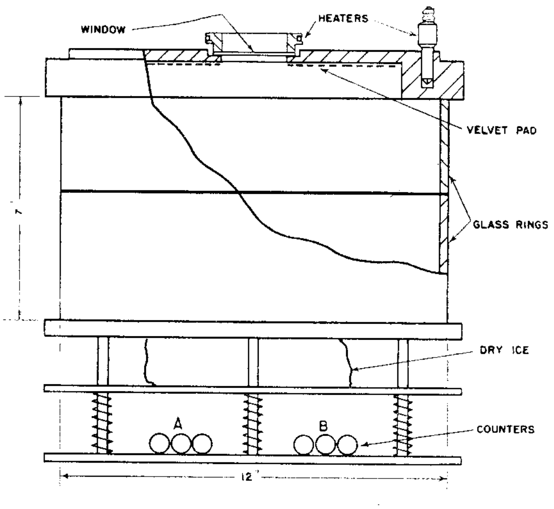

FIG. 2. Construction of chamber shown in Fig. 1.

the chamber, or to corona from fine points if a high sweep voltage is used. Streamers resulting from the circulation of contaminated air through leaks, which are especially likely to occur when the top is cooling, appear like small waterfalls in the chamber and may be stable over considerable periods of time. Brass, aluminum, rubber, Neoprene, and several types of cloth have all been placed in direct contact with the liquid in the top of the chamber without causing any apparent trouble.

Air may be used as the inert gas in the chamber, although argon gives better results, especially if ethyl alcohol is used in the mixture. If the molecular weight of the vapor is heavier than the molecular weight of the inert gas, there will be some unstable motion of the gas near the top of the chamber, resulting in considerable condensation on the walls of the chamber. However, the lower layers of gas in the chamber will still be stable, and tracks have been observed even using combinations such as helium and ethyl alcohol. Experiments made to determine the optimum pressure in the chamber showed that in the range of 0.1 to 2 atmospheres the difference in performance, which was difficult to measure because the optimum temperature and height vary with pressure, was not sufficient to justify the added difficulty in operating at a pressure different from one atmosphere.

The floors of the chambers have been made of aluminum blackened by an anodizing process or of black Bakelite. When the bottom becomes covered with alcohol, the black surface makes an excellent background for photography or viewing if the source of illumination is arranged so that its reflection is not

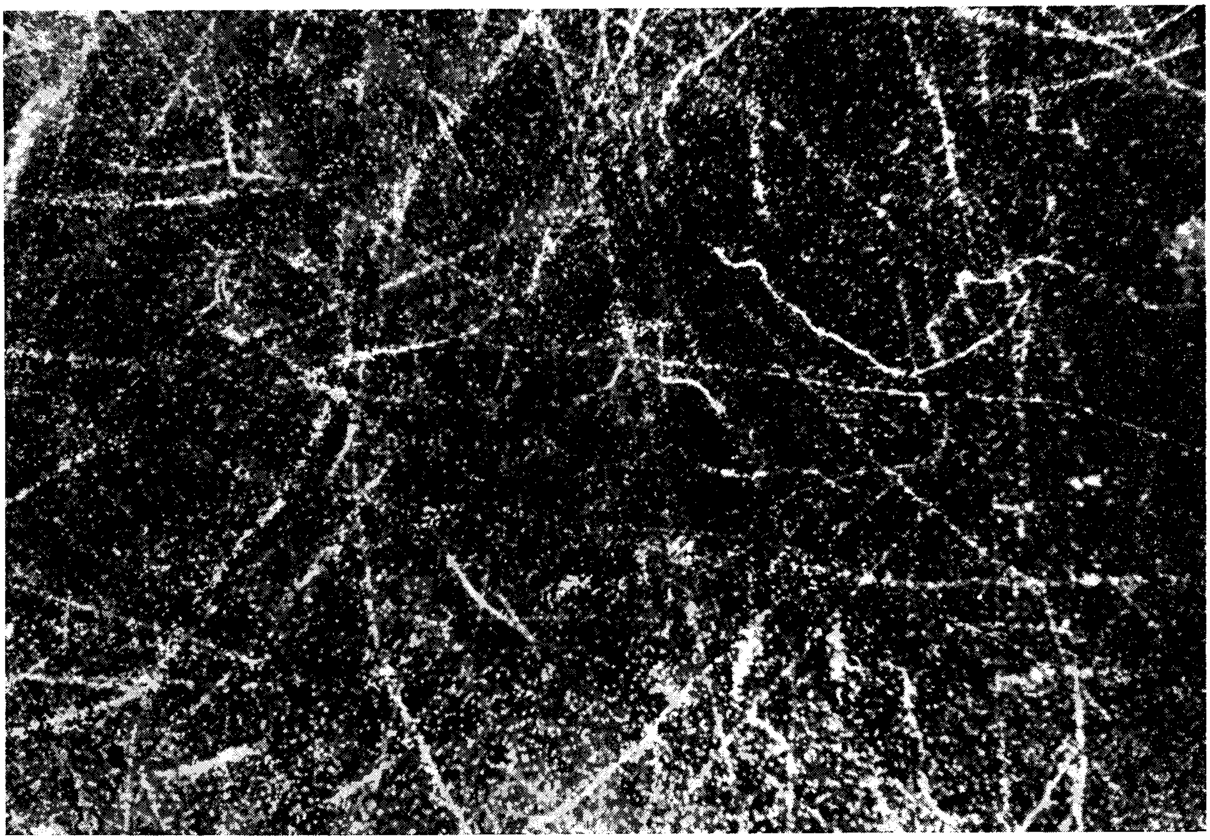

FIG. 3. Tracks produced in chamber by exposure to radium source.

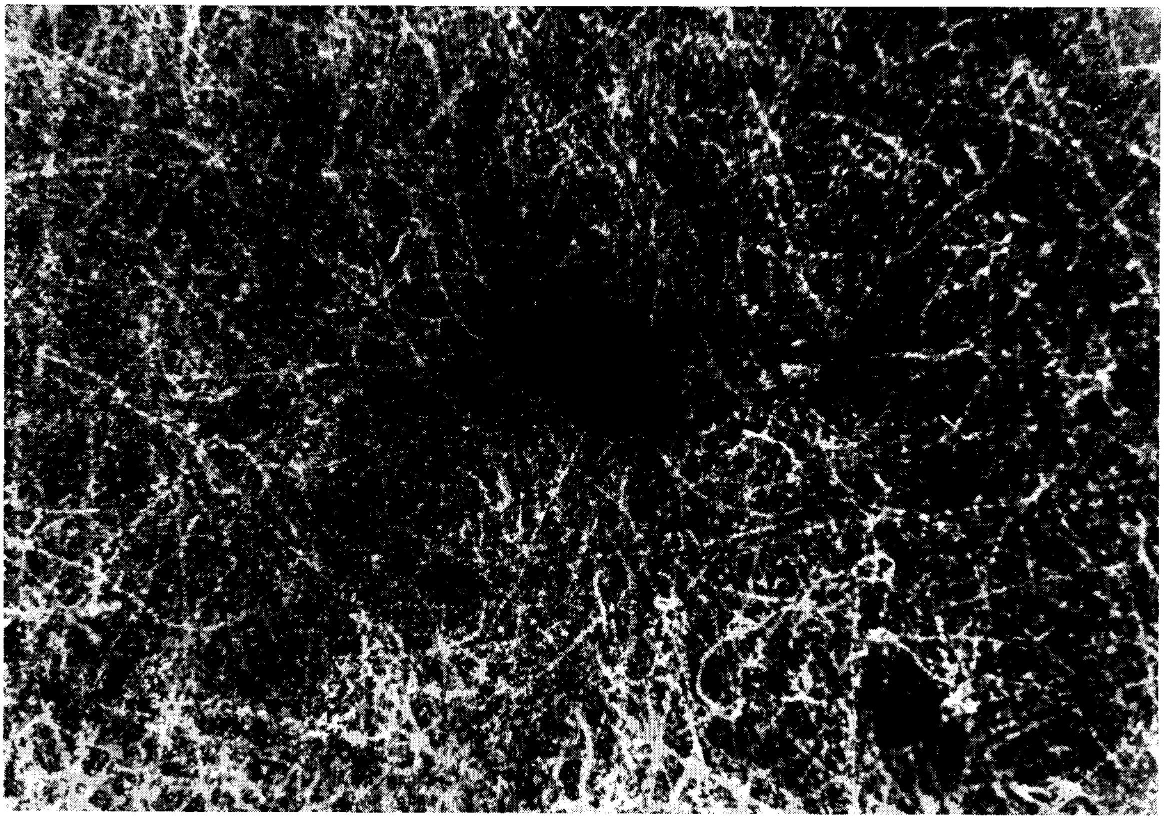

FIG. 4. Photograph of chamber after heavy exposure to radium source.

visible in the bottom. The temperature of the floor of the chamber is not at all critical. Tracks are first observed as the temperature is lowered below about −30°C, and below −70°C (with methyl alcohol) droplets begin to form without ion nuclei, producing a thin cloud layer about one-eighth of an inch deep on the floor. The most convenient method of cooling the bottom is by direct contact with a block of dry ice (−78°C). If the illumination is such that the cloud layer on the floor forms an objectionable background, a thin heat insulator between the dry ice and the bottom may be used to raise the bottom temperature slightly. Another method of cooling is by partially submerging the bottom of the chamber in a bath of alcohol and dry ice, which gives a temperature just above that necessary for the cloud layer on the floor to form.

With a pressure of one atmosphere in the chamber, the height of the chamber giving the deepest sensitive layer is about eight inches. If the diameter is considerably larger than this height the sensitive layer is uniform in depth except near the walls. With a diameter about the same as the height, the layer becomes mound shaped with the greatest thickness at the center.

The chamber shown in Figs. 1 and 2 was designed with the idea of possible use with the synchrotron now under construction at the California Institute of Technology. A camera with a wide-angle lens of 28-mm focal length is mounted above a small window in the top of the chamber, which has a cylindrical glass wall. The construction is shown in Fig. 2. A velvet pad with a hole in the center is sewed to a piece of perforated sheet aluminum that is in turn fastened to an aluminum top plate, which is sealed to the glass ring forming the walls of the chamber. This plate is heated by three pencil-type soldering iron tips inserted into holes around the edge of the metal plate. About 40-watts power is needed for normal operation. A small additional heater is wound around the clamping ring for the top window to prevent vapor from condensing on the window.

The alcohol is contained in a reservoir and fed through a needle valve to the velvet pad, over which the alcohol becomes uniformly distributed. The bottom of the chamber is made of anodized aluminum, and dry ice is held in contact with it by a spring-supported plate. The cylindrical glass wall is made of two twelve-inch diameter glass rings, the lower one being four inches high and the upper three inches high. These rings are separated by a conducting rubber gasket which is one of the sweep-field electrodes. The other sweep-field electrode is formed by the top and bottom of the chamber connected electrically. This arrangement removes the ions from the upper part of the chamber without pulling them down into the sensitive layer.

Rubber gaskets are used to seal the rings to the top and bottom of the chamber, which may be pulled tightly against the rings by Bakelite rods running from the top to the bottom. When the chamber is used at atmospheric pressure the Bakelite rods may be omitted and the chamber clamped together only by the weight of the top plate. If the rings are accurately ground the leaks are small enough not to disturb the operation of the chamber seriously, although the displacement of inert gas out of the chamber by vapor may change the operating conditions. The outside of the lower ring occasionally must be wiped with a cloth moistened with alcohol to remove the frost that accumulates.

When the chamber is used with the synchrotron, it is planned to pulse the sweep field by applying a voltage to remove the ions after each burst of particles from the synchrotron. The photograph in Fig. 3 was taken after the chamber was exposed to a sudden pulse of radiation from a radium source. With a properly synchronized sweep-field voltage pulse of about 600 volts amplitude, the chamber will recover sufficiently fast to be sensitive to a large pulse of radiation, such as shown in Fig. 4, at intervals of three or four seconds. Although a continuous background of ionization reduces the height of the sensitive layer, the chamber operates satisfactorily with a background several times the normal background ionization at sea level.

With argon and methyl alcohol in the chamber, the sensitive layer is about three inches deep in the center of the chamber at the optimum roof temperature of 39°C. With air and methyl alcohol the sensitive layer is about three inches deep at a roof temperature of 44°C, but there is some turbulence near the top of the chamber which limits the depth of the sensitive layer. The addition of water to the alcohol causes the droplets to grow more slowly. With a liquid mixture of about equal parts of methyl alcohol, ethyl alcohol, and water, it is possible to obtain a sensitive layer five or six inches deep after a pulse of sweep voltage. The tracks in the upper part of the layer, however, are diffuse, indicating that the supersaturation is barely sufficient for ion condensation, and, except for a small time after the pulse of sweep voltage, the sensitive layer divides into the two parts mentioned earlier. A roof temperature of 55° to 65°C is best for the mixture given above when using argon in the chamber.

This chamber also has been operated with the coincidence-counter arrangement shown in Fig. 2, which tends to select cosmic-ray showers of two or more particles. A coincidence between any counter in group *A* and any counter in group *B* triggers a flash lamp after a 180-millisecond delay. Figure 5 shows a small cosmic-ray shower photographed with this type of counter control. Since the tracks are very sharp this arrangement operated at high altitudes could provide an

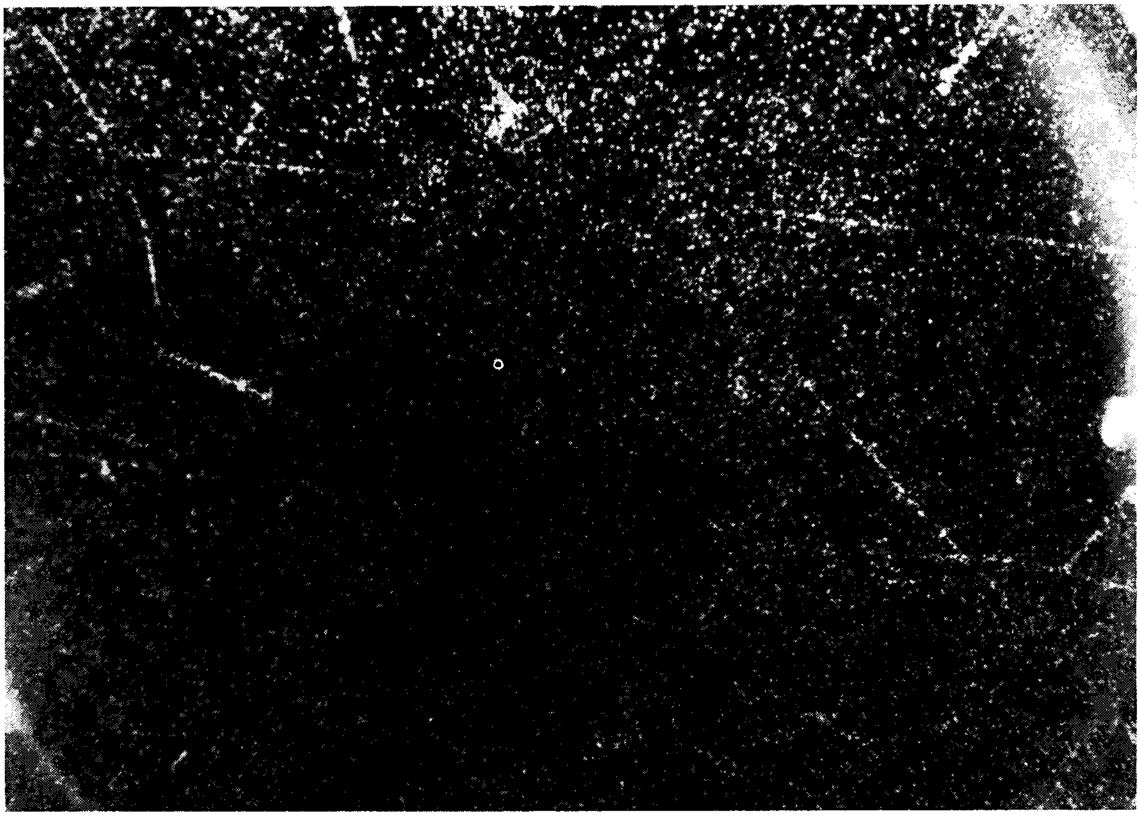

FIG. 5. Small cosmic-ray shower photographed with counter control.

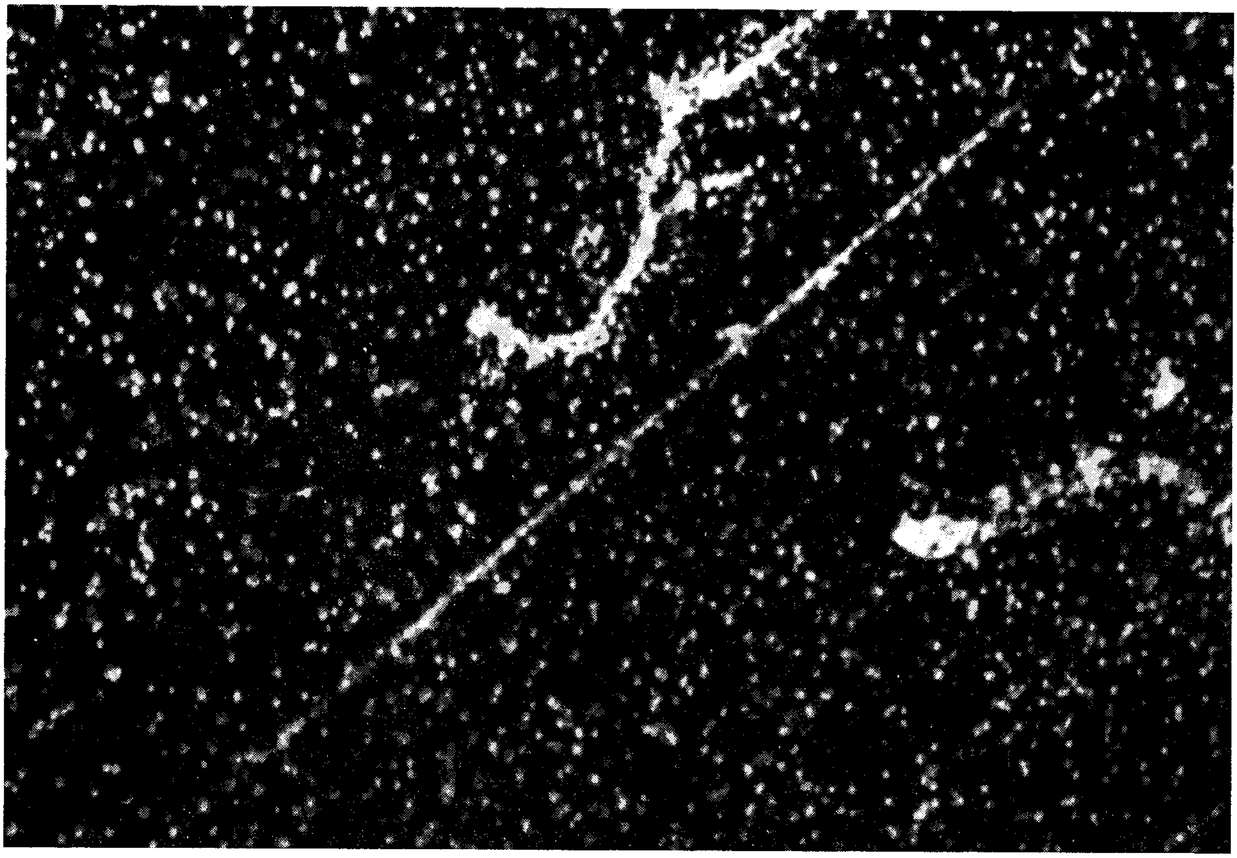

FIG. 6. Sharp cosmic-ray track photographed with 20-msec. light delay (actual projected length of track as viewed by camera about 6 cm). Crooked track was made by low energy electron at an earlier time, and droplets have separated while falling.

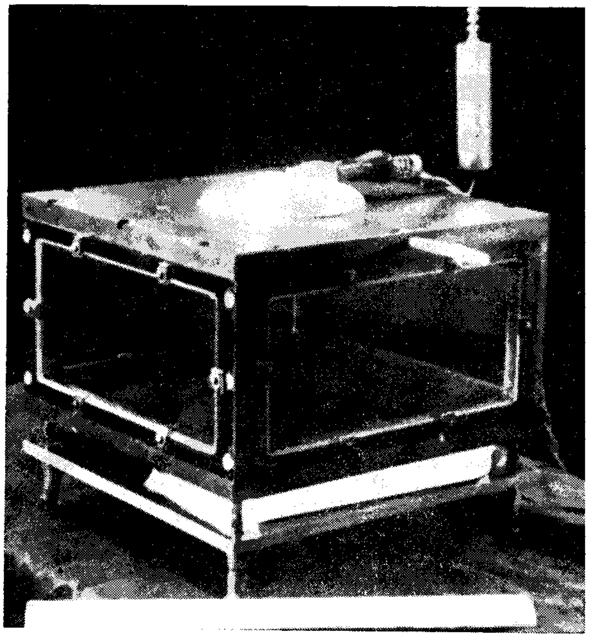

FIG. 7. Continuous chamber designed to be photographed from side.

effective means of studying the cores of large air showers.

The flash lamp is a General Electric Type FT-422, connected to 250 μf charged to a voltage of 2000 volts. Only the region from $\frac{1}{4}$ in. to $2\frac{3}{4}$ in. above the floor is illuminated by the flash. A lens aperture of f/8 gives adequate exposure on Linagraph Pan or Linagraph Ortho film. Under these conditions the photograph may be taken as soon as twenty milliseconds after the counters are tripped, although a very short delay is not essential since the diffusion chamber is not troubled, as is the expansion-type cloud chamber, by the diffusion of ions before droplet growth begins. The stable atmosphere of the diffusion chamber also alleviates the problem of distortion. Figure 6 is an enlarged photograph of a sharp cosmic-ray track photographed 20 milliseconds after the counters were tripped. When the chamber is operated with counter control, a sweep voltage pulse of 1.5 seconds duration and 600 volts amplitude is applied every 45 seconds.

The rectangular chamber shown in Fig. 7 was designed to be photographed from the side for studies of cosmic rays. With the thought in mind that this chamber might be used later in a magnetic field, the smallest dimensions consistent with good results were used. The inside dimensions are 9×9×5 in. high, and the maximum depth of the sensitive layer, using methyl alcohol and argon, is $2\frac{1}{2}$ in. with a roof temperature of 34°C. A window of black glass in the back provides a background for taking a photograph through the front window, and the sensitive volume is illuminated through the side windows. The windows are mounted in Bakelite frames that are held together with screws and Bakelite cement to form the walls of the chamber.

The construction of the top and bottom of the chamber is very similar to that of the first chamber described except that the heater consists of the heating element from a coffee percolator clamped to the center of the top. A pulsed sweep voltage of 600 volts is applied between the top and bottom plates.

The continuously sensitive diffusion chamber makes an ideal demonstration unit, both because the continuous operation makes the tracks easy to observe, and because of the simplicity of construction. A glass ring resting on a black Bakelite base placed on a cake of dry ice makes a very simple demonstration chamber. The vapor source may be a doubled layer of black cloth tied over the top and saturated with warm alcohol. If operation for a considerable time is desired, a metal plate warmed by a flat iron may be placed on top of the cloth. The chamber floor should be covered with a layer of alcohol to seal the bottom to the glass ring and to provide a good viewing background. A battery of several hundred volts may be connected by clip leads between the cloth and the Bakelite (with the clip in contact with the alcohol puddle around the ring) to provide a sweep-field, although this is not essential. With a good source of parallel light projected horizontally through the chamber, a large group can observe the tracks from all directions except when looking directly into the light. A continuously sensitive demonstration chamber has been used for several lectures, and for several months it has been one of the regular demonstrations shown visitors to this laboratory.

I would like to express my appreciation for the encouragement and advice in this work by Dr. C. D. Anderson, who, in 1936, made some of the first investigations of this type of chamber.

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A Rapid Method for Calculating and Using Platinum Thermohm Tables

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A method is described whereby resistance-temperature tables can be calculated in a few hours using punched cards. The method is much simpler and quicker to use than the "platinum temperature" tables. An example is given for reducing resistance measurements to temperature and a method for checking bridge and thermohm drift with respect to the tables is proposed.

THE THERMOHM AS THE INTERPOLATION INSTRUMENT

THE International Temperature Scale of 1948 defines the temperature °C from the ice point to the antimony point by the formula

$$R_t = R_0(1 + At + Bt^2),$$

and from the oxygen point to the ice point by the formula

$$R_t = R_0(1 + At + Bt^2 + C(t - 100)t^3).$$

R_t is the resistance of the thermohm at any temperature t°C and R_0 is its resistance at the ice point. The constants A, B, and C are obtained by measuring R_t at the steam, sulfur, and oxygen points. The constants for any thermohm may be obtained by having the thermohm certified at the National Bureau of Standards. From these constants, a table may be calculated of values of R_t/R_0 *vs.* t°C and t°F whereby the resistance may be converted to temperature. The thermohm and its table, together with a Mueller Bridge, form one of the primary temperature standards from the oxygen point to the antimony point.

CALCULATIONS FROM THE OXYGEN POINT TO THE ICE POINT

The following constants were obtained from a National Bureau of Standards Certificate for one of two thermohms in use at present.

$$A = 3.9821 \cdot 10^{-3};$$
$$B = -5.862 \cdot 10^{-7};$$
$$C = -4.351 \cdot 10^{-12}.$$

Write the formula as

$$\begin{aligned} R_t/R_0 &= 1 + At + Bt^2 + C(t - 100)t^3 \\ &= 1 + At + Bt^2 + Ct^4 - 100Ct^3. \end{aligned}$$

By setting $t = 0, -1, -2, -3, -4,$ and -5°C in the expression for R_t/R_0, we may obtain the successive differences. The fourth difference is a constant as the