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Reviewed by C. W. Huntington 8/21/79

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LIMITATIONS AND PAST APPLICATIONS OF THE CLOUD CHAMBER

(Information Report)

Date: March 23, 1949

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Distributed: AUG 25 1949

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INTRODUCTION

The cloud chamber is a means of observing the path of ionizing radiation. It does not reveal the radiation directly, but gives a visible trail of the path along which the radiation has traveled. The trail is formed by vapor condensing upon pairs of ions remaining after an ionizing particle has passed through the medium.

The mutual interaction among rays, atoms, nuclei, and particles, can be studied and measured with the aid of vapor trails. Measurements of changes in direction and range as recorded on the photographs may be interpreted in terms of changes in momentum and energy of the particles in these reactions.

To obtain a precision measurement is difficult with a cloud chamber. The dependence of the apparatus upon a sudden gas expansion is certain to create distortions resulting from turbulence. Furthermore, since any radiation is subject to variations, precision measurements can be obtained only be the collection of numerous observations for statistical analysis.

DESCRIPTION

The essential portion of a chamber is the volume of gas and vapor enclosed by a glass cover plate, a circular glass rim, and a moveable diaphragm. This volume is subjected to an adiabatic expansion that causes the saturated vapor present to become supersaturated. When the adiabatic expansion occurs, the ions in this space become drop centers, and about them drops grow to a visible size by condensation of the vapor. The path of the ionizing radiation in this volume can then be observed visually or photographically. The droplets formed about the ions in the wake of a moving particle appear as a line when proper illumination is used.

The sensitive time of a chamber is defined as the time interval associated with a single expansion during which any radiation in the chamber is made visible by that expansion. For obtaining sharp tracks, the sensitive time is usually a fraction of a second so that the ions do not diffuse before the photograph is taken. It is possible to obtain more tracks per expansion by using a large sensitive time. Williams,[1] using a rubber-diaphragm type chamber thirty centimeters in diameter and thirty centimeters in depth, showed that an increase in the depth of a chamber increased the sensitive time. Most chambers used in nuclear research have had to forfeit this depth because of difficulty in obtaining a large, linear field distribution when the chamber is used in conjunction with a magnet. However, a large volume and large sensitive time make a cloud chamber a very sensitive detector of radiation.

To operate a chamber continuously by performing successive expansions on the working volume, it is necessary to provide some means for removing old drops. This removal can be accomplished by sweeping ions from the chamber with a potential gradient and waiting for precipitation of neutral droplets. Blackett[2] has determined a cycle requiring a minimum of fifteen to twenty seconds that allows old drops to be removed, some of the condensate to re-evaporate, and the chamber to re-establish thermal equilibrium.

Continuous cyclic operation is useful in the investigation of nuclear phenomena that are so rare that numerous pictures must be taken to detect a single event; and it is desirable for the most rapid accumulation of the large amounts of data necessary for statistical studies. For an accurate β-ray spectra determination, it is necessary to record some ten-thousand pictures depending on the number of tracks per picture. When it is necessary to take a large number of photographs, an automatic arrangement is required for controlling the sweep voltage, the expansion, the lighting, the camera, and the resetting of the chamber. This is easily accomplished by the use of electronic circuits in which relays are operated at the proper instant.

MEASUREMENTS WITH THE CLOUD CHAMBER

Specific Ionization

A determination of an ionization density is readily made with the cloud chamber. For alpha particles and protons, the ionization density is large, and therefore they tend to produce a heavy solid-looking track. These tracks are usually straight but occasionally there is a deflection where the particle has closely approached a nucleus. For electrons and positrons, the ionization is weak and the tracks look thin. In this case, it is convenient to count the total number of ions produced per centimeter of path which is by definition the specific ionization. An approximation of the velocity of beta particles can be obtained from specific ionization. Mesotrons have a tendency to produce an intermediate degree of ionization. For neutrons, neutrinos, and gamma rays little or no ionization is obtained directly, and these studies must resort to secondary recoil particles.

As regards the medium the radiation traverses, the specific ionization is directly dependent on the number of electrons per cubic centimeter. The specific ionization depends on the charge and to a large extent varies inversely as the square of the velocity of the incident particle. The average rate of dissipation of energy through ionization and excitation by fast primary particles has been determined by Rossi and Greisen.[3]

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Although there are many ways of measuring the specific ionization of a charged particle, the cloud chamber is the only method that enables one to determine the primary and the total ionization separately. There exist errors which are due to recombination of ions and to losses of energy which are less than the ionization energy.

Range

The range of particles is of great importance because it is possible to deduce the energy and origin from this observation. To determine the exact range is difficult because of unknown losses of energy in reaching the surface of the source and the effects of straggling in the medium. The measured range is corrected to centimeters of dry air at 15°C. and 76 centimeters of mercury pressure.

To obtain the energy, or the velocity, as a function of the range, one may resort to curves and tabulated data given by Livingston and Bethe[4] and Eular and Heisenberg.[5] The observed range of the natural alpha groups agrees with the theoretical range-energy relations of Livingston and Bethe since the constants were chosen to overcome uncertainties in the average excitation potential and losses through capture-recapture electrons at the end of the track.

Momentum and Magnetic Curvature

A homogeneous magnetic field applied to the chamber provides a convenient means for measurement of momentum and for discrimination between negatively and positively charged particles through the bending of the cloud track. This allows measurements of very high energy. The magnetic field selected must not allow the ionic particles either to pass undeflected or to revolve in the chamber. Usually a field of a thousand gauss can be used for energies between 100 Kev. to 10 Mev. for heavy particles. However, for gamma and beta study, it is found that field strengths as high as 2000 gauss are required.

A knowledge of the field strength and the radius of curvature makes it possible to determine the momentum of a particle when its mass and charge are known. Equations exist that connect these values with the energy and the velocity of the particle.

The measurement of the rate of change of momentum is accomplished by the introduction of a dense medium, such as lead, into the path of the radiation. Since negligible variation of curvature is observed in a path when a fast particle travels through a medium of low density, the curvature of any track inside the chamber is assumed to be constant. Curvature measurements in the gas before and after the radiation travels through the dense medium reveal the rate of change of momentum.

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Mass Determination

The mass of an unknown particle can be determined by cloud chamber measurements. This requires the knowledge of any two of the following: specific ionization, range, magnetic curvature, and the rate of change of magnetic curvature. Some of these methods have been developed specifically for the study of the properties of high energy cosmic particles. For low velocity particles, the mass can be recognized by observation of the density of ionization as this identifies the radiation present.

Nuclear Reactions

The observation of individual collisions as they occur in nature is effectively accomplished with the cloud chamber. The laws of the conservation of momentum and energy can be applied to close nuclear encounters through the separate ranges and angles involved. The masses and energies of the product nucleus, of the target nucleus, and of the bombarding particles, and the reaction energy of the transmutation are all involved in a single collision. It is possible to calculate anyone of these unknown when the other values are determined. Calculations of this kind are used for determining constants and conversion factors.

Alpha particles, protons, deuterons, neutrons, and gamma rays may be used for producing excited states of nuclei. When the excited state exhibits a resonance effect, the width and the energy for that resonance level can be determined as the complete reaction is recorded on the cloud chamber photograph. The selection rules which govern nuclear disintegration can be readily demonstrated by such observations.

Spectra

A study to obtain the number of particles within definite ranges reveals the spectrum of those particles. Studies dealing with the complexity of alpha-ray spectra have been carried out by numerous investigators. The difference between the discrete emission energies for alpha particles has been accounted for by gamma radiation since the lower range alphas are associated with gamma rays of discrete energy levels.

The continuous spectra of beta rays and the line spectra of secondary electrons give information concerning the nuclear particles that are involved in a reaction. Nuclear gamma rays produce the photoelectrons and conversion electrons observed in the line spectra; and these electrons provide a means of identifying the gamma ray energies emitted from the nucleus.

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The problem of counting neutrons and measuring their energies to obtain the neutron spectra is answered best by using a cloud chamber. The observation of neutrons is accomplished indirectly by resorting to recoil protons. The energy of these protons can be associated with the energy of the neutron responsible for the collision. A detailed study of various energy distributions of neutrons and the ranges of the recoil protons in a cloud chamber has been accomplished by Bonner[6] for various light elements. Neutron spectra have been studied by various authors, Fermi,[7] Chadwick,[8] Kurie,[9] Dunning,[10] Their results show it is possible to associate the neutron spectra of a definite energy distribution with the reaction that could produce such neutrons.

DISCUSSION OF A PROPOSED CHAMBER

The radiations and energy ranges to be studied are of primary importance in designing the working volume. In order to accomodate a wide range of radiations and energy, it is desirable to design some portions of the chamber so that they may readily be interchanged. This should allow using various sources and expansion ratios. A preliminary chamber design is shown in Figure 1.

The variation of the expansion ratio is to be accomplished by a new design. Large variations of the expansion ratio would be obtained by interchanging different thicknesses of the circular rubber ring holding the rubber diaphragm. The vernier adjustment would be obtained by regulation of the compression on this rubber ring. This compression would be controlled by special nuts on studs arranged around the chamber. It has been computed that four circular rubber rings would cover an expansion ratio from 1.2 to 1.4 without difficulty. These controls are not illustrated on the schematic drawing.

The use of various gases such as hydrogen, helium, nitrogen, oxygen, argon, or methane in the working volume makes it possible to change the stopping power of the chamber volume for a certain radiation. The gas employed may be operated at a variety of pressures: low pressures for low energy study, and high pressures when the energy is large. The gas used and the pressures chosen for a particular study will be constant while obtaining the required data.

The pressure of the air under the rubber diaphragm would be caried both above and below the pressure in the working volume. This would give the required motion of the diaphragm and cause the adiabatic expansion. The magnetic valves which control the pressure change may be operated synchronously with the component parts of the chamber.

The use of a standard sample, such as a known alpha emitter, gives a path of known initial energy at the conditions in the working volume. This allows a comparison method of determining the [redacted]

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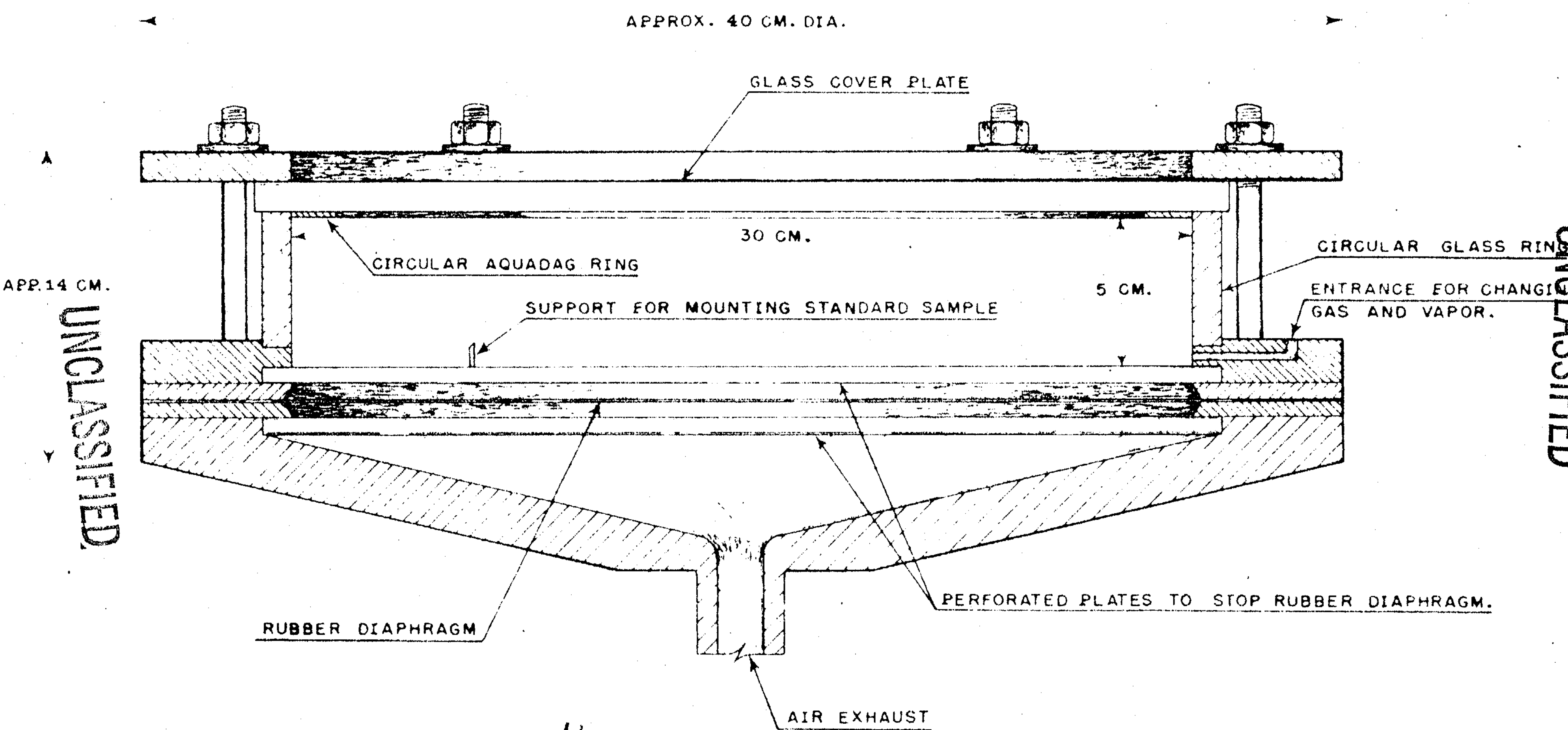

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Figure 1

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Likewise, an observed stopping power obtained at the working conditions can be compared to tables of stopping power of the gas at standard conditions when corrections are made for temperature, pressure, latitude, humidity differences, and for the stopping power of the water vapor.

A colloidal graphite ring that is painted around the inside edge of the cover plate is to be used to apply the sweeping potential for clearing old ions in the chamber. Various types of coatings on this cover plate have proven satisfactory for other investigators; however, a report from Argonne relates that the adjustment of the expansion ratio and the elimination of background fog are dependent on the coating.

Illumination of the tracks will be accomplished by using two repeating flashtubes. This provides light approximating that from a black body at about 7000° Kelvin. The short time interval of this light will eliminate the need for a camera shutter.

A single camera is to be utilized for obtaining stereoscopic pictures by using a prism and mirror system mounted directly over the chamber. Viewing of the film can be accomplished by the same or a simular optical system which projects the dual chamber image onto an adjustable screen from which the necessary measurements are obtained. This allows one to measure any track inside the chamber with a degree of accuracy which is limited by the distortions from turbulance in the chamber rather than by optical errors.

The arrangement of the unknown source to be studied will depend upon the radiation present. Because of the limitations of the range of alpha emitters, such a source is usually placed in the chamber. A thin window can be utilized for beta-rays with little loss of energy when traversing the window thickness. Gamma-rays are observed by the photoelectric effect, Compton effect, or by electron-pair formation. A thin sheet of light material such as carbon gives the desired Compton effect when the carbon is subjected to gamma radiation. One may use a thin layer of lead to study the photoelectric effect or electron-pair formation from gamma radiation. A hydrogenous substance, usually a gas, gives the observed recoil protons for the study of neutrons.

REFERENCES

1. Williams, E. J., Proc. Comb. Phil. Soc., 35, 512 (1939).
2. Blackett, P. M. S., J. Sci. Inst., 6, 184 (1929).
3. Rossi, B. and Greisen, K., Rev. Mod. Phy., 13, 240 (1941).
4. Livingston, M. S. and Bethe, H., Rev. Mod. Phy., 9, 285 (1937).
5. Eular, H. and Heisenberg, W., Ergeb. d. exakt. Naturwiss, 17, 1 (193[illegible]
6. Bonner, T. W., Phys. Rev., 59, 237 (1941).

UNCLASSIFIED

[redacted]

7. Fermi, E., Neutron Physics, Course Notes, Los Alamos, N. M. February 5, 1946, MDDC-320.
8. Chadwick, J., Proc. Roy. Soc., A142, 1 (1933).
9. Kurie, F. N. D., Phys. Rev., 44, 463 (1933).
10. Dunning, J. R., Phys. Rev., 45, 586 (1934).

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