A STUDY OF SOME PARAMETERS AFFECTING THE OPERATION OF A DIFFUSION CLOUD CHAMBER

by

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B. S., Kansas State College of Agriculture and Applied Science, 1951

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Physics

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1953

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INTRODUCTION

For over half a century scientists have used several instruments to study the properties of particles which produce ions as they pass through a gas. One type of instrument used for this purpose is known as the cloud chamber which consists of a chamber filled to a given pressure with a gas and vapor mixture. With proper control of this mixture a track along the path of the particle will form in the chamber whenever an ionizing particle passes through the chamber. By studying the track made by such a particle, scientists have been able to determine the charge, mass, and energy of the ionizing particle.

The Expansion Cloud Chamber

Until recently the only practical cloud chamber in use has been the expansion type developed by Wilson (10). The first instrument of this type consisted essentially of a glass cylinder closed on one end by a glass viewing window and on the other by a tight fitting piston. This chamber was filled to a required pressure with a mixture of air and methyl alcohol vapor. When the volume of the chamber was suddenly increased by moving the piston, the vapor was cooled adiabatically, thereby becoming supersaturated. The ions created in the gas by a charged particle passing through the chamber at the time of the expansion served as nuclei for droplet formation and the resultant track, composed of hundreds of tiny droplets of alcohol, was formed. This track was made visible by flooding the chamber with light from some intense source.

The expansion chamber described above was slow acting and very difficult to maintain in operating condition. Many refinements have been made. In 1933 Wilson (9) substituted a rubber membrane actuated by compressed air for the movable piston. When the pressure was released, the membrane rebounded and caused the necessary expansion. This modification made the chamber easier to construct and it could be used in any position.

One of the inherent limitations of this type of chamber is its short sensitive time. The sensitive time is defined as that period of time immediately after the expansion during which tracks will form. The length of the sensitive period depends on several factors some of which are the expansion ratio, geometry of chamber, gas pressure, and type of gas employed (11). Many attempts have been made to extend the sensitive time of the chamber. Bearden (1), by making mechanical modifications and using various vapor and gas mixtures, succeeded in extending the time to about two seconds. Johnson, De Benedetti, and Shutt (3), by means of high gas pressures ranging up to 200 atmospheres, have successfully operated chambers with sensitive times of about five seconds. Even these extended sensitive times are relatively short. Not only is the sensitive time short but only a few expansions can be made each minute. Thus the effective operation time is only a small fraction of the total time that the chamber is in operation.

To make the chamber more efficient for taking photographs of the tracks, the motion of the rubber membrane and the switching of lights used to expose the film are controlled by elaborate circuits which are actuated only when an ionizing particle passes through the chamber. This practice greatly increases the probability that a track will be formed and photographed when an expansion occurs.

Besides the short sensitive time and the complicated circuits necessary for efficient operation of the expansion chamber, the chamber has another serious fault. Before a chamber can be used to study tracks it must be cleaned of all dust particles and other contaminants which might act as nuclei for the formation of unwanted background droplets. In the expansion chamber the "clean up" time is excessively long and often lasts for many hours during which a large number of slow expansions are made.

The Diffusion Cloud Chamber

To overcome the above mentioned limitations of the expansion chamber, several investigators have turned their attention to the diffusion cloud chamber. Two types of these chambers have been studied. The first type which was investigated by Vollrath (8) in 1936 consisted of a circular glass cylinder of constant volume closed on both ends. The bottom of the chamber was covered with a pool of hydrochloric acid which vaporized and diffused upward. The top of the chamber contained a reservoir of distilled water which vaporized and diffused downward. In a certain region near the middle of the chamber the two vapors mixed and each became supersaturated with respect to the other. In this supersaturated region cosmic ray tracks were observed. Apparently this type of chamber proved impractical because it was never used.

The second type of diffusion chamber first studied by Langsdorf (4) in 1939 also consisted of a glass chamber with both ends closed. In this type of chamber either the top or bottom is heated and the other of the two surfaces is cooled. Thus a temperature gradient is maintained across the chamber. Those chambers which have their top surface heated are known as downward diffusion chambers since a volatile liquid introduced at the warm top will vaporize and diffuse downward. Likewise those chambers which have their bottom surface heated are known as upward diffusion chambers because the volatile liquid is located in a pool on the bottom and after vaporization it diffuses upward. In both the downward and upward diffusion chambers a supersaturated region forms near the cool surface in which tracks occur if an ionizing particle is present in that region. As in the expansion chamber the tracks are made visible by passing a strong beam of light through the chamber in the sensitive region. This type of chamber is continuously sensitive and has a "clean up" time of only a few minutes.

Langsdorf (4) used a downward diffusion type chamber in which the bottom was cooled by circulating refrigerated methyl alcohol. Methyl alcohol was used as the vapor source. A carbon arc was used for illumination of the tracks. The chamber was not very successful and was abandoned.

Nothing more was published about the diffusion chamber until 1950 when Cowan (2) and Nielsen, Needles, and Weddle (6) reported their work. Cowan built several downward diffusion chambers of both circular and square cross sections. The bottom of each chamber was cooled with dry ice and the top heated by an electric heating element. He filled the chambers with various inert gases at atmospheric pressure and used a mixture of methyl alcohol, ethyl alcohol, and water as the vapor source. He reported that the sensitive layer increased in depth until an optimum top temperature was reached. At temperatures above the optimum value, the sensitive layer broke into two parts and the quality of the tracks rapidly deteriorated. The background fog also became worse. Cowan stated that the optimum temperature was characteristic of the geometry of the chamber. He also reported that when ethyl or n-propyl alcohol was used for the vapor source, an inert gas of high molecular weight gave better results. Cowan obtained best results with Argon gas.

Nielsen, Needles, and Weddle (6) built both upward and downward diffusion chambers. In the upward diffusion type the bottom was heated by circulating hot water through a double bottom while the top was cooled with dry ice. A pool of liquid on the floor of the chamber formed the vapor source. They reported sensitive layers several inches deep when they used helium at atmospheric pressure as the inert gas and n-propyl alcohol for the vapor source.

With the downward diffusion chambers, Nielsen, Needles, and Weddle used dry ice to cool the bottom and electric heating elements to heat the top. They were able to obtain sensitive layers several inches deep when the top temperature was above 50° C. and the bottom temperature about -60°C. For the above results n-propyl alcohol and water were used as the vapor source and Argon as the inert gas. They also reported that no tracks were observed when the top was at a temperature above 80°C.

Statement of Purpose

This thesis describes an investigation of some parameters affecting the operation of the diffusion chamber. Discussions of optimum operating conditions and possible applications are also included.

EXPERIMENTAL APPARATUS

The investigation involved the use of several pieces of apparatus besides the chamber. The following paragraphs describe in detail the chamber and the accessory apparatus.

The Chamber

The chamber used in this investigation was of the downward diffusion type, as shown in Fig. 1. It consisted of a glass chamber 8 inches high and 10 inches square. The top and bottom plates were made of 1/8 inch thick sheet brass. The corner pieces were 1 inch wooden dowels in which were cut grooves to accommodate the glass sides. These wooden dowels were fastened with brass screws to the bottom plate. Small metallic channels, into which the glass sides were fitted, were soldered to the bottom plate. A short piece of brass tubing of 1/8 inch outside diameter, soldered into a hole located in one corner of the bottom plate, served as a drain for excess alcohol that collected in the bottom of the chamber. The upper surface of the bottom plate,

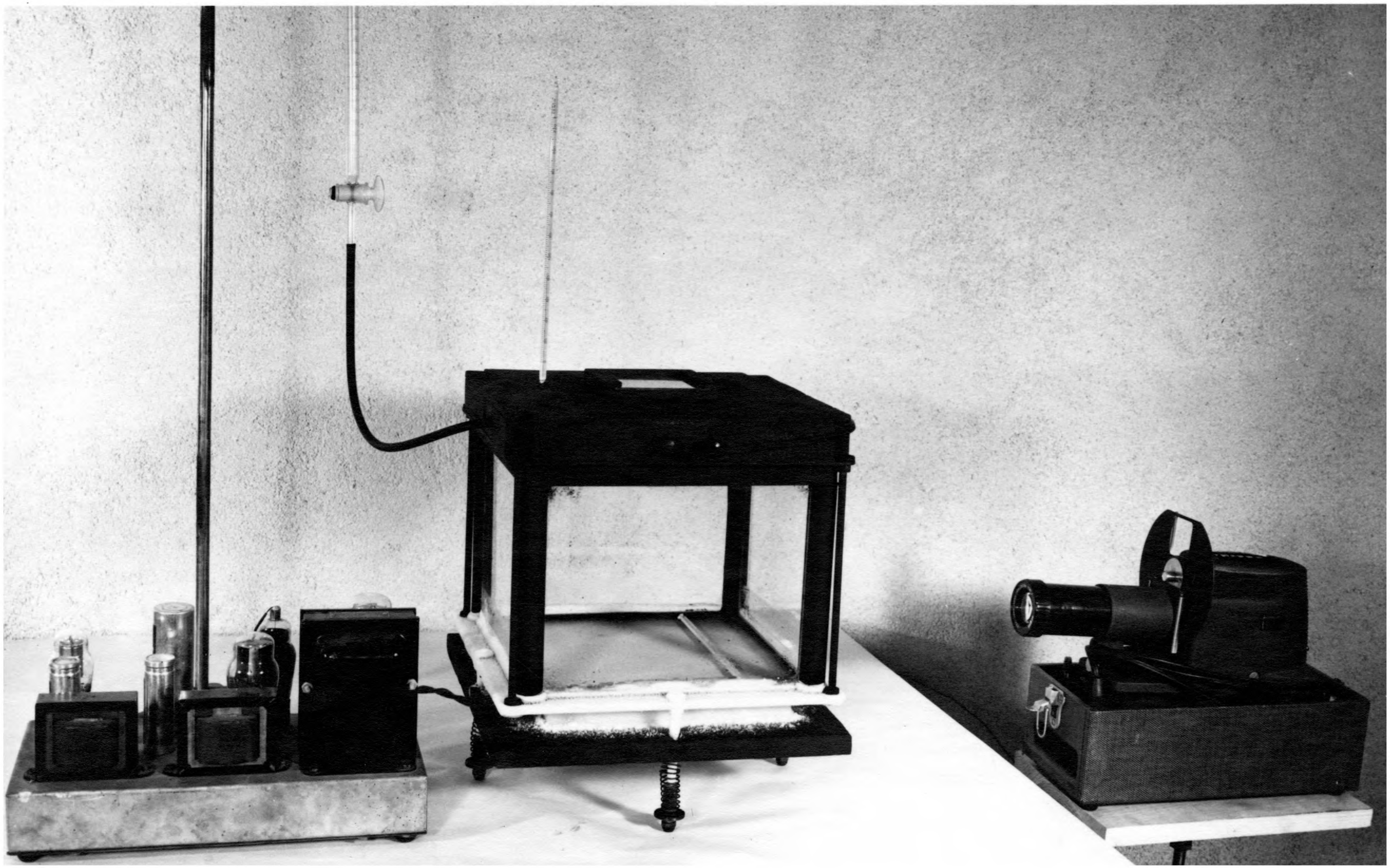


Fig. 1. The chamber and accessory apparatus.

as well as the four corner pieces, were painted black to assure a good background for observation. The bottom was cooled by a slab of dry ice approximately the sime of the bottom plate. The ice was held against the bottom plate by compression springs located on the four legs of the chamber.

The brass plate used for the top of the chamber had a 3-inch square hole cut in its center which served as a viewing window and nine 1/4 - inch diameter holes for the brass tubes which supplied the top of the chamber with the liquid used as the vapor source. To the upper surface of the top plate were soldered three 1/4 - inch diameter brass tubes, 1-1/2 inches long which supported the thermometers used to measure the temperature of the top plate. These tubes were partially filled with specially shaped lead slugs to insure intimate contact between the top of the chamber and the thermometer bulbs. Finally, a 3/8-inch hole was drilled through the top plate through which radioactive samples might be inserted in the chamber. The relative positions of these holes are shown in Fig. 2. The lower surface of the top plate was covered with a piece of velvet which absorbed the volatile liquid admitted from the reservoir and acted as the vapor source.

The plate glass walls were set in grooves cut in strips of wood fastened with brass screws to the top plate. The top plate was held to the lower part of the chamber by means of four insulated brass rods. A liberal use of rubber gaskets made the chamber free from large leaks which might have resulted in turbulence due to convection air currents.

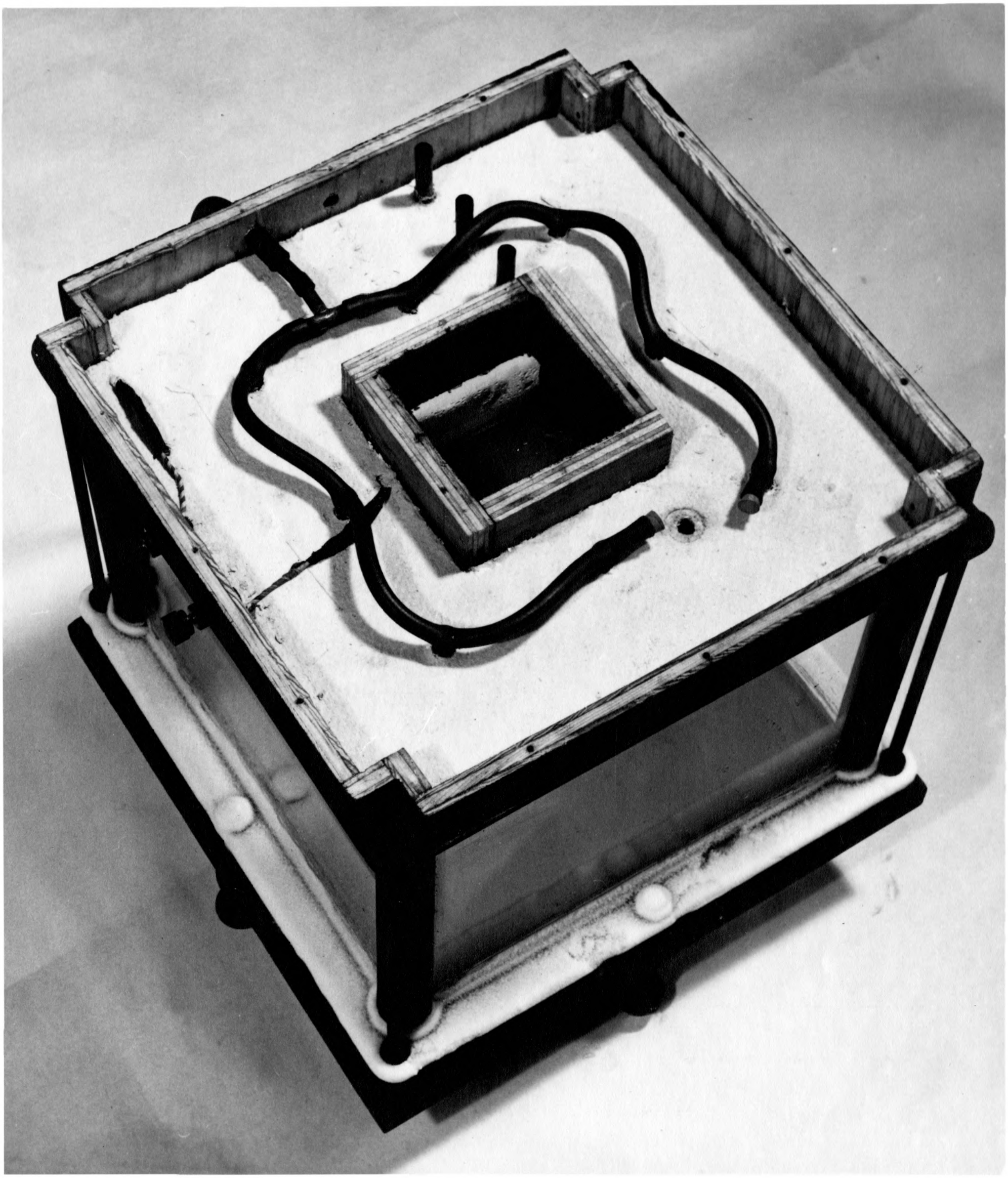


Fig. 2. Top view of chamber with heating element cover removed.

The Heating Element

The top plate of the chamber was warmed by an electric heating element. This element consisted of 30 feet of number 26 nichrome wire sewed to a piece of sheet asbestos with ordinary cotton thread. The element was designed to raise the temperature of the top plate to a maximum value of 100° C. This limiting temperature was obtained without the nichrome wire reaching a temperature high enough to char the cotton thread.

The sheet of asbestos with the element attached was secured to the upper surface of the top plate with rubber cement. Wet, powdered asbestos was then spread over the element. This proceedure formed an asbestos pad about 1/4-inch thick with the element in its center. The upper surface of this pad is shown in Fig. 2.

The Vapor Source

The liquids used for vapor sources were supplied from the 50 ml. burrette shown in Fig. 1. The liquid was allowed to flow through a rubber tube to the top of the chamber. As seen in Fig. 2. the liquid flow divided once it entered the chamber and each branch of the liquid flow supplied one-half of the brass tubes which fed the liquid to the velvet pad on the under surface of the top plate. To prevent unequal distribution of the liquid to various parts of the velvet pad, those tubes first to receive the liquid were partly filled with cotton. The cotton impeded the liquid flow in those tubes and allowed more liquid to go to the remaining tubes.

Accessory Apparatus

The light source used in this investigation was an Argus, forced - air cooled, 2 - inch slide projector using a 200 watt projection lamp. A 2 - inch square piece of thin cardboard was cut for use as a mask. This mask had a slit 3/10 mm wide and 30 mm long cut in it parallel to one pair of its sides. The mask was inserted into the projector so that the slit was horizontal. By making focal adjustments with projector located about 2 feet from the chamber, a beam of light with a horizontal cross section nearly equal to that of the chamber and about 1 mm thick was produced. The light source was placed on an adjustable stand such that the source could be raised or lowered. The light source and its stand can be seen in Fig. 1.

Two commercially built, regulated, power supplies were used to produce electric clearing fields for the chamber. One was rated at 300 volts and the other at 2,000 volts. Potentiometers were used to vary the potential across the chamber.

All data taken in the investigation was with cosmic rays as the ion source.

EXPERIMENTAL TECHNIQUES

The main objective in all of the experiments was to measure the depth of the region in which tracks formed and also note the quality and quantity of the tracks and the amount of background fog present each time a trial was made. The data was collected in two series of experiments combined with some miscellaneous measurements. The first series was performed using pure methyl alcohol as the vapor source while the second series involved the use of pure ethyl alcohol as the vapor source.

Each of the two series of experiments was subdivided into three groups of measurements. Three trials, separated in time by several days, were made for each measurement. A measurement is defined as a determination of the depth of the sensitive layer under a given set of conditions. The average value of each set of three trials was calculated and used to plot a series of curves.

The first group of measurements of the first series was made with the velvet pad saturated with methyl alcohol. Keeping the top of the chamber at any one of several temperatures ranging from 20 to 55°C., the bottom temperature was varied from -15 to -45°C. in 5 degree intervals. The variation of the bottom temperature was read on a thermometer placed in a pool of methyl alcohol on the floor of the chamber. The depth of the pool was held constant at about 1/8 inch by draining off all excess alcohol. To make a measurement, the top and bottom temperatures were adjusted to the values desired then the light source was raised or lowered until cosmic ray tracks just began to form in the beam. This level marked the top surface of the sensitive layer. The level was read on a vertical millimeter scale located at the edge of the light beam. The lower limit of the layer was taken as the upper surface of the alcohol pool in the chamber. Nine curves, each representing a given temperature of the top and showing the variation of the sensitive layer with changes of the bottom temperature, are shown in

Plate I. The same data were replotted with the top temperature as abcissa and are shown in Plate II where each curve represents a given bottom temperature.

The second group of measurements of the first series was obtained in the following manner. The top and bottom of the chamber were first adjusted to a given temperature and held at that temperature during that set of measurements. Next, the velvet pad was saturated with methyl alcohol and the alcohol supply removed. Finally, the depth of the sensitive layer was measured immediately after the removal of the alcohol supply and at 5 or 10 minute intervals thereafter until the sensitive layer disappeared. The average values of three trials for each measurement were plotted against time and are shown in Plate IV. Each curve represents a given top and bottom temperature for the chamber.

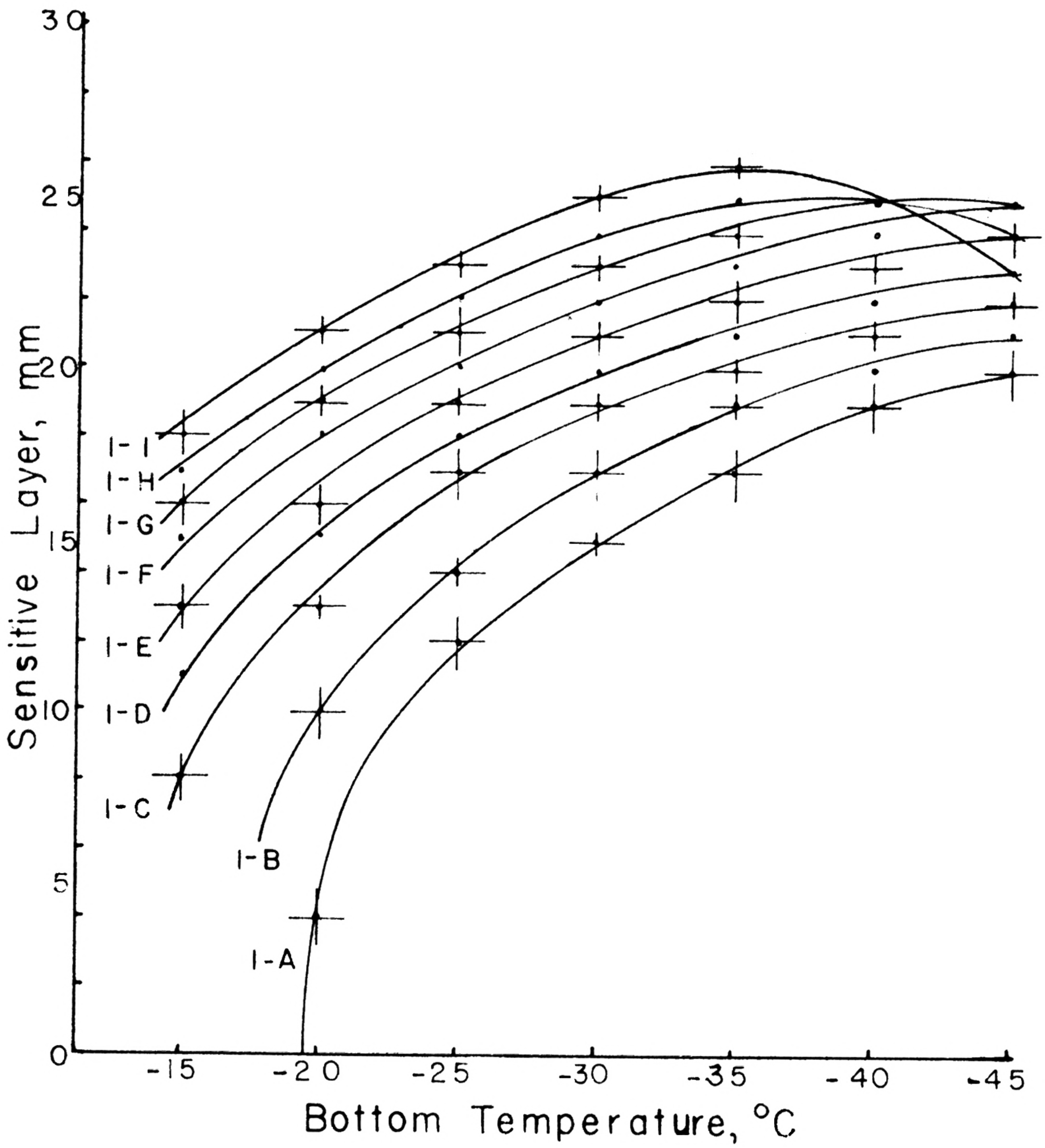
The two groups of measurements just described were made with no potential difference existing between the top and bottom plates of the chamber. In the third group the pad was saturated with methyl alcohol and the top and bottom temperatures were held constant for each set of readings while the potential difference across the chamber was varied from 0 to 2,000 volts. Voltages in excess of 100 were found to produce no change in the sensitive layer. By using a power supply which delivered 300 volts, it was possible to measure small increases in voltage across the chamber. Thus, in the third group of measurements, readings were taken for voltages ranging from 0 to 50 volts in 5 or 10 volt steps first with the bottom plate negative and then with the bottom positive. The results of this set of measurements are shown in Plate III.

EXPLANATION OF PLATE I

Plot of sensitive layer depth vs bottom temperature for various top temperatures using methyl alcohol as vapor source.

Curve	Top temperature
1-A	20° C.
1-B	25° C.
1-C	30° C.
1-D	36° C.
1-E	40° C.
1-F	42° C.
1-G	46° C.
1-H	50° C.
1-I	55° C.

PLATE I

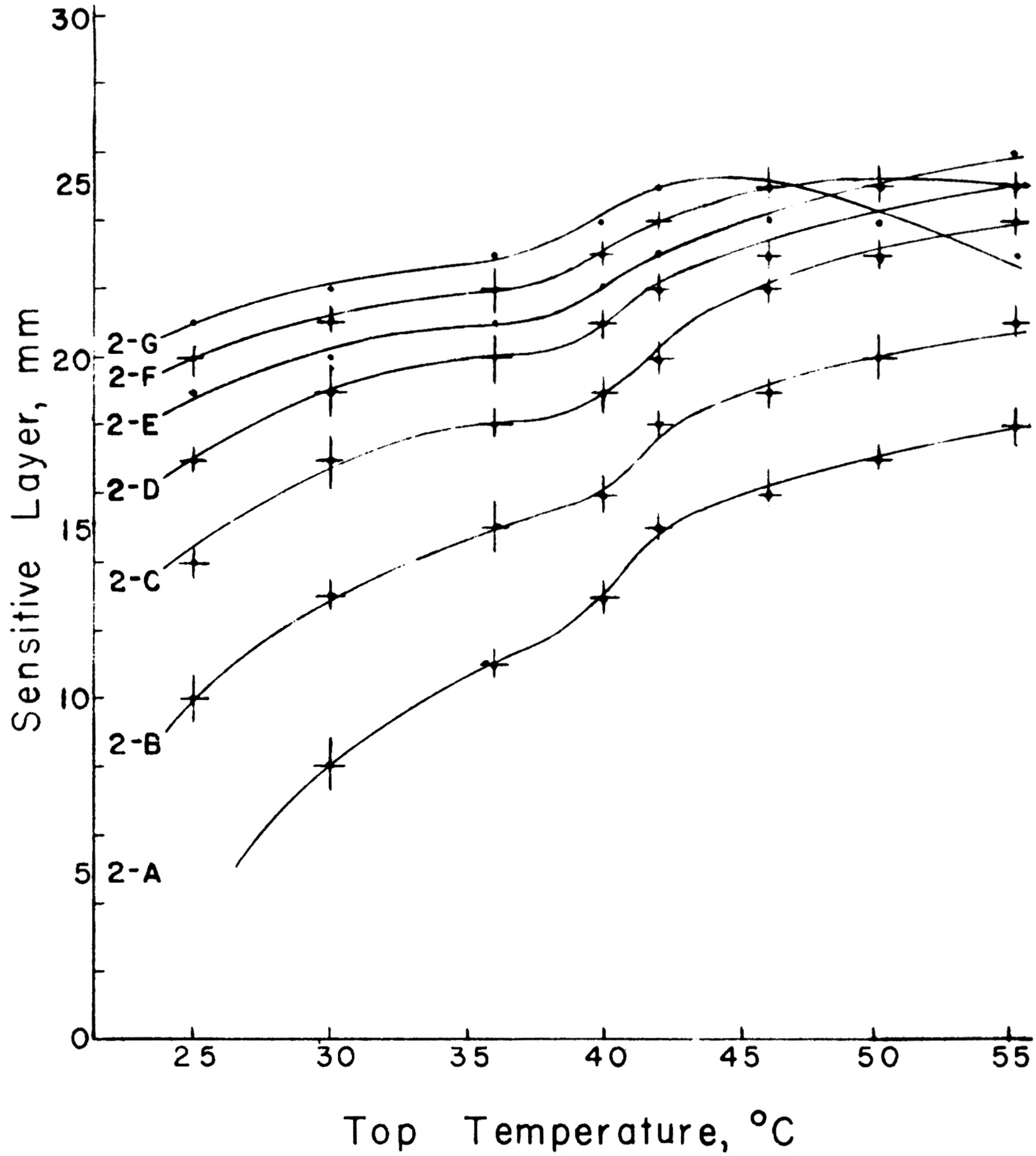

30
25
20
15
10
5
0
Sensitive Layer, mm
-15
-20
-25
-30
-35
-40
-45
Bottom Temperature, °C
1-I
1-H
1-G
1-F
1-E
1-D
1-C
1-B
1-A

EXPLANATION OF PLATE II

Plot of sensitive layer depth vs top temperature for various bottom temperatures using methyl alcohol as vapor source.

Curve	Bottom Temperature
2-A	-15° C.
2-B	-20° C.
2-C	-25° C.
2-D	-30° C.
2-E	-35° C.
2-F	-40° C.
2-G	-45° C.

PLATE II


30
25
20
15
10
5
0
Sensitive Layer, mm
2-G
2-F
2-E
2-D
2-C
2-B
2-A
25
30
35
40
45
50
55
Top Temperature, °C

EXPLANATION OF PLATE III

Plot of sensitive layer depth vs potential across the chamber for various bottom temperatures. The top temperature was held constant at 40°C. and methyl alcohol was used as the vapor source.

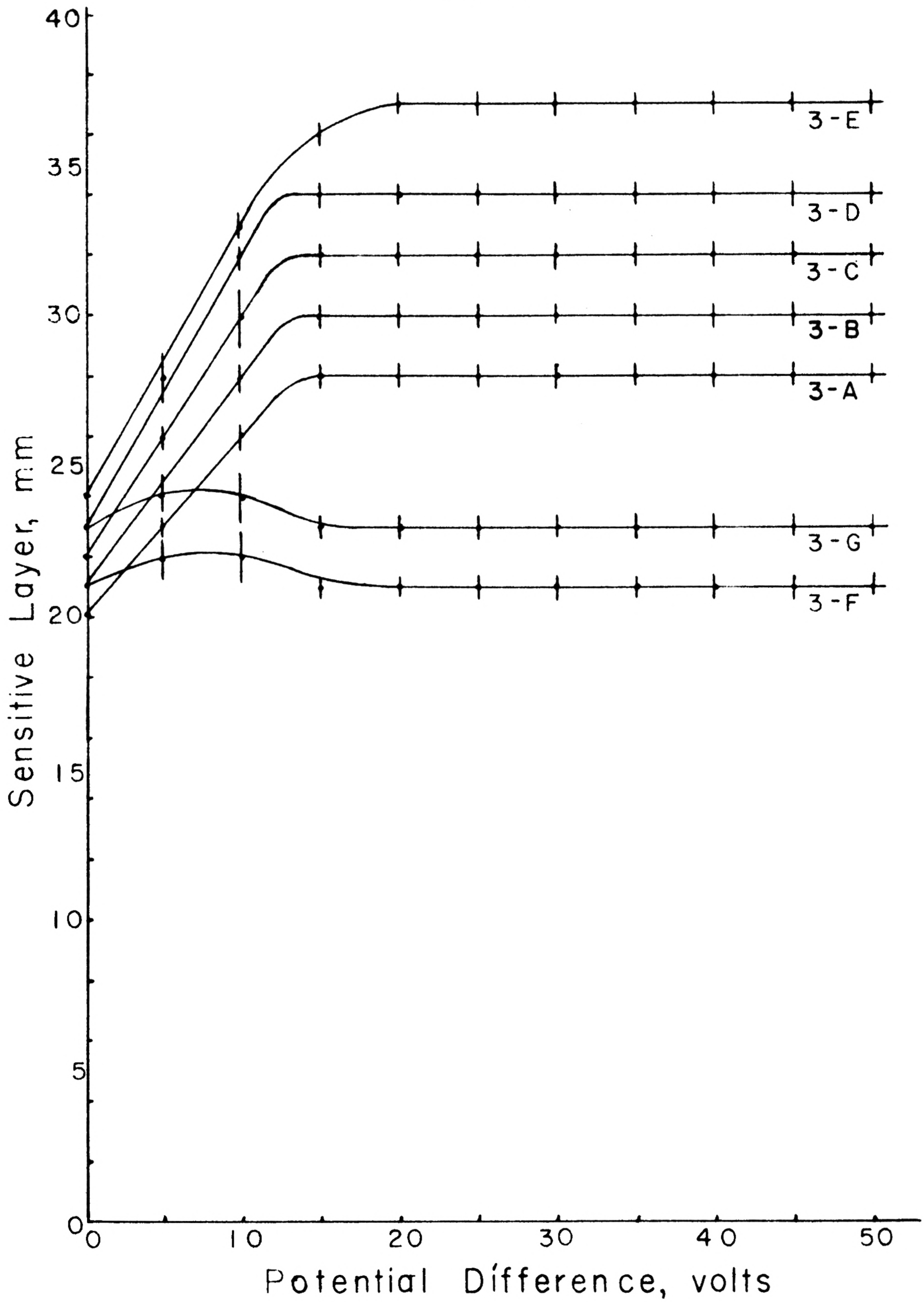
Bottom Negative

Curve	Bottom Temperature
3-A	-25° C.
3-B	-30° C.
3-C	-35° C.
3-D	-40° C.
3-E	-45° C.

Bottom Positive

Curve	Bottom Temperature
3-F	-35° C.
3-G	-40° C.

PLATE III



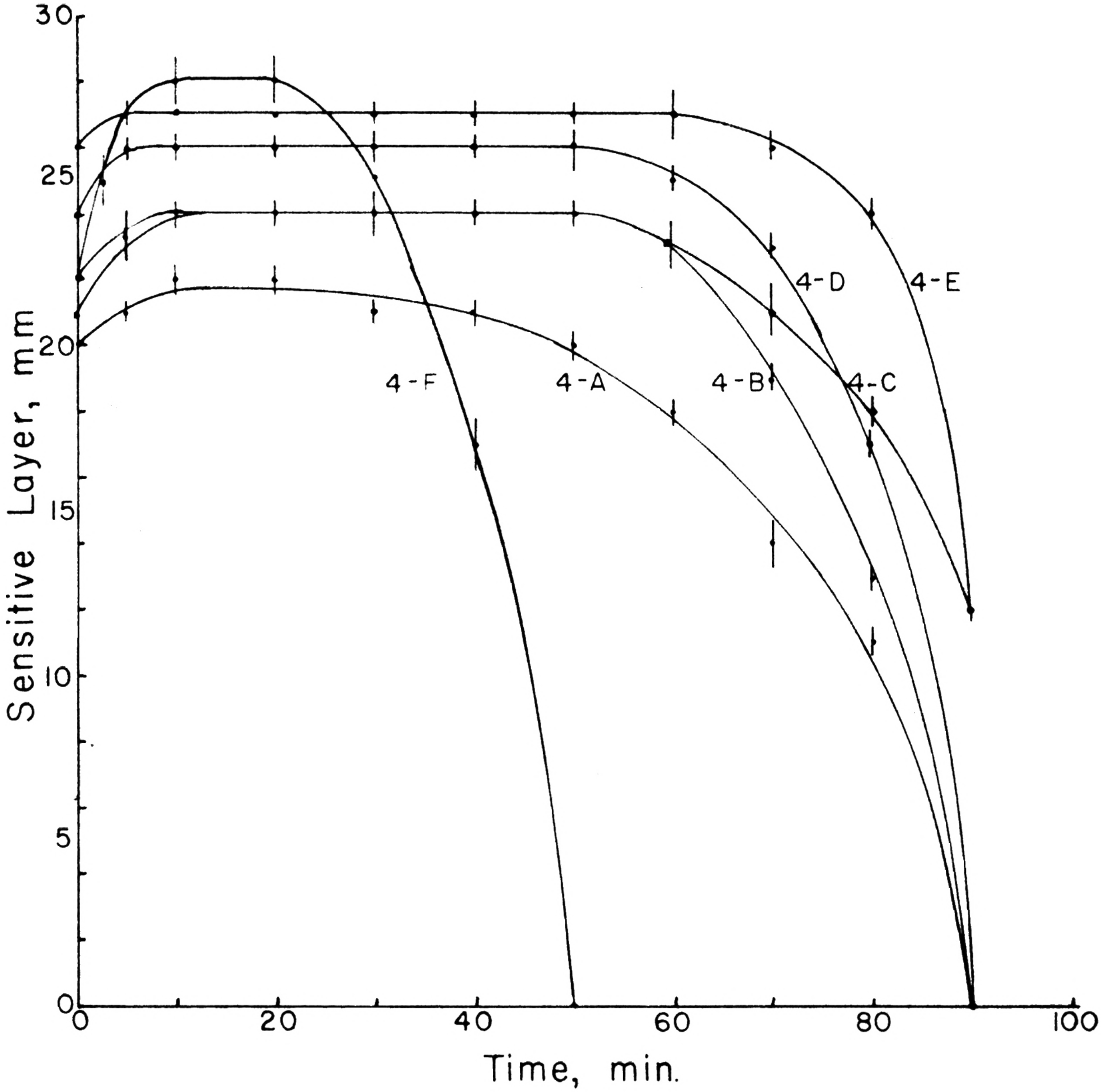
40
35
30
25
20
15
10
5
0
Sensitive Layer, mm
3-E
3-D
3-C
3-B
3-A
3-G
3-F
0
10
20
30
40
50
Potential Difference, volts

EXPLANATION OF PLATE IV

Each curve was obtained by first saturating the top of the chamber with methyl alcohol and then removing the alcohol supply. Sensitive layer depth vs time after cutting off the alcohol supply was plotted for various top and bottom temperatures.

Curve	Top Temperature	Bottom Temperature
4-A	40° C.	-30° C.
4-B	40° C.	-35° C.
4-C	40° C.	-40° C.
4-D	40° C.	-45° C.
4-E	30° C.	-40° C.
4-F	50° C.	-40° C.

PLATE IV



30
25
20
15
10
5
0
Sensitive Layer, mm
0
20
40
60
80
100
Time, min.
4-A
4-B
4-C
4-D
4-E
4-F

The second series of measurements were identical to those of the first series except that ethyl alcohol was used as the vapor source instead of methyl alcohol. The bottom temperature versus sensitive layer for various top temperatures are shown in Plate V. Plate VI are the curves showing the variation of the sensitive layer with time when the top and bottom temperatures were held constant and the supply of alcohol allowed to diminish. Variations of sensitive layer with changes in potential across the chamber are shown in Plate VII.

ANALYSIS OF DATA

Each set of curves shown in Plates I through VII show several characteristic features which can be classified according to whether they involve changes in temperature, changes in quantity of alcohol present in the chamber, or changes in the potential across the chamber. In the following paragraphs each of the sets of curves will be discussed and attempts will be made to explain them.

Variation With Temperature

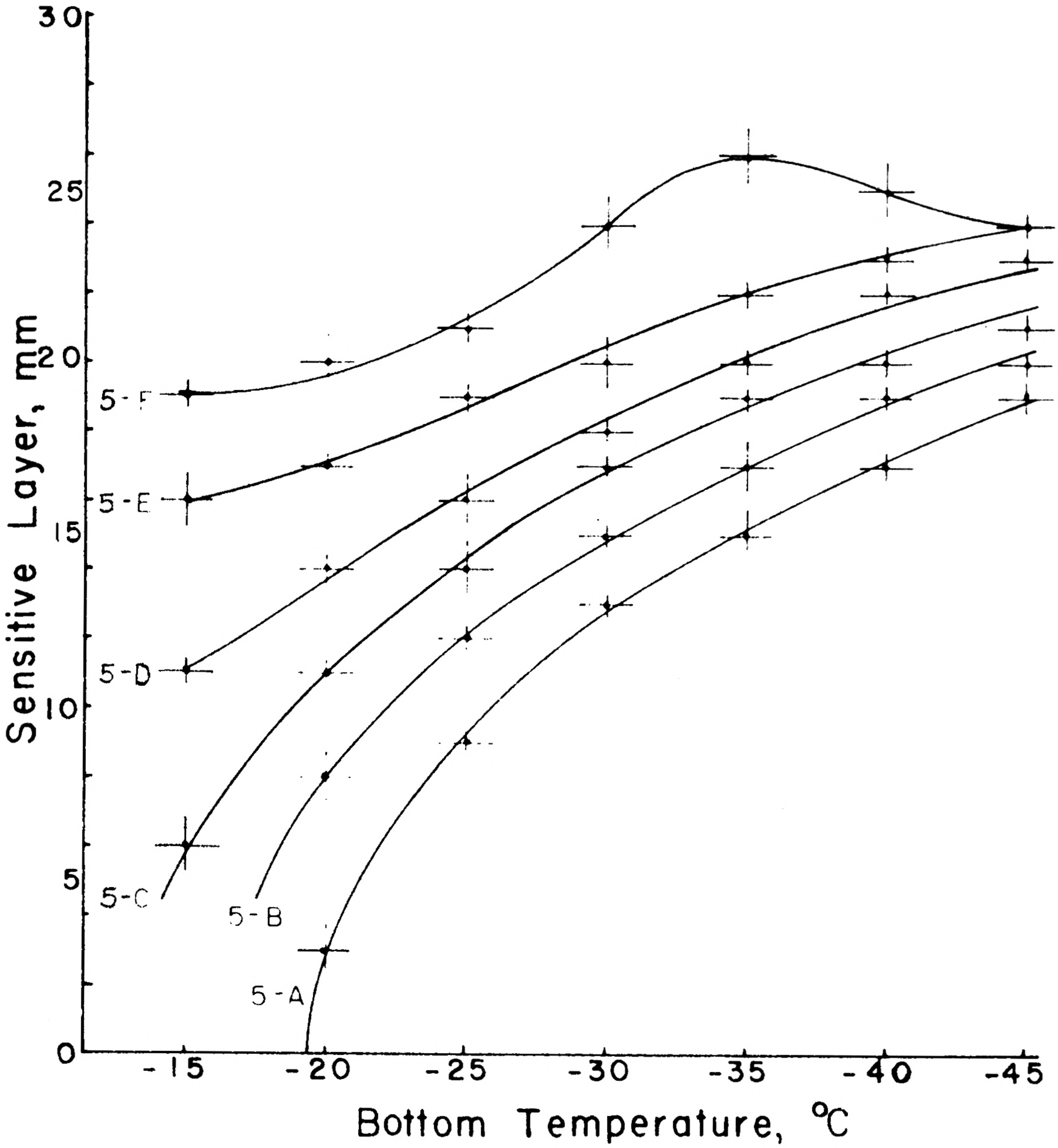
The curves in Plate I show that for a given top temperature, as the bottom temperature of the chamber was lowered, the sensitive layer increased in depth. The curves also show that the slope of any given curve decreased as the bottom temperature was lowered, and when the top temperature was raised to values above 45° C., the slope became negative for bottom temperatures lower than -35° C.

EXPLANATION OF PLATE V

Plot of sensitive layer depth vs bottom temperature for various top temperatures using ethyl alcohol as vapor source.

Curve	Top Temperature
5-A	20° C.
5-B	30° C.
5-C	36° C.
5-D	40° C.
5-E	44° C.
5-F	50° C.

PLATE V

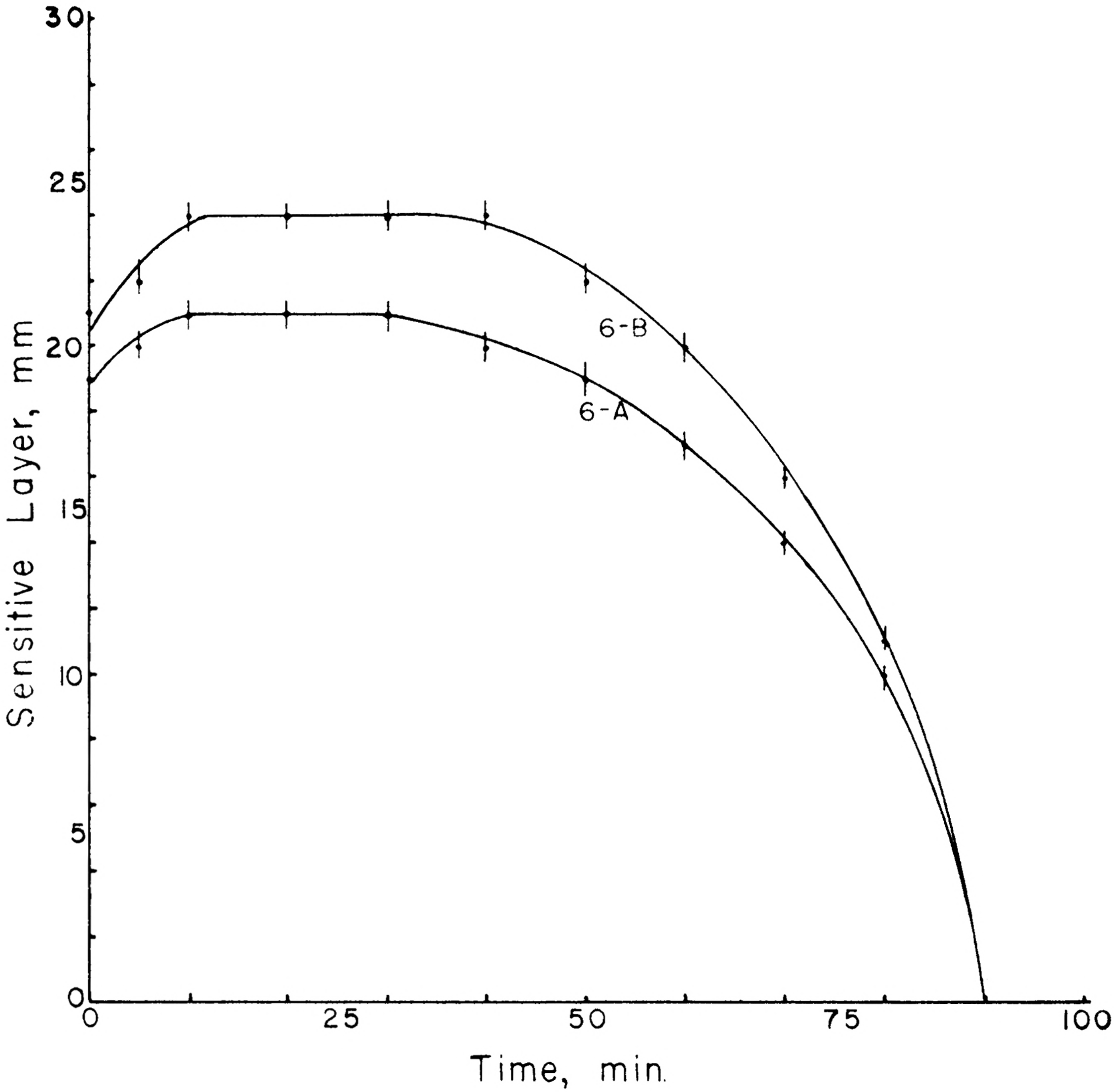

30
25
20
15
10
5
0
Sensitive Layer, mm
5-F
5-E
5-D
5-C
5-B
5-A
-15
-20
-25
-30
-35
-40
-45
Bottom Temperature, °C

EXPLANATION OF PLATE VI

Each curve was obtained by first saturating the top of the chamber with ethyl alcohol and then removing the alcohol supply. Sensitive layer depth vs time after cutting off the alcohol supply was plotted for various top and bottom temperatures.

Curve	Top Temperature	Bottom Temperature
6-A	40° C.	-30° C.
6-B	40° C.	-40° C.

PLATE VI

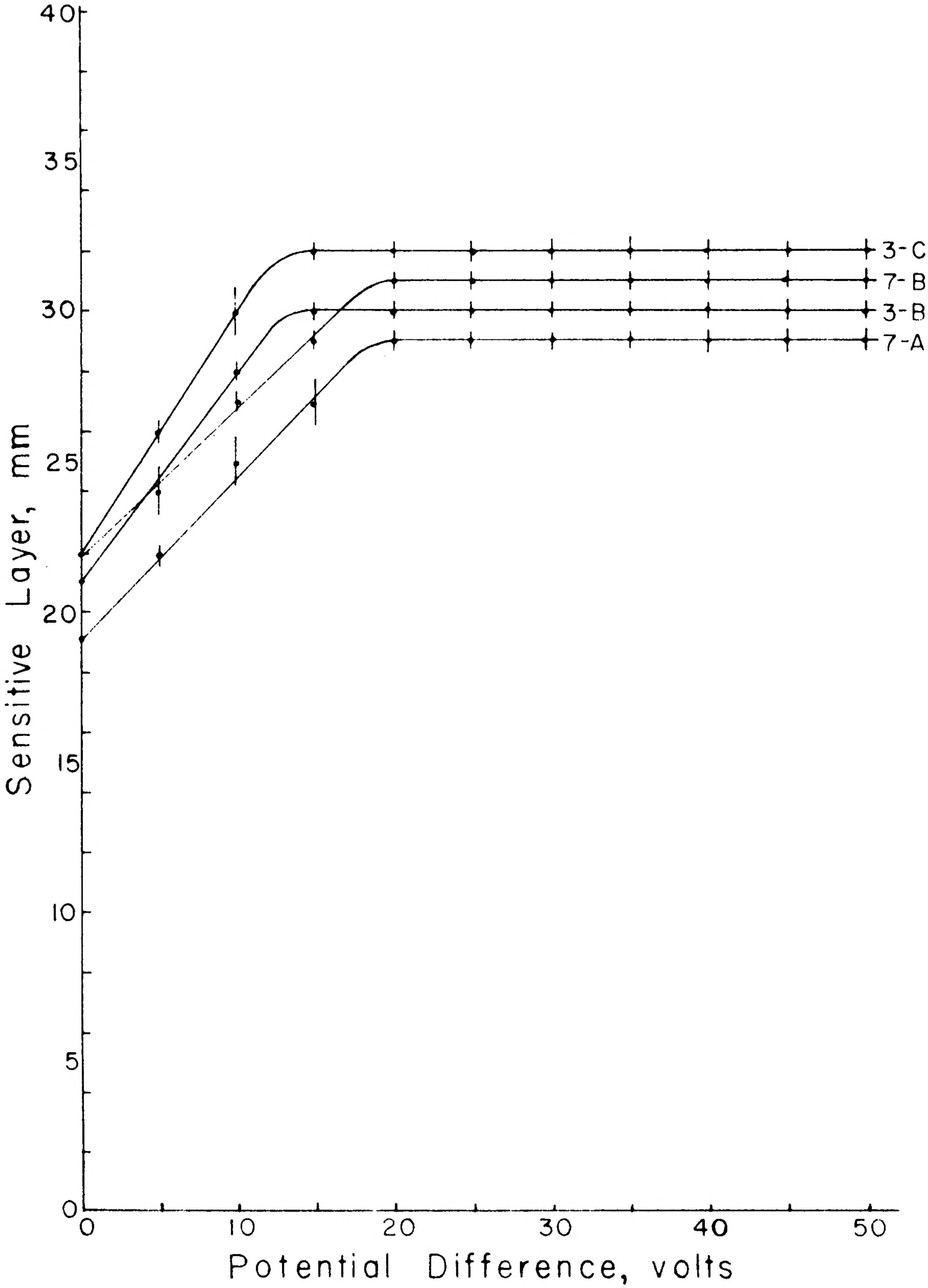


EXPLANATION OF PLATE VII

Plot of sensitive layer depth vs potential across the chamber for various bottom temperatures. The top temperature was held constant at 40° C. and ethyl alcohol was used as the vapor source. Bottom plate was negative for all curves. Curves 3-B and 3-C are those plotted in Plate III.

Curve	Bottom Temperature
7-A	-30° C.
7-B	-35° C.
3-B	-30° C.
3-C	-35° C.

PLATE VII


40
35
30
25
20
15
10
5
0
Sensitive Layer, mm
0
10
20
30
40
50
Potential Difference, volts
3-C
7-B
3-B
7-A

The general shape of the curves can be explained by considering what happens to the region of supersaturation in a chamber when the top and bottom temperatures are varied. Nielsen, Needles, and Weddle (6) have shown that the region for track formation does not ordinarily involve the entire supersaturated region. The tracks appear only in the lower part of that region. In the upper part of the supersaturated region background droplets form but no tracks are seen. These results have been confirmed by the author. Also, Morrison and Plain (5) have shown that there is a certain minimum temperature gradient necessary in the supersaturated region before tracks will form. This minimum value was found to be 10° C./cm. for the chamber they used.

Thus, for any given top temperature, as the bottom temperature was lowered, there were no tracks seen until the supersaturated region achieved a certain minimum temperature gradient. When the bottom reached the temperature where the necessary temperature gradient occured, the sensitive layer where tracks were seen suddenly increased in depth until its upper surface reached a place where the supersaturation was not sufficient to form tracks. In the investigation just completed it was found that as the bottom temperature of a chamber is lowered, for a given top temperature, the supersaturated region increases its depth, but for each increment of temperature the depth increases at a decreasing rate. Thus, as the bottom temperature was lowered the curve leveled off. As the temperature of the top was raised the supersaturated region increased in depth and the set of curves in Plate I resulted.

There appears to be no simple explanation for the sharp increase in the depth of the sensitive layer which occured when the top temperature was raised from 40° C. to 42° C. This increase is shown by by the separation between curves 1-E and 1-F in Plate I and the sharp change in slope in each of the curves in Plate II. This sudden increase in depth of sensitive layer was accompanied with a marked reduction in background fog and sharper tracks. No similar result occured when ethyl alcohol was used for the vapor source.

The maxima occuring in curves 1-H and 1-I in Plate I may confirm observations made by Cowan (2). He found that when the top of a chamber is raised to a temperature greater than an optimum value determined by the geometry of the chamber, the sensitive layer breaks into two horizontal layers. In the upper layer ions continue to act as nuclei for droplet formation. The droplets grow very rapidly because of the large amount of alcohol vapor present in that part of the chamber and fall to the bottom. As they fall they remove so much of the vapor from the normal sensitive region that tracks fail to form. Very near the bottom of the chamber where the temperature is quite low, there is enough vapor present for track formation and this shallow region forms the lower part of the sensitive layer.

The chamber used in the present investigation apparently had an optimum top temperature of about 42° C. The measurements made for curves 1-G, 1-H, and 1-I were probably on the upper surface of the lower part of the sensitive layer which split when the bottom temperature reached -35° C. When the author tried to find the upper section of the sensitive layer, he found a region of general background fog but no tracks. The upper surface of the region in which background fog formed continued to increase in height while the region where tracks were seen decreased in height. These observations seem to confirm Cowan's report.

From observation it can be generally stated that a decrease in the bottom temperature caused a decrease in the background and with this decrease the tracks became sharper. Observations showed that best tracks formed when the bottom temperature was about -40° C. However, a somewhat different effect occured when the top temperature was increased. As long as the top temperature was less than 38° C. or above 42°C. the background fog was bad. Whenever the top temperature was between 38° C. and 42° C. the background fog was seen to decrease and the tracks became very sharp. The general increase in the background as the top temperature was raised is in agreement with the theoretical results that Shutt (7) reached. There appears to be no conclusion from his theoretical approach which would predict the results obtained for the top temperatures about 40° C. mentioned above.

The curves plotted in Plate V show the same general shape for ethyl alcohol as those in Plate I show for methyl alcohol. The maximum occuring in curve 5-F of Plate V is seen to be more pronounced than the maxima in curves 1-G, 1-H, and 1-I in Plate I. Another difference between the methyl and ethyl alcohol curves is that the ethyl alcohol curves show no distinct optimum top temperature. As a general observation, the tracks obtained with pure ethyl alcohol were more diffused and harder to obtain. There seemed to be no more background for a given top and bottom temperature with ethyl alcohol than with methyl alcohol.

Variation With Quantity of Alcohol

The curves shown in Plate IV show the variation in the sensitive layer when the velvet pad was first saturated with methyl alcohol and then the alcohol supply removed. During the first 5 to 10 minutes after the removal of the alcohol supply, the sensitive layer increased its depth and then remained constant for approximately an hour. Plate IV shows for most top and bottom temperatures tried, the sensitive layer existed for about 1-1/2 hours after the alcohol supply was removed.

When the velvet pad was completely saturated with alcohol, the background was very bad but was much improved 10 minutes after the alcohol source was removed. As the background diminished the quality of the tracks improved and good quality tracks were observed from then until the sensitive layer disappeared. The curves present no pecularities except the rise immediately after the removal of the alcohol supply. These rises may have been observational error since the exact level of the sensitive layer was very difficult to determine because of the great number of background droplets present. Similar results were obtained with ethyl alcohol as shown in Plate VI.

Variation With Potential

The curves in Plate III show how the sensitive layer varied when a variable potential was placed between the top and bottom plates.

Curves 3-A to 3-E are those obtained when the bottom was negative, while 3-F and 3-G were obtained with the bottom positive. Each curve represents a given top and bottom temperature and was obtained with the velvet pad nearly saturated with methyl alcohol.

Each of the curves obtained with the bottom plate negative show a marked increase in the depth of the sensitive layer which is nearly linear until the potential across the chamber reached about 20 volts. As seen by the curves further increases in potential had no effect on the depth of the sensitive layer. It was observed that high potentials tended to distort the tracks. In most cases, when the potential was raised to 20 volts the sensitive layer increased its depth until its upper surface coincided with that of the region where the background droplets formed.

The curves 7-A and 7-B in Plate VII show the same general results for ethyl alcohol when the bottom of the chamber was made negative as were obtained with methyl alcohol. Although not plotted, observations showed that a positive bottom produced practically no change in the sensitive layer. Comparison of 7-A and 7-B with 3-B and 3-C in Plate VII show that the maximum depth of sensitive layer was reached at a lower potential for methyl than for ethyl alcohol. Also, the maxima for ethyl alcohol are not as large as for methyl alcohol.

Nielsen, Needles, and Weddle (6) report that alcohol droplets form better around positive ions than around negative ones because a smaller supersaturation is necessary for formation of droplets with positive ions as nuclei. This report helps explain the shape of the curves in Plates III and VII. When no field was present, both positive and negative ions used their share of the limited vapor supply. When the bottom plate was made negative, the negative ions were repelled which left more vapor available for the descending positive ions. The fact that the supersaturated region does not have the same supersaturation at all levels and that positive ions can act as nuclei for droplets at smaller supersaturations than negative ions can, resulted in the observed increase in the sensitive layer depth. On the other hand, when the bottom was made positive, the negative ions were attracted to the bottom and acted as nuclei for droplet formations. No significant increase in the sensitive layer was observed because the supersaturation was insufficient at higher levels for droplet formations with the negative ions.

APPLICATIONS

At the present time the diffusion cloud chamber is limited in its operation by the fact that the top and bottom plates must be nearly horizontal for good operation. Also, because of the chambers large horizontal cross section, placing the chamber in horizontal magnetic fields becomes almost impossible. The combination of the two limitations just mentioned probably prevents its use as an instrument for the study of vertical cosmic rays.

Because there is a limited amount of vapor present in the sensitive layer at any given time, only a limited amount of ionization is practical. Large numbers of highly ionizing particles serve to render the chamber inoperative since all the vapor present in the lower part of the chamber is used for condensations and no further tracks can form. Shutt (7) has shown that for ionization densities greater than four times that of sea level cosmic rays, the chamber, when operating at atmospheric pressure, becomes inoperative.

At the present time the diffusion cloud chamber has three main uses. The first is its use as a piece of demonstration equipment. The fact that the chamber will operate for an hour or more without attention makes it very well adapted for this use. With proper location of the light source a fair-sized group of people can observe the tracks at one time. It may be possible to construct a chamber so that the tracks can be projected onto a screen. This, of course, would make it an ideal demonstration unit.

The second use is in nuclear physics for the study of low activity sources. Cowan (2) reports that he used a chamber to study the highly ionizing pulsed ion beams from a synchrotron. Thus short pulses of highly ionizing particles can be used as ion sources. The last major use of the chamber is in the study of condensation phenomena.

SUMMARY

To study some of the factors affecting the operation of the downward diffusion type cloud chamber, a chamber of square horizontal cross section was constructed. Two series of experiments were performed. The first involved the use of pure methyl alcohol as the vapor source while the second series was performed using pure ethyl alcohol as the vapor source.

Each series was subdivided into three groups of measurements. The first group involved the measurement of the variation of the sensitive layer with changes of the top and bottom temperatures, while the second group determined the variations produced by limiting the quantity of alcohol admitted to the chamber per unit time. The last group of measurements revealed the variations in the sensitive layer caused by changes in the potential and its polarity between the top and bottom plates of the chamber. No attempt was made to ascertain the effects produced by changes in the gas pressure within the chamber and, since only air was used in the chamber, the variations which result when different gases are used in the chamber were not studied.

The results show that, for methyl alcohol, a top temperature of 40 to 42° C. gave the sharpest tracks and less background fog. No optimum top temperature was found for ethyl alcohol. For both methyl and ethyl alcohols bottom temperatures ranging from -40 to -45° C. gave deepest sensitive layer. The tracks were sharpest when the bottom was at -40° C. Limited amounts of either alcohol gave better results than were obtained when the velvet pad in the top of the chamber was saturated with the liquid.

Potentials ranging up to 2,000 volts were placed between the top and bottom plates of the chamber. The sensitive layer noticeably increased in depth and the tracks became sharper when potentials ranging up to 25 volts were placed across the chamber with the bottom plate negative. Potentials greated than 25 volts produced no added change in the layer. With a 25 volt potential across the chamber the upper surface of the sensitive layer coincided much of the time with the upper limit of the region in which the background fog was observed. When the polarity of the potential across the chamber was reversed, entirely different results were obtained. For potentials somewhat less than 100 volts no appreciable change occured in the depth of the sensitive layer. However, the tracks did become more diffuse and the exact limits of the sensitive layer were difficult to determine. At potentials ranging from 100 to 2,000 volts the sensitive layer decreased in depth and finally disappeared. Approximately the same results from potential variations were obtained with either methyl or ethyl alcohols.

When the top of the chamber was saturated with either methyl or ethyl alcohol and the alcohol supply removed, the chamber remained in operation for about an hour. This result indicates that the chamber could be used for lecture demonstration without frequent attention, as well as for research applications involving weak activities where the continuous sensitivity of the diffusion cloud chamber constitutes an important advantage.

ACKNOWLEDGMENTS

The author greatly appreciates the many important suggestions given him by his major instructor, Dr. Robert Katz, concerning the construction and subsequent work with the diffusion cloud chamber. His continued interest in the project served as an inspiration for the author. His numerous helpful suggestions for writing this thesis are also much appreciated.

The author also wishes to thank Mr. D. A. Rittis for his many helpful suggestions concerning the construction of the instrument, Dr. L. D. Ellsworth for his assistance in electronics, Dr. A. C. Andrews, and Dr. W. H. Slabaugh for helpful discussions on the physical properties of methyl and ethyl alcohol.

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A STUDY OF SOME PARAMETERS AFFECTING THE OPERATION OF A DIFFUSION CLOUD CHAMBER

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B. S., Kansas State College of Agriculture and Applied Science, 1951.

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Physics

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1953

To study some of the factors affecting the operation of the downward diffusion type cloud chamber, a chamber was constructed and measurements of the depth of the sensitive layer were made first using methyl and then ethyl alcohol as vapor sources. The effects caused by variations in top and bottom temperature, variations in quantity of alcohol in the chamber, and variations in potential across the chamber are discussed.

When methyl alcohol was used as the vapor source, best tracks were observed when the top was at a temperature between 40 and 42° C. and at a bottom temperature of -40° C. Also, better results were obtained when a limited amount of alcohol was used than when the velvet pad in the top of the chamber was saturated. Potentials across the chamber increased the sensitive layer depth and also improved the quality of the tracks when the bottom of the chamber was negative. If the bottom was positive the tracks were more diffuse.

No optimum top temperature was found for ethyl alcohol but tracks were best when the bottom was about -40° C. as was the case with methyl alcohol. Results concerning the quantity of alcohol to use and for potentials across the chamber were about the same for ethyl as for methyl alcohol. As a general observation the tracks were better for methyl alcohol than for ethyl alcohol.