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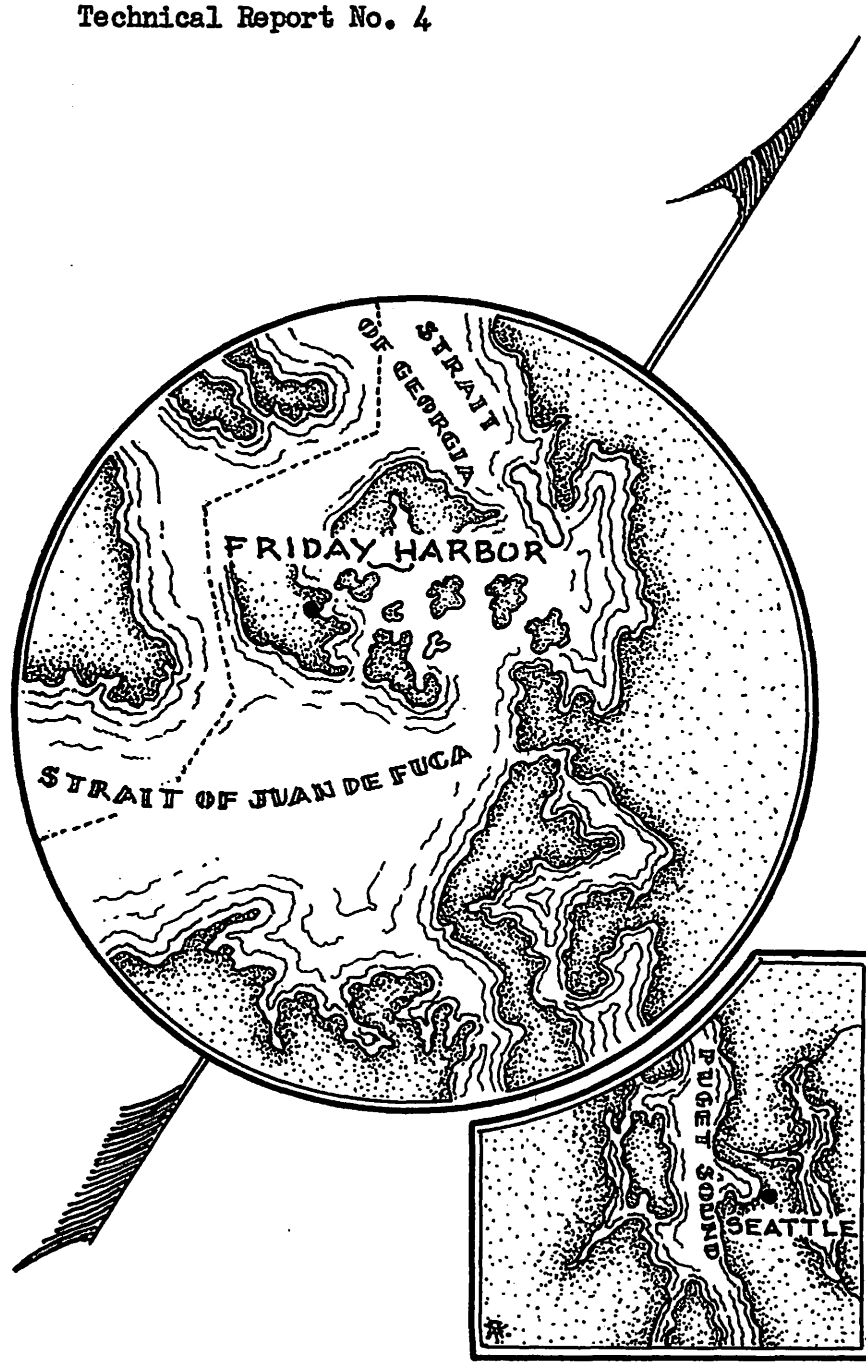
APPARATUS FOR MEASURING ELECTRICAL CHARGES AND OTHER PROPERTIES OF FOG

Technical Report No. 4



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APPARATUS FOR MEASURING ELECTRICAL CHARGES AND OTHER PROPERTIES OF FOG

by

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Thomas G. Thompson
Director

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APPARATUS FOR MEASURING ELECTRICAL CHARGES AND OTHER PROPERTIES OF FOG

SUMMARY

An apparatus is described which will measure the individual electrical charges and diameters of large numbers of droplets of natural fog and permit a direct determination of the particulate count. It is also applicable to other aerosols of a similar size range.

Size and charge are determined by photographing the trajectories of the fog particles falling in a parallel-plate condenser subjected to a transverse commutated electric field. The rate of vertical motion yields the radius, and the amplitude of zigzag motion yields the charge. The polarity is also determined. Particulate counts are determined in the same apparatus by substituting flash-tube illumination for the steady light source and counting the resulting images on the photograph. The apparatus is reasonably portable provided electrical power is available.

The lower limit of charge measurements ranges from 50 electron units on a droplet of 4 microns radius to 800 electron units on a droplet of 20 microns radius. Droplets down to 1 micron radius or smaller appear on the photograph and radii may be determined in the range of 3 to 45 microns.

In the measurement of particulate counts, particles down to perhaps 0.3 microns radius are photographed. The particulate counts are

therefore usually much higher than previous values which were obtained by indirect methods based upon an "average" particle size.

Some typical results are presented. The charge measurements differ greatly from the type of results published in 1926 by Wigand. The size distributions are quite similar to those obtained by sampling with oiled slides except that more particles are found in the region below 5 microns, perhaps sufficient to indicate the existence of a secondary maximum here.

It is expected that information obtained with this equipment will give an insight into the mechanisms of charging of fog and other atmospheric aerosols and the effect of charges on the stability. Particulate counts and size distribution measurements in the very small sizes hitherto not measured may be useful in establishing the mechanism of formation of fog from vaporous water.

APPARATUS FOR MEASURING ELECTRICAL CHARGES AND OTHER PROPERTIES OF FOG

INTRODUCTION

The physical-chemical properties of fog are of considerable interest from the point of view of colloid science. Much is known about the charges of liquid colloidal dispersions, but very little about electrical charges on dispersions in gases. A number of authors, Bancroft (1), Schmauss (2), Schmauss and Wigand (3), and Wigand and Frankenberger (4) (5), have postulated that the stability of fogs clouds and smokes is due to mutual repulsion of charges on the particles, but very little has been proved. Wigand (6) measured the charges on fog particles by a method to be discussed below. High charges have been found on dust clouds, and many investigators have measured the charges on raindrops. There was thus considerable reason for expecting fogs to be charged, and for the charges to effect the stability. The present research has therefore concerned itself with the development of a suitable method and apparatus for the determination of the electrical charges on natural fogs in hope that an understanding might be reached with regard to charges and stability and that the information might be useful in the study of fog dispersal.

Wigand (6) has determined the charges on natural fog by measuring the change in charge on an electrified plate exposed to the fog, the weight of water collected on the plate, and the average size of the fog droplets. He found charges of the order of 1000 electron units per droplet on "dry" fogs, ranging to values of the order of 50 electron units on "wet" fogs. His method is open to several serious objections. First, it determines only the average charge on charged particles and ignores the possibility that only a small fraction of the particles are charged. Secondly, it assumes that the charged particles which are collected are the same average size as those giving rise to the "corona" phenomenon used for the size measurement. This is not likely to be true. In this method of collection the most mobile particles will be emphasized, and the distribution of charge with size of particles could conceivably cause a mobility maximum of a very greatly different size than the average. Thirdly, it is not at all clear from Wigand's paper how adequately he has treated the conditions where particles of both polarities exist. His method extracts particles of one polarity from the fog and two separate determinations are required to find the contribution of both polarities. He does not appear to have done this in all of his measurements. Other objections exist all pointing to the necessity of direct determination of charge, particle by particle, with a sufficient number of determinations to permit conclusions of statistical significance.

A method has therefore been devised which permits the observation of charges on fog droplets in large numbers. Measurement of the size of the droplets is integral with the method and a simple adaptation has permitted the direct determination of particulate counts.

METHOD

Charge and Size Determination:

The method used for charge and size determination is an adaptation of a method originally due to Wells and Gerke (7) who determined the diameter of charged smoke particles (assumed to bear unit electronic charge) by photographing the zig-zag wanderings of the particles in a commutated electric field. This was done by ultramicroscopic techniques. Fuchs (8) later indicated the use of the same principle for determination of the size and charge of droplets of oil fog, again microscopically, but presented no data. Hopper and Laby (9) used the principle for determination of the electronic charge. Kunkel and Hansen (10) constructed a "Dust Electricity Analyzer" since the inception of the present work, making use of the same principle.

The apparatus described herein consists essentially of a chamber containing a pair of vertical parallel plates which are charged, one in the sequence +, -, o, and the other -, +, o, by a switching mechanism operated by a synchronous motor. One cycle requires one-fifth second. Fog falls freely between the plates from the top, and charged droplets fall in zig-zag paths. These are photographed by a horizontal camera with an exposure of about one-half second under forward-angle illumination. The type of photograph resulting is shown in Figure 1.

The vertical component of velocity depends upon a balance between the downward force of gravity and the frictional resistance of the air. The latter is given with sufficient accuracy by Stokes' Law. It is readily shown then that the vertical component of velocity V_v obtained from the photograph yields the radius of droplet, r, according to the equation:

$$r = \sqrt{\frac{9V_v\eta}{2dg}} \qquad (1)$$

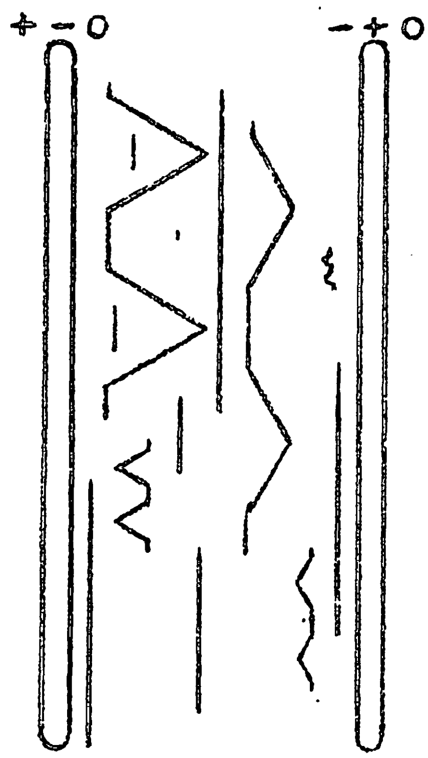


Figure 1

where η is the viscosity of the air, d is the density of the droplet material (here water), and g the acceleration of gravity.

It is not necessary that the particles be charged to measure the size, but the motion of the charged particles does provide a calibration of the time of exposure. With exposures of about 1/2 second, droplets smaller than about 2 or 3 microns radius make too short a trace for reliable measurement and those larger than 45 microns pass out of the field of view. Moreover, particles smaller than 2 or 3 microns appear on the photograph only if they are in good focus and in a well-lighted portion of the field and they move so little that they are difficult to detect against a background of other traces. Hence this portion of the size distribution curve is in considerable question.

The horizontal motion during 1/15 second is the amplitude of one of the zig-zag peaks. This velocity V_h is produced by the interaction of the uniform field E and the charge on the droplet e, and the motion is resisted by friction, again given by Stokes' Law. Then

$$e = \frac{6\pi\eta r V_h}{E} \qquad (2)$$

where r is given by Equation (1). When c.g.s. units are used the charge is expressed in e.s.u.

It will be noted that the commutation sequence is asymmetric hence the trajectories of the charged droplets have two forms depending upon polarity. In Figure 1 those having the peak of zig-zag motion to the left are negative.

Particulate Count Determination.

With the same equipment the number of droplets per unit volume may be measured by replacing the light source with an electronic flash tube. Each particle in the field then appears as a tiny black spot on the film. The determination of particulate count then depends upon the volume photographed. The latter quantity was determined by probing the field of view, under the same conditions of illumination, with fine fibers 2 microns and greater in diameter drawn from rubber cement. It is believed that the portion of the field of view chosen for measurement records droplets of 2 microns radius throughout, with a sensitivity greater than 1 micron in 85% of the volume. Experiments with smokes indicate that particles near 0.3 microns are photographed throughout the major part of the illuminated volume. An unevenness in distribution is due to the impossibility of achieving absolute uniformity of lighting, to variations in focus, and to the fact that the angular relationship between light, droplet, and camera, and hence the scattered intensity, change with position. These variations are minimized by using only a restricted portion of the field of view for measurement.

This method of determining particulate count is to be contrasted with previous methods which obtain it indirectly from a measurement of water content and an average particle size. The latter method cannot take account of the small droplets below 10 microns in diameter since they contribute relatively little to the water content of the fog. It is believed that more consideration must be given to these small particles if an understanding is to be had of the mechanism by which larger drops form.

DESCRIPTION OF THE APPARATUS

The apparatus was constructed with compactness and portability in order that it might be operated at any desirable location. The essential requirement is a 120 volt, 60-cycle, power supply which may originate from regular power outlets or from a portable gasoline generator.

It is composed of two fundamental parts, an electrode chamber with illuminating system and camera, and a supporting cabinet containing the accessory power equipment and controls. The various units of the apparatus are identifiable from Figures 2, 3, and 4. Parts are numbered in these three figures and reference is made to the numbers in the description below.

The apparatus makes use of the principle of forward-angle illumination in which the light beam is directed through the electrode space toward the camera. This results in more efficient scattering of light toward the camera by the fog droplets than is accomplished by perpendicular illumination. Excellent photographs of droplets as small as 1 micron are obtainable by this method.

The plan view drawing, Figure 2, shows the arrangement of the camera, electrode chamber, electrode assembly, and the illuminating source. The electrode chamber (2), figures 3 and 4, forms a protective housing for the electrode assembly (1) and a light shield for the camera. It is of plywood and masonite construction and is easily detachable from the power box (9) below.

A 1000-watt motion picture projection lamp is used as the light source. At a proper distance from it is a cylindrical lens (14) made of plexiglass mounted at the left rear corner of the electrode chamber. The lamp and lens illuminate the electrode space by directing a narrow rectangular beam of light through window openings in the electrode assembly. The forepart of the chamber and a light shield reduce the amount of stray light reaching the camera lens.

The electrode assembly consists of a framework of black plexiglass, which supports and provides insulation for the electrodes. The electrodes are aluminum plates 2 inches wide and 5-1/2 inches long firmly attached to the inner walls of the plexiglass form. They are smoothly rounded on all corners and edges and are painted black with a special preparation of carbon black. Their separation is 3.20 cm. The assembly has vertical windows in the left rear and right front to permit the light beam to pass through. The plexiglass windows are set at an angle to pass the light beam with a minimum of reflection.

An integral part of the chamber is a suction unit for pulling in fog for particulate count measurements. There is a hole in the base of the electrode assembly which terminates in a cavity below. A tube joins this cavity with a small box (3) on the right side of the chamber which contains motor and exhaust fan.

The camera (7) is a Zeiss Ikon Maximar, 6.5 x 9 cm., with an f/4.5 lens. A roll film adapter is provided so that size 120 (2-1/4 x 3-1/4) roll film may be used. By using a special mask just wide enough to receive the image of the electrodes, approximately 35 exposures can be made on one "8-exposure" roll of film. Eastman Kodak Super XX at an aperture of f/8 gives satisfactory results. Development is in high contrast developer such as D-11 or D-8.

The apparatus is equipped with a 1000-watt projection lamp for photographs involving charge and size determination, and an electronic photoflash tube (11) for particulate count measurements. These lamps are mounted on adapters which plug into a dual purpose receptacle located in the top of the power box. These adapters, which are made of micarta, give correct height to the lamps for best illumination. A blower (4) is provided to cool the projection lamp, and a water cell (13) filters heat rays from the light beam.

During ordinary use the electrode assembly is exposed to the atmosphere as shown in the photographs. This helps maintain temperature equilibrium with the air, but during the daytime, the side pieces (10) are used to enclose the assembly to maintain photographic contrast by elimination of stray light. Piece (10), Figure 5, is mounted above the electrode assembly. Particles of fog enter through the square opening. A short tower (5) is used in slight wind to prevent turbulent motion of the particles.

The power box (9) upon which the chamber rests is constructed of plywood. It is 14 inches wide, 12 inches high and 30 inches long. At the front is a control panel for operation of the electrical units contained within. At the top center is a microammeter for indication of the electrode voltage. On the left is an a.c. voltmeter to indicate the voltage delivered to the electrical units. This voltage is adjusted by the variable transformer at the bottom center of the control panel. Compensation for variation in the line voltage can be made by the transformer, and the electrode voltage can be adjusted to a fixed value. A frequency meter is on the right. It is useful in checking the frequency of the power source being used. This check is necessary on portable gasoline generators which develop 60 cycles only at the proper speed. The speed of the synchronous motor driving the high voltage commutator is determined by the frequency.

The interior of the power box is shown in Figure 5. It contains three main units, the high voltage supply (2) (3), the high voltage commutator (1), and the electronic photoflash power supply (4) (5). These are fully described in the appendix. Voltages of 5000 and 2400 volts are provided for the electrodes and 2200 volts for the flash unit.

Connections to the electrodes are made through an enclosed system to prevent personal contact with the high voltage. The output wires from the commutator terminate at two stand-off insulators on the under side of the top of the power box below the electrode chamber. Holes have been drilled in the top of the power box above these insulators and corresponding holes have been made in the electrode chamber. Micarta dowels (8) having a brass conducting rod through their center are inserted down through the holes in the chamber and make electrical contact with the stand-off insulators below. Connections to the electrodes are made by short wires from the dowels to compressed springs which pass through the walls of the electrode assembly contacting the electrodes.

The dowels also serve to center and secure the chamber to the top of the power box.

The entire apparatus weighs about 80 pounds and is small enough to be carried by a single person.

CHARGE MEASURING APPARATUS

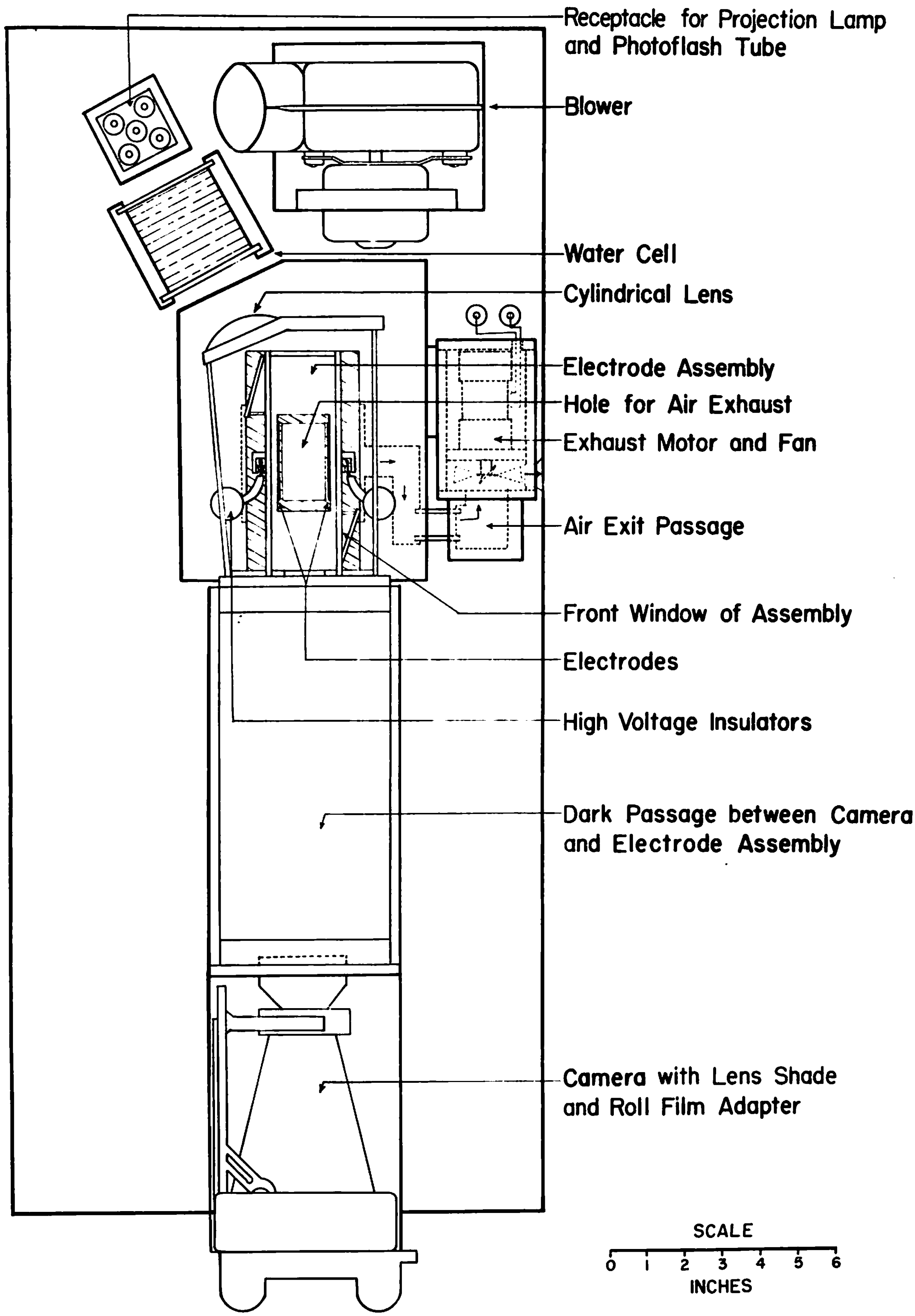


Figure 2 Top Plan View

CHARGE MEASURING APPARATUS (FRONT VIEW)

(1) Electrode assembly, plexiglass construction.

(2) Electrode chamber, fundamental unit of the apparatus housing the electrode assembly.

(3) Housing for exhaust motor, an integral part of the chamber.

(4) Blower for cooling the 1000 watt projection lamp.

(5) Short tower to direct particles into the electrode region.

(6) Peep hole through which the particles may be viewed.

(7) Camera.

(8) Insulating dowel which contains a conductor to bring the high voltage from the commutator to the electrodes.

(9) Power box, contains electrical units and controls.

(10) Side pieces to enclose the electrode assembly if desired.

(11) Photoflash lamp mounted in special micarta base.

(12) Control Panel.

From the upper left to bottom:

Projection lamp switch
Blower switch
A. C. Voltmeter
Commutator switch
Master switch

From upper center to bottom:

0-100 microammeter
5000 volt supply switch on left, 2400 volt on right.
0-130 volt A. C. variac transformer

From upper right to bottom:

Photoflash triggering switch
Photoflash power switch
58-62 cycle frequency meter
Rheostat control for exhaust motor
Exhaust motor switch

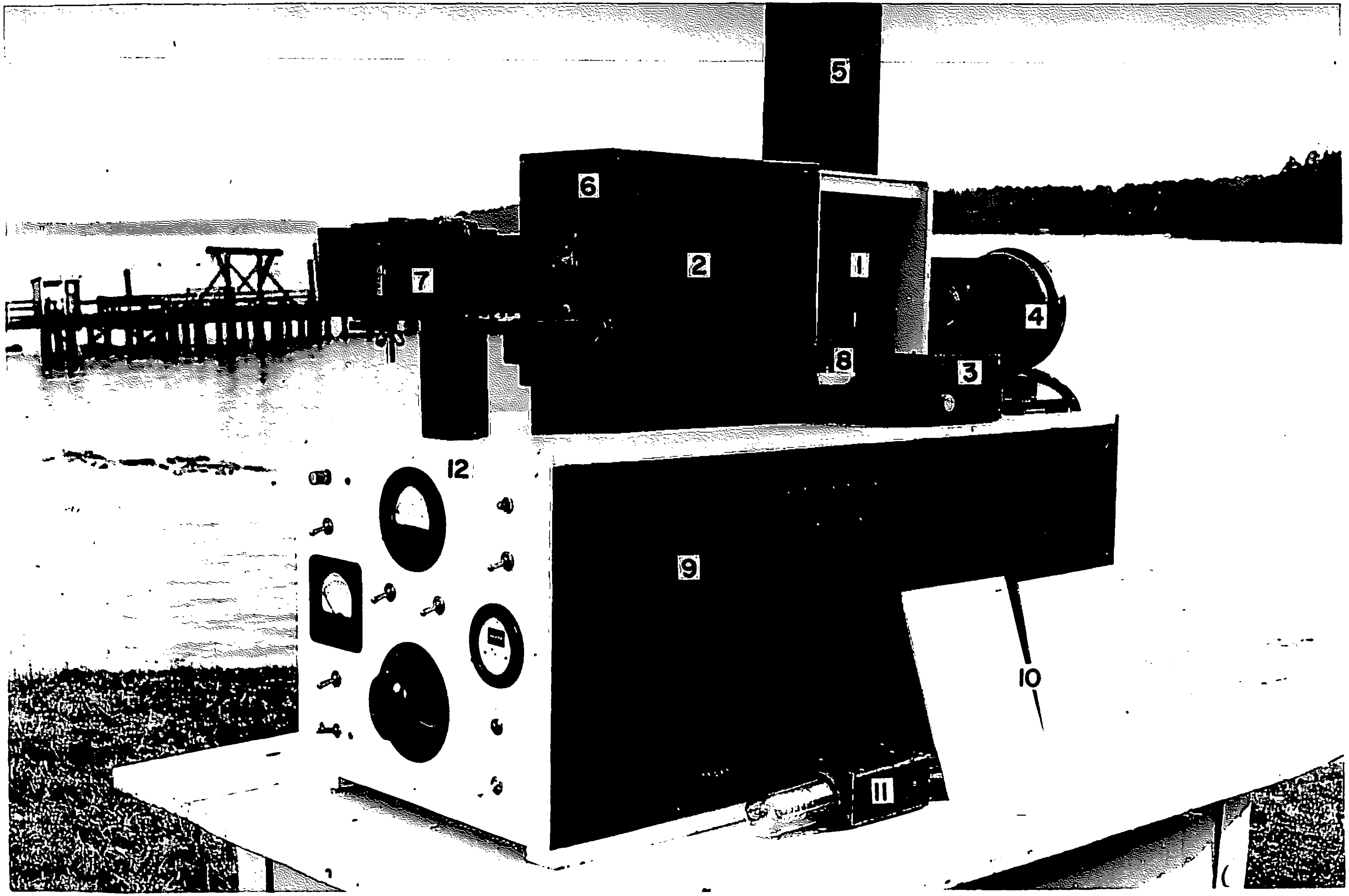


FIGURE 3 CHARGE MEASURING APPARATUS (FRONT VIEW)

CHARGE MEASURING APPARATUS (REAR VIEW)

(1) Electrode Assembly

(2) Electrode Chamber

(3) Housing for exhaust motor

(4) Blower for cooling the projection lamp

(5) Tower

(6) Projection lamp, mounted in position

(7) Camera

(8) Insulating dowel for high voltage connection to the electrodes

(9) Power box

(10) Top piece which covers electrode assembly

(11) Photoflash lamp

(12) Power inlet receptacle

(13) Water cell

(14) Cylindrical lens

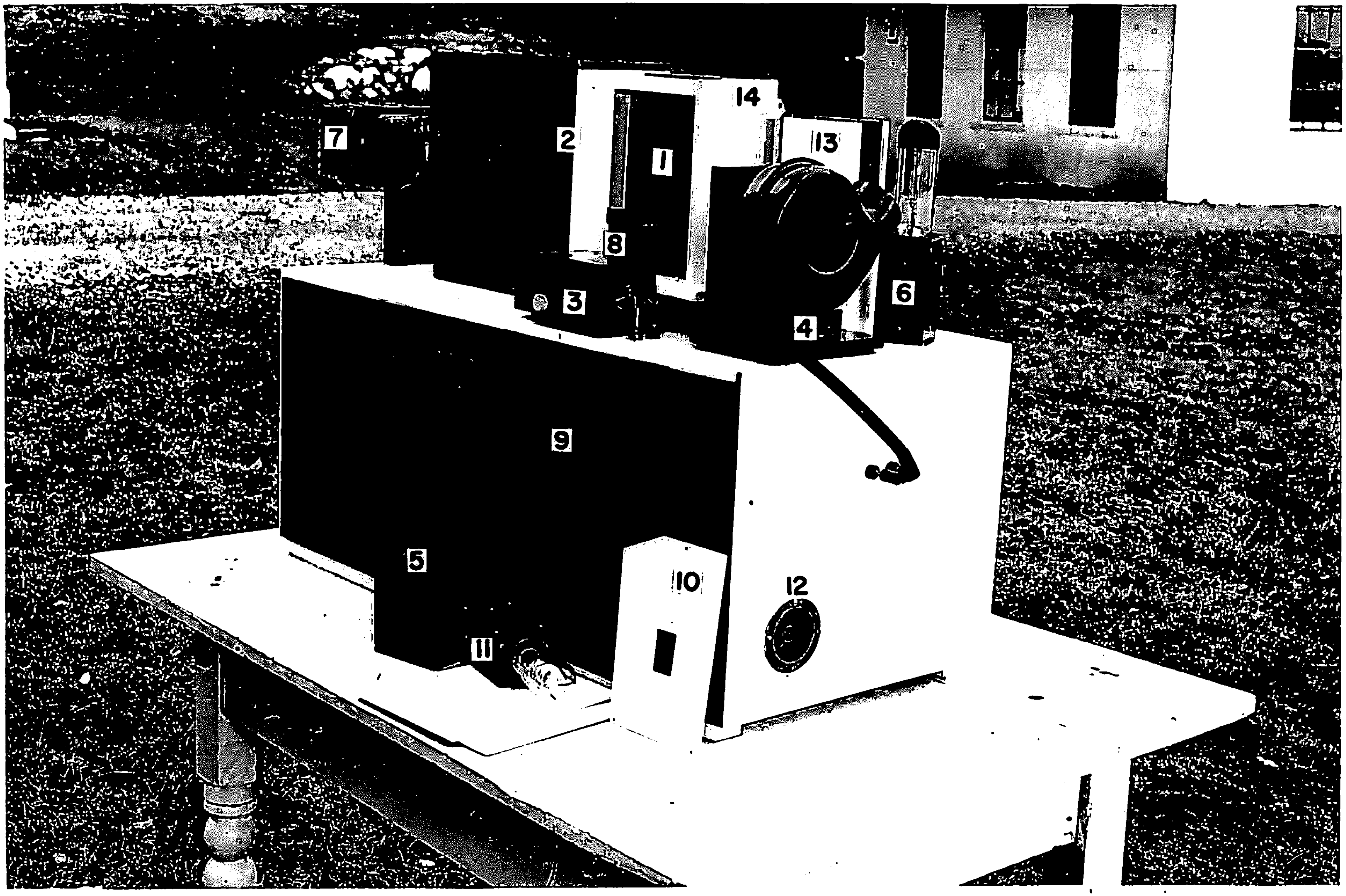


FIGURE 4 CHARGE MEASURING APPARATUS (REAR VIEW)

POWER BOX INTERIOR

(1) High voltage commutator

(2) 5000 volt power supply

(3) 2400 volt power supply

(4) Photoflash rectifier, 1100 volts

(5) Photoflash components (2500 volt, 25 mfd. capacitor below).

(6) High voltage selector switch

(7) Panel containing precision resistors in voltage measuring circuit

(8) Battery to operate photoflash triggering relay and exhaust motor

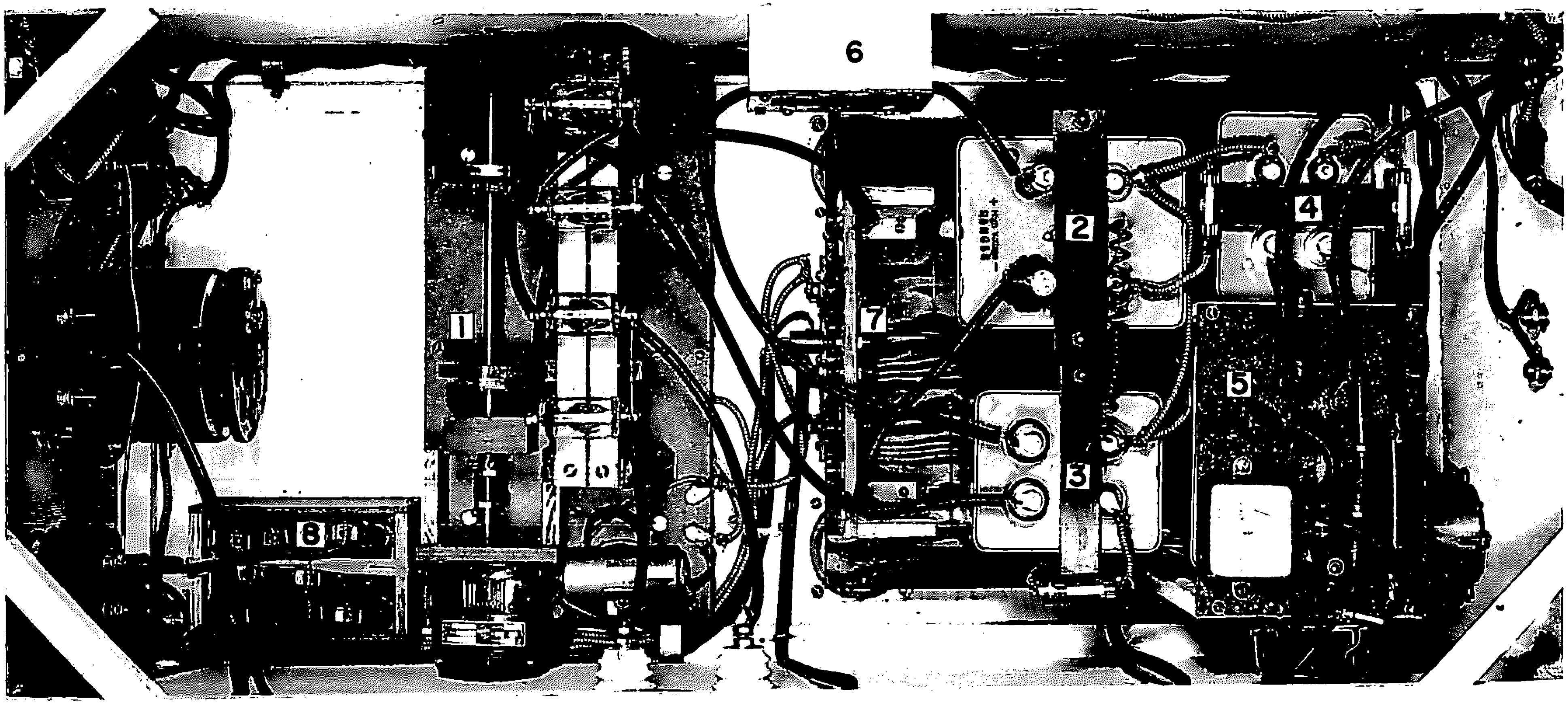


FIGURE 5 POWER BOX INTERIOR

OPERATIONAL TECHNIQUES

Field Operations:

During the foggy season which is intermittent between September and March, the charge measuring apparatus is kept in readiness for immediate use. In order that it might be at the same temperature as the outside air when operations are commenced, the apparatus is stored in an unheated building and not used for at least one-half hour after it has been set up in a fog.

Particulate count measurements are made with the electrode assembly completely uncovered. The exhaust motor and fan are used to keep a steady flow of particles into the apparatus while a photographic exposure is made with flashtube illumination. Two or three exposures are made to obtain a check on the count.

For pictures involving charge and size determination, the projection lamp is momentarily turned on for each exposure after turning on the commutator and adjusting the high voltage to a desired value. Not more than four or five photographs are taken in one operation and the apparatus is left idle for about 20 minutes before operations are resumed. Minimum use of the projection lamp and only periodic use of the apparatus is necessary to prevent warming above the natural air temperature. Even slight warming will disturb the free fall of the smaller particles by evaporation and upward air currents.

It is essential that turbulence within the electrode chamber be controlled for satisfactory operation of the apparatus. It is also necessary to control the number of particles sampled in very dense fogs lest there be too many in one photograph for easy identification and measurement. The number of entering particles may be limited by decreasing the size of the entrance slit above the electrodes or placing the short tower (5) above the entrance. In a calm stable fog turbulence presents no special problem. The fog droplets will enter freely with the electrode assembly open to the atmosphere or covered by piece (10), Figure 4, which directs the particles into the electrical field. If the fog is being stirred by light breezes, the short tower placed above the entrance will calm the air and prevent turbulent motion. If appreciable wind is present and the tower does not prevent turbulence, exposures are made at moments of "calm" when the wind has momentarily ceased.

If charged particles are not visually observed, it has been found wise to spray a few charged droplets above the apparatus with an atomizer since the trajectory of a charged particle is required to calibrate the camera shutter speed.

The apparatus may be transported by automobile to any desired location. Sixty-cycle alternating current with at least 15 amperes capacity at 120 volts should be available for satisfactory operation.

Calculation of Charge and Particle Size:

After development of the film, measurements are taken while projecting an enlarged image of the negative on to a screen of graph paper ruled in millimeters. The image is enlarged to ten times the actual dimensions of the electrode area included in the photograph.

In the case of charged particles the horizontal amplitude and the vertical fall in one commutation cycle are recorded, and the charge is calculated by equations (1) and (2). The total number of particles appearing on a film are counted in order to evaluate the percentage of the particles which are charged.

When size distributions are being determined it is very cumbersome to record the length of the trace for each particle appearing on the film and then calculate each particle size. A simplified system is used in this case. The distribution curve is usually plotted as the number of particles found in a given size interval. The intervals of particle size are expressed on the abscissa of the graph paper in terms of the equivalent intervals of trace length, and as each trace is measured one unit on the ordinate is marked off in the appropriate trace length interval. In this manner the size distribution curve is roughly plotted as the data is being taken.

LIMITS OF ACCURACY

Sampling:

In general, most ideal sampling is obtained when the electrode plates are as nearly as possible directly exposed to the fog. When towers or other collimating devices are used to prevent intrusion of turbulent eddies, a smaller number of particles enters the field of view. This effect becomes greater with smaller diameters and greater heights of towers. This is due mainly to three causes. With turbulent motion some of the larger particles are lost by being thrown against the walls of the tower before the turbulence is damped out. Some of the smaller droplets are lost by evaporation. Extremely small increases in temperature suffice, and even with the precautions taken to avoid appreciable heating by the light source, restricted towers prolong the contact with slightly warmed air sufficiently to cause considerable evaporation. Thirdly, upward motion of the air in the tower due to heating is accentuated, as in a chimney, and very small droplets because of their low settling velocity may fail to enter. This is also partly true of the slit used to restrict the number of particles entering. Thus there may be a considerable deficiency in the very small particles and a small deficiency in the very large particles. These difficulties have been avoided to a great extent when possible by working without a tower and waiting for a quiet period to make the exposure. Also the chamber is freely exposed to the fog by opening the top until immediately before photographing. After replacing the top and tower, suction is applied until just before the shutter is tripped. The resulting size distribution curves agree well with those taken by collection on narrow (2 mm) oiled slides except that more particles below 5 microns radius are shown in the present method. However, experiments have shown that in the flash photographs taken for particulate counts, about 1.7 times as many counts are obtained when the foggy air is sucked into the measuring chamber artificially than when fog settles in naturally through the open top. Suction has therefore been used for all particulate count measurements. It is believed that the difference occurs mainly in particles in the size region of 1 micron radius or smaller which evaporate with extreme readiness. The apparatus is consistent and duplicate determinations agree very well.

Size and Size Distribution Measurements:

As has been mentioned, the sizes of droplets smaller than 2-3 microns radius are not determined because they move too little during the exposure for their free fall velocity to be measured. Moreover, the very short traces are hard to distinguish against a background of other traces. Increase in exposure time is not a very practical solution since more of the rapidly falling particles then fill in the background and stray light increases the general background fog. Also, more of the large particles are then lost by passing entirely through the field of view.

The latter phenomenon leads to errors in the counts of large particles. Droplets larger than 45 microns radius traverse the entire field in 1/2 second and therefore escape measurement completely. In general it may be stated that if a particle falls with such a velocity as to traverse 1/n of the field in the exposure time, the fraction of that size group escaping is 1/n. The number in each size group should then be multiplied by $\frac{n}{n-1}$. At 20 microns radius, this factor is about 1.2 and decreases rapidly with smaller sizes. Thus it seriously affects only the particles which are occurring in numbers so small as to have little statistical significance. Therefore no attempt to apply the corrections has been made.

Another error arises from parallax in the optical system. Particles nearer the camera appear to fall farther than those farther away. The error at the extremes is ± 6%. Statistically this error should approximately balance out.

The accuracy in measurement of trace length varies with the length of trace. With the large particles, it is better than 1% and becomes progressively poorer with smaller sizes.

Stokes' Law begins to fail significantly at about 15 microns radius where the droplets fall too slowly by a factor of 1.01 and are therefore ascribed a radius too small by $\sqrt{1.01}$ or 1.05. At 20 microns the error in radius is ~~1.10~~ 1.02, at 30 it is ~~1.18~~ 1.03 and at 40 it is ~~1.26~~ 1.07. These factors are calculated from the table of drag coefficients for spheres presented by Langmuir (11).

Correction could be made for these discrepancies but they begin to be serious only in size regions where very few particles are found, and the correction is neglected.

Charge Measurements:

All of the errors entering into measurements of radius affect the calculated charge since by Equation (2) $e = \frac{6\pi\eta r V_h}{E}$. When V_v is high due to parallax, V_h will also be high. The failure of Stokes' Law also affects V_h, but V_h is ordinarily somewhat less than V_v. However, the square root does not enter, and on the average it is estimated that the error due to this cause is about the same as or somewhat less than the error in r. Thus at 20 microns radius the charge is low by a factor of about 1.2 due to Stokes' Law, the error decreasing very rapidly with decrease in size.

Errors due to voltage measurement and control are about 3% maximum. There are some end effects near the edges of the electrodes and due to the window openings which contribute a maximum of perhaps 5-10% of error to a relatively small proportion of the measurements.

The lower limit of charge detected depends upon the radius of droplet. Other factors being equal, the amplitude of zig-zag motion is proportional to e/r. But a given amplitude of lateral motion becomes increasingly difficult to detect and measure with longer traces. It is estimated that the minimum detectable charge is about 50 electron units at 4 microns radius, 155 at 9 microns and 800 at 20 microns. These values also represent the absolute limits in accuracy of measurement of the deflections.

In general then it may be stated that for most of the particles there will be a relative error of about ± 10% superimposed upon an absolute error of the magnitudes mentioned above.

Theoretically, it would appear easy to extend the sensitivity by merely increasing the electrical field strength decreasing the frequency of commutation and increasing the exposure. The field strength is already 1780 volts per centimeter and it is desirable to avoid excessively high fields because of the danger of corona discharge with consequent spurious charging of the particles. Increasing the exposure time and decreasing the frequency of commutation increases the background fog, increases the number of particles striking the electrodes and being captured, and the number passing out of the field before completing 1/3 cycle. Each trace would then block out more of the photograph and fewer particles could be measured. Considering also that in the problem of fog stability one is interested more in the relatively high charges which have strong interactions, the present conditions were considered the best compromise.

Particulate Counts:

Particulate counts probably contain little error due to sampling and counting. However, one might reasonably suppose that the count would increase as the sensitivity of the method is extended to smaller and smaller sizes. Thus the significance of the results depends upon the lower size limit. As stated under "METHOD" it is quite certain that this limit extends to 1 micron radius and very possibly to 0.3 microns in some portions of the field. However, this lower size limit is not accurately known. Experiments are being devised to establish this limit more accurately.

RESULTS

Much data has been obtained with this apparatus which remains to be analysed and interpreted and more is being taken. Some typical results are presented in Figures 6 and 7 as an illustration of the types of data obtained. A more complete discussion of the results will be made in a subsequent report.

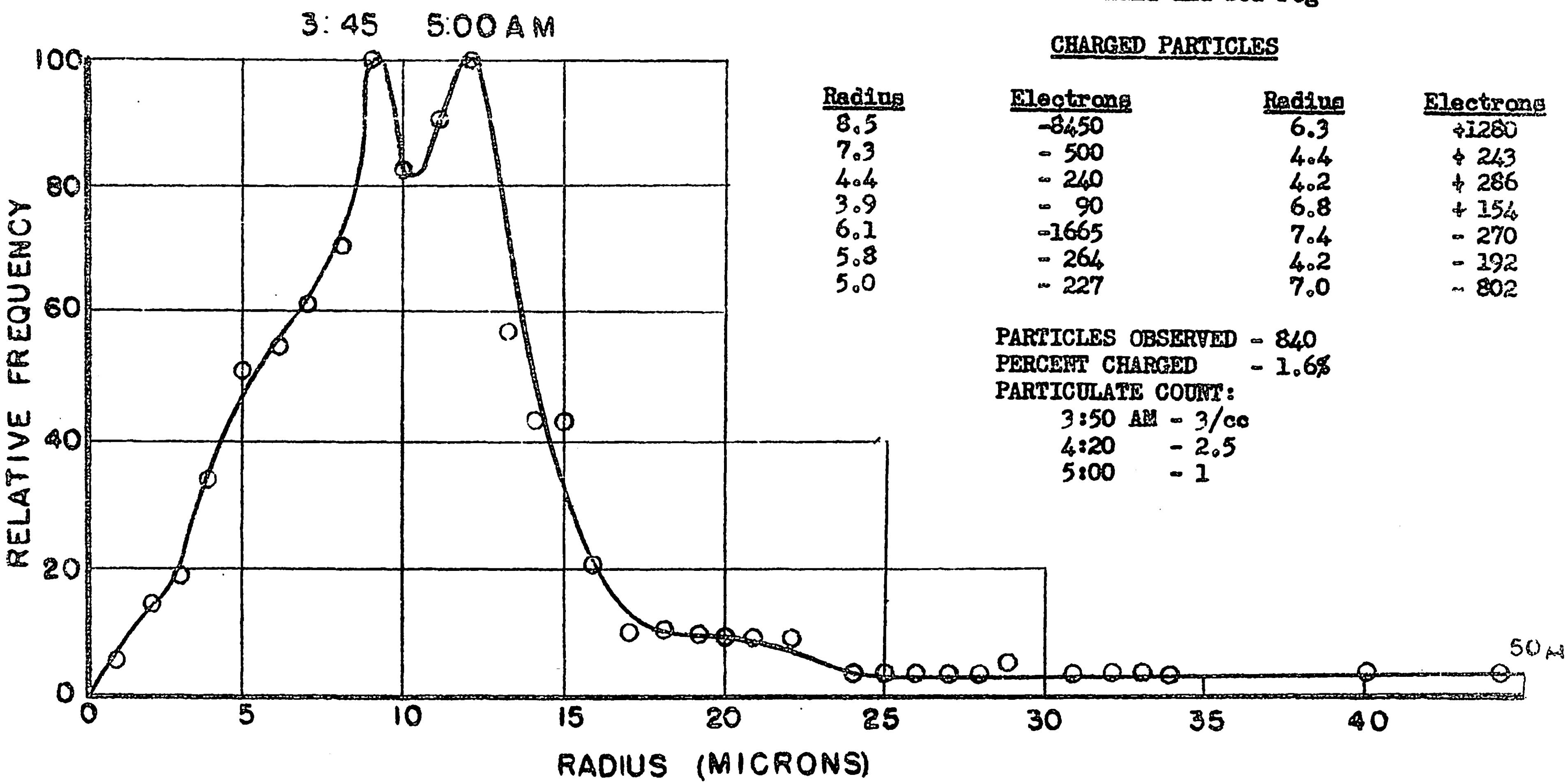
It will be noted that only a small percentage of the droplets are charged and that both polarities are present, negative preponderating. This is to be contrasted with Wigand's conclusion that all the droplets were charged with charges about this same order of magnitude and preponderately positive.

The size distributions are typical of fogs in this area with a frequency maximum at about 10 microns radius. The portion of the curve extending beyond 25 microns was contributed mainly by data taken after 4:30 A.M. when the fog degenerated into a drizzle and gradually dissipated. Below about 3 microns the results are inconclusive for the reasons mentioned previously. In Figure 7 an attempt was made to count all of the traces showing no movement and enough were found to suggest the possibility of the existence of a secondary maximum in the small size range such as that indicated by the dotted curve.

The particulate counts are usually much higher than those obtained by other methods, in some cases being as high as 15 or 20. Considerable work is necessary in correlation of these values with other properties of the fog in order to make the results meaningful.

FIGURE 6

SIZE DISTRIBUTION



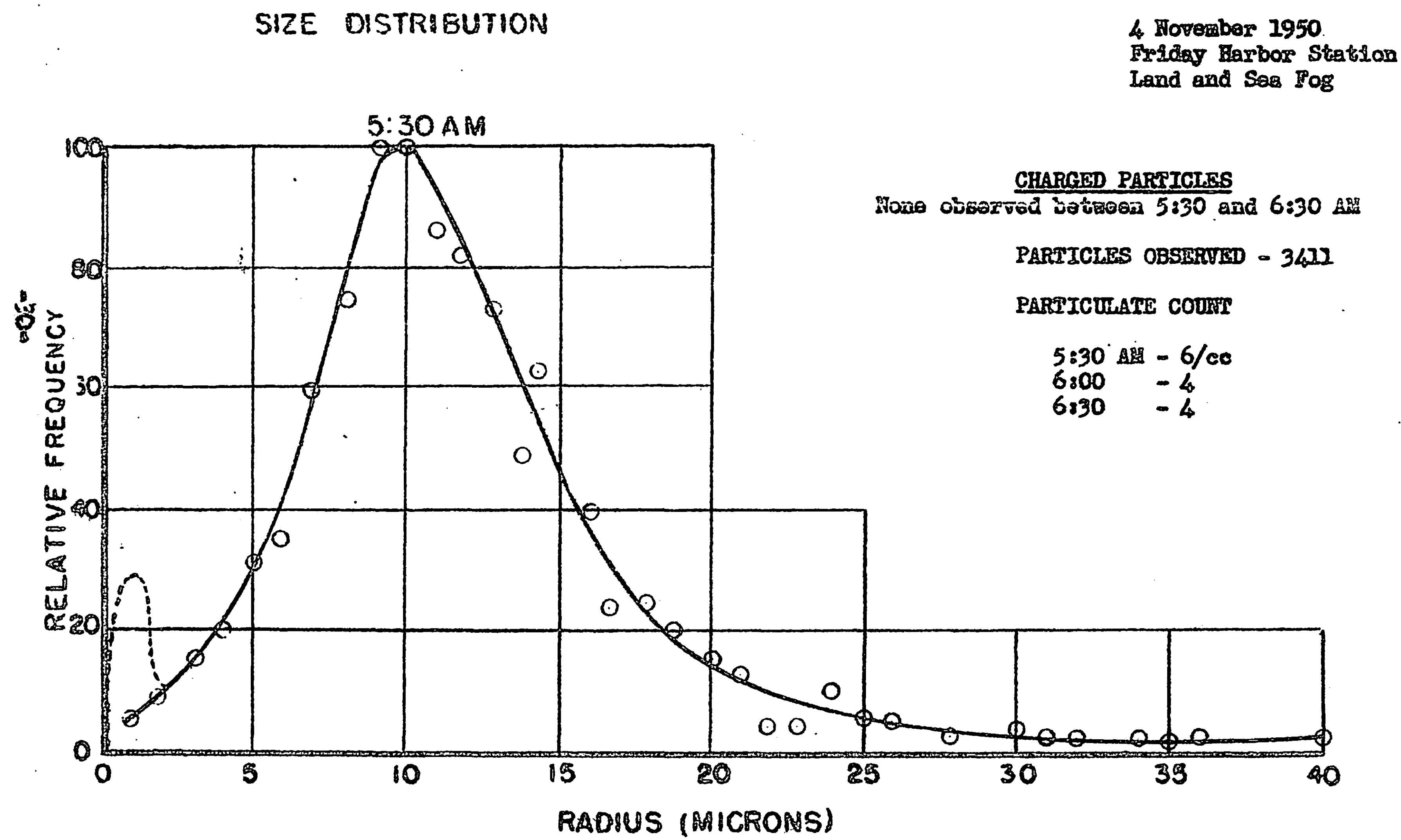
4 November 1950
Friday Harbor Station
Land and Sea Fog

CHARGED PARTICLES

Radius	Electrons	Radius	Electrons
8.5	-8450	6.3	+1280
7.3	- 500	4.4	+ 243
4.4	- 240	4.2	+ 286
3.9	- 90	6.8	+ 154
6.1	-1665	7.4	- 270
5.8	- 264	4.2	- 192
5.0	- 227	7.0	- 802

PARTICLES OBSERVED - 840
PERCENT CHARGED - 1.6%
PARTICULATE COUNT:
3:50 AM - 3/cc
4:20 - 2.5
5:00 - 1

FIGURE 7


SIZE DISTRIBUTION
4 November 1950
Friday Harbor Station
Land and Sea Fog
5:30 AM
CHARGED PARTICLES
None observed between 5:30 and 6:30 AM
PARTICLES OBSERVED - 3411
PARTICULATE COUNT
5:30 AM - 6/cc
6:00 - 4
6:30 - 4
RELATIVE FREQUENCY
100
80
60
40
20
0
0
5
10
15
20
25
30
35
40
RADIUS (MICRONS)

APPENDIX

HIGH VOLTAGE SUPPLY AND MEASUREMENT

The portable apparatus uses two compact HI-VOLT power supplies manufactured by Condenser Products Co. One is rated at 2400 volts and the other 5000 volts d.c. These units were designed for use at a fixed voltage so two were used to give some choice of voltage.

Figure 8 is a diagram of the high voltage system. The negative leads of the two power supplies form a common input to the commutator. The positive leads terminate at opposite terminals of a single pole double throw switch (6), Figure 5. The switch is used to select the power supply to be fed to the commutator and the electrodes. Separate switches to turn on the power supplies are located on the control panel below the microammeter. The selector switch is on the left side of the power box.

A series of six ten-megohm resistors are connected across the output of the voltage supply. At the midpoint of the resistor chain and in series with it is connected a 0-100 microammeter for voltage measurement. Two 1/2 megohm resistors are connected across the microammeter and the center point is grounded to the rectifier case. This places the microammeter at a low potential with respect to ground and establishes ground potential at the approximate mid-point of the voltage difference.

The ten-megohm resistors are the "Precistors" Type DCH made by the International Resistance Co. These have an accuracy rating of

±1% at 25°C. a temperature coefficient of -0.025% per degree, and a voltage coefficient of -0.001% per volt. Since a maximum of 830 volts appears across each resistor the error from the latter source is 0.8%. The temperature coefficient is negligible since the resistors are used only briefly and heat very little. The over-all accuracy in voltage control and measurement is about ±3%.

HIGH VOLTAGE COMMUTATOR

The commutator consists of four Sperti vacuum switches Type S1, operated in proper sequence by rotating cams. The cams are turned by a 300 r.p.m. synchronous motor. The switches are a single-pole double-throw type rated for 7500 volts. The wiring diagram is shown in Figure 9 and a photograph of the commutator in Figure 10. The mechanism of operation will be evident if it is noted that the pair of switches to the right connect the left pair to the output terminals or short circuit the latter in the two positions. In the left pair the usual reversing switch connections are made except that when the right pair of switch arms are in position B the left pair are in a middle position making no contact.

The sequence of operations is to first electrify the electrodes at opposite polarities for 1/15 second, reverse the polarities for the same period, and finally to short the electrodes, making a complete cycle 1/5 second long. The switching requires about 1/600 second, or 1/40 of one-third cycle. During this period, however, the electrodes retain their previous charge to a great extent and this effect can be neglected in calculation.

HIGH VOLTAGE SUPPLY

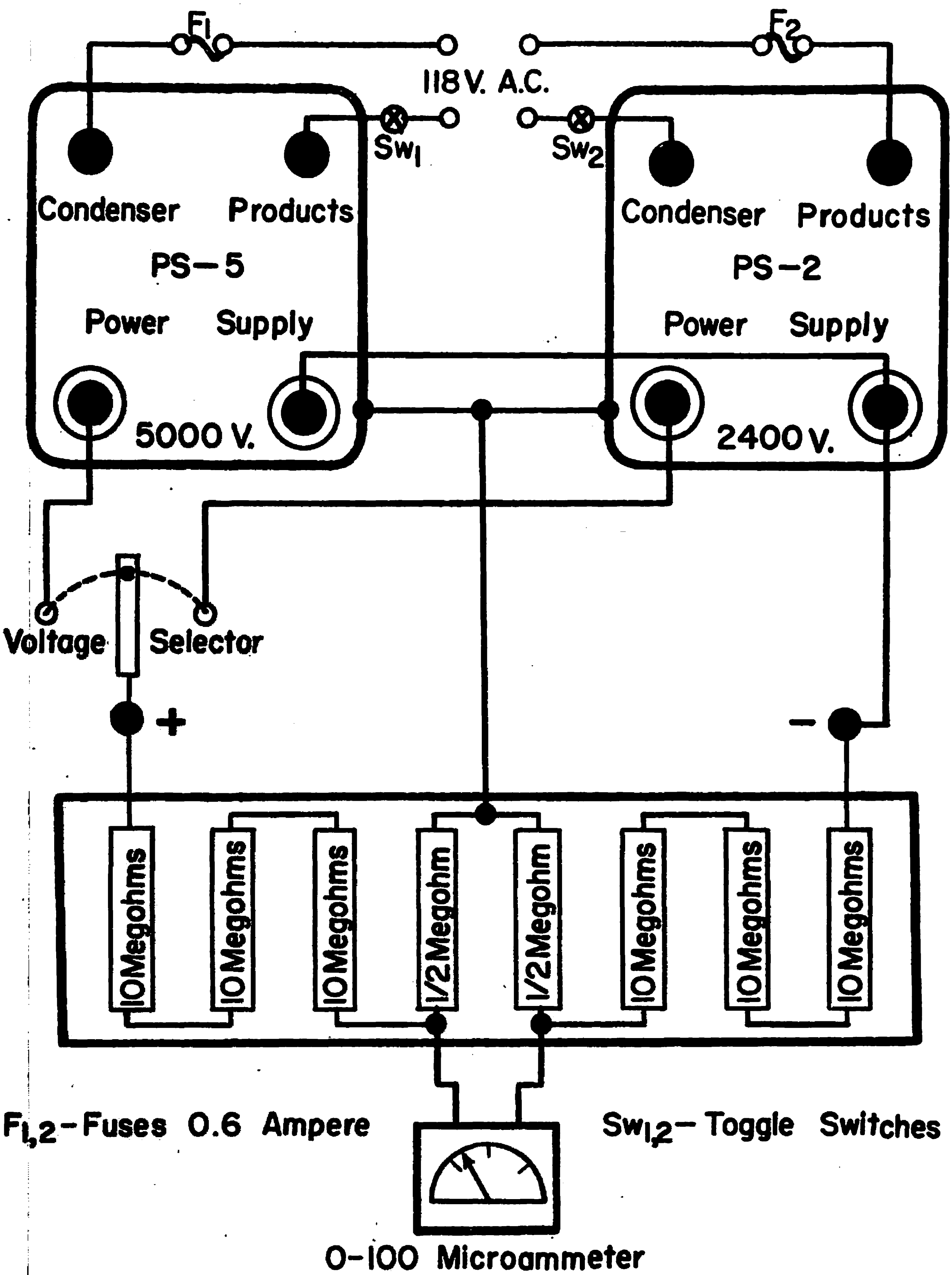


Figure 8

HIGH VOLTAGE COMMUTATOR

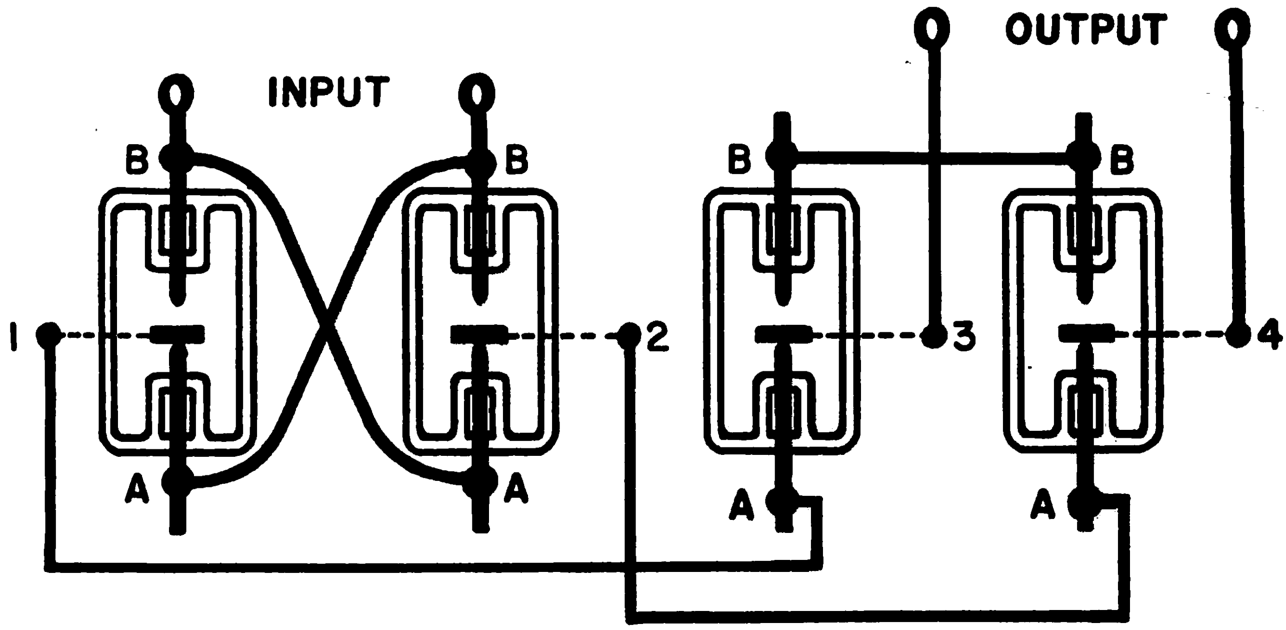


Figure 9 , Wiring Diagram

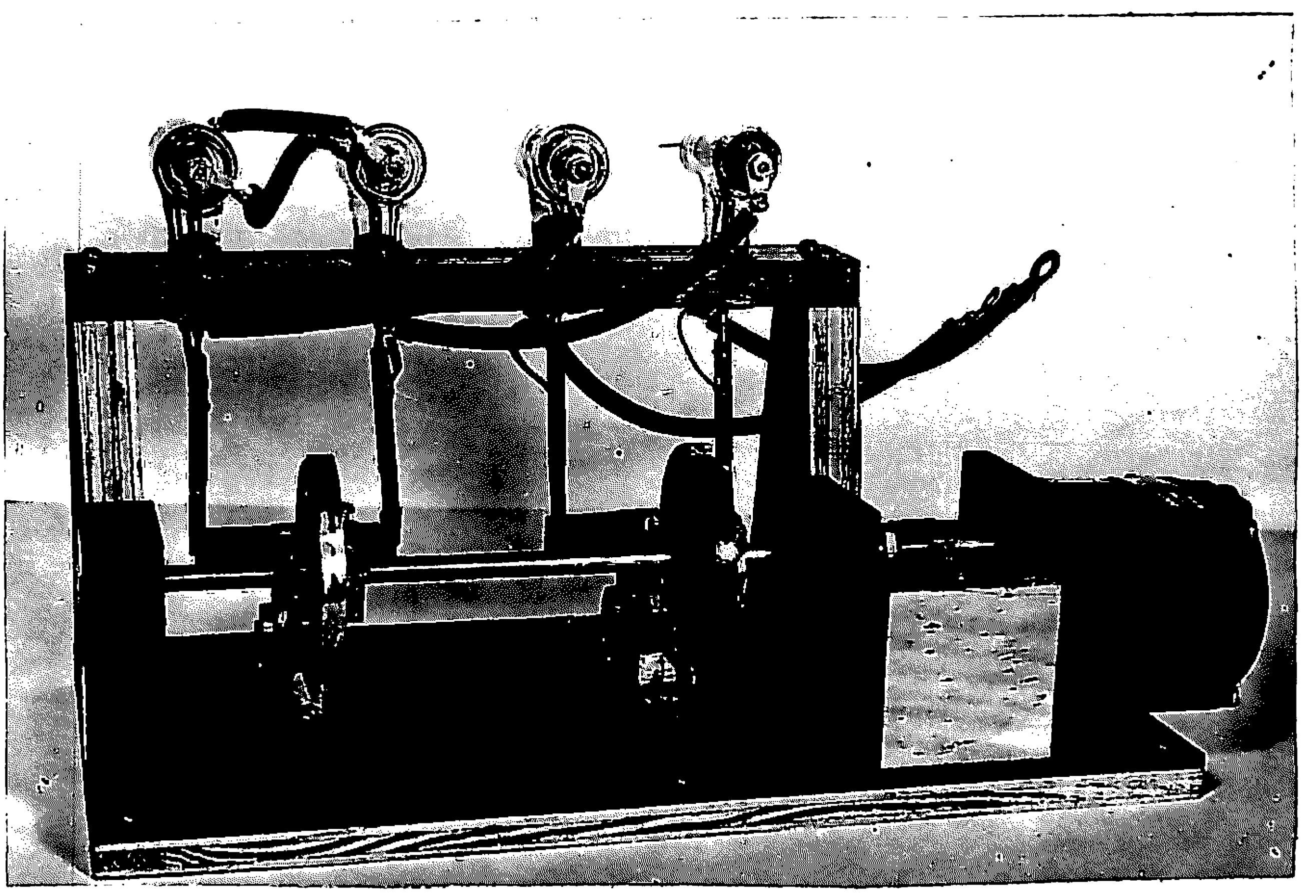


Figure 10, Commutator Photograph

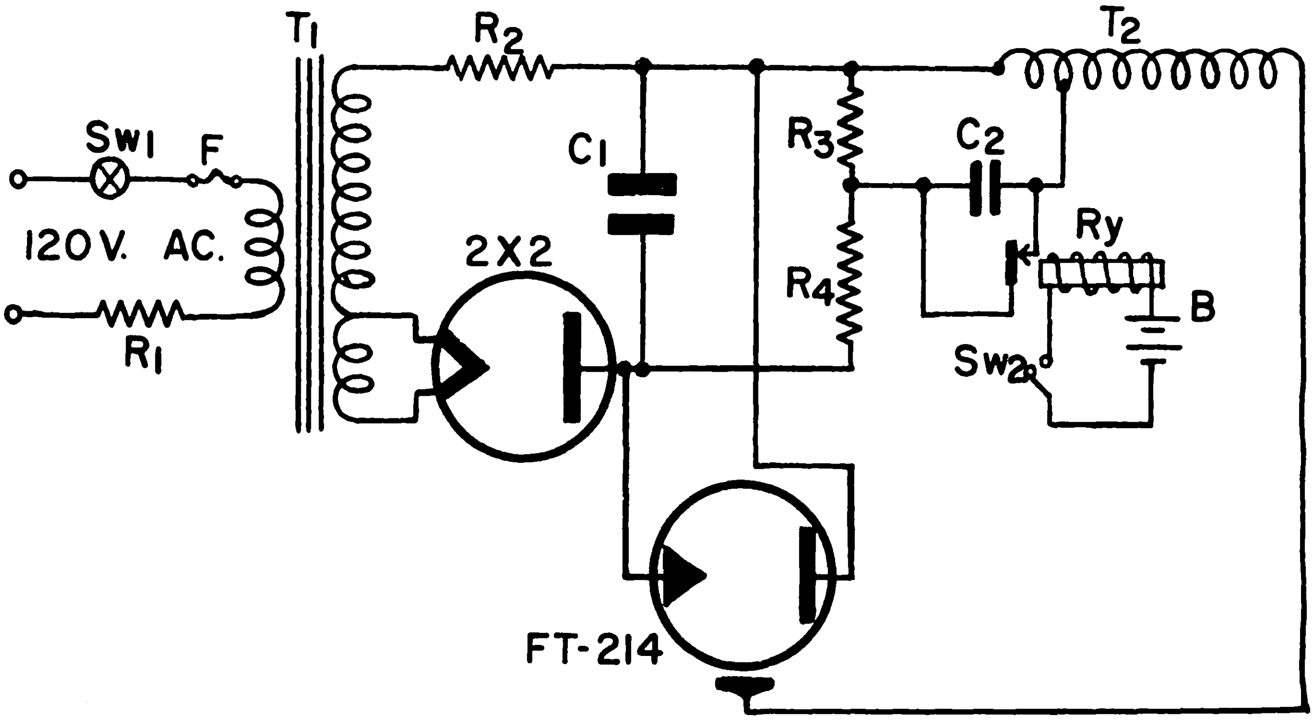
PHOTOFLASH POWER SUPPLY

The electronic photoflash power supply is of conventional design, essentially that shown in Figure 11 except that the rectifier tube and transformer are replaced by the packaged power supply Type PS-1 of Condenser Products Co. with an output of 2400 volts.

There are three highly insulated wires leading from the power supply to the flashtube. Two are from the photoflash capacitor and the other from the triggering transformer. These wires terminate at the dual-purpose lamp socket located in the top lid of the power box. Proper connections are made to the flash tube when it is set in place.

The photoflash components are located on the same platform as the other high voltage equipment. The flashtube is triggered by a relay switch located at the top right corner of the control panel.

PHOTOFLASH POWER SUPPLY



T_1 – Power Transformer, 1100V. & 2.5V. Sec.

T_2 – UTC Trigger Transformer, PF-3

Sw_1 – Power Switch

Sw_2 – Triggering Switch

F – 1/4 Ampere Fuze

R_1 – 15 Ohm, 10 Watt

R_2 – 2000 Ohm, 10 Watt

R_3 – 1/2 Megohm, 2 Watt

R_4 – 2 Megohm, 2 Watt

C_1 – Photoflash Capacitor, 25 Mfd., 2500V.

C_2 – 1.0 Mfd., 600 V.

B – 12 Volt Battery

Ry – SPST Relay, 12V. Coil

Figure 11

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